Patricia G. Patrick *Editor*

Preparing Informal Science Educators

Perspectives from Science Communication and Education

Springer

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Foreword

I entered the informal/free-choice science learning field in 1978, the summer after I graduated from the University of Miami, with a B.S. in Biology and Philosophy. Within days of graduating, Wit Ostrenko, up until recently, the Director of the Museum of Science & Industry (MOSI) in Tampa, Florida, but at that time, a former Graduate Teaching Assistant of mine at the university, called me to see whether I would teach an outdoor marine biology course for 9- and 10-year-old youth in a summer camp program at the Miami Museum of Science (now the Patricia and Phillip Frost Museum of Science).

This summer job continued into the fall and I was totally captivated and transformed by the experience, so much so, that I decided to change my career path and focus on education, rather than the graduate degree in forest ecology I had planned. I earned a teaching credential and became a middle and high school science teacher at a parochial school in Miami, teaching introductory physical sciences, biology, physics, and field biology. I enjoyed being a classroom teacher, particularly in a parochial school where I had some flexibility and control over what and how I taught. However at the end of the year, I realized that despite the freedom I had, much of my role was focused on the management and teaching of students, rather than on facilitating their learning. This was a seminal moment—in the process of teaching children in a museum and outdoor settings, I became intrigued by the question of how to effectively facilitate learning. At the time I had no knowledge that the field of science education existed.

A few years later I moved to Gainesville, Florida and was fortunate to meet John J. Koran, Jr., Professor of Science Education and Cognitive Science at University of Florida. Koran was interested in the notion of museums as environments in which to study learning and he became my advisor, both for my master's and doctorate. Although it was wonderful to have such intellectual support in my major professor, the M.Ed., and ultimately the Ph.D., I earned was in Curriculum and Instruction. At that time (early 1980s), the curriculum for such a program focused on the history and foundations of education, as well as the principles of teaching. Unfortunately though, education was narrowly defined; the entire focus of the program was on schooling. For the most part, notions of motivation, free choice and/or control over one's learning were not discussion points unless I brought them up. I describe this formative period in which I prepared for my career in free-choice/informal science learning as my "pretzel" years, bending and curving myself around in order to pursue my interests and background into such a confined set of courses.

So, imagine my pleasure when Patricia Patrick contacted me to see if I was interested in writing a chapter for a book she was editing, Preparing Informal Science Educators: Perspectives from Science Communication and Education. As it turned out, I did not have the time to devote to a chapter, but offered to write the foreword instead. Given the preparation I had experienced, it is quite easy to see what excited me about this project; an international edited volume of 27 chapters, a preface and a concluding chapter, with a focus on the preparation of informal science educators. With the exception of only a few chapters that seem inappropriate and/or disconnected from the purpose of the volume (Chap. 12[1] in particular), the chapters reflect the tremendous changes that have occurred worldwide in the preparation of informal/free-choice science educators since I entered the field.

There is great diversity among the chapters—provocative ideas for discussion, for example, rethinking the definition of informal/free-choice learning, integrating reflective practice into preparation with different approaches presented throughout the book, and the role of identity in the development of an informal science educator. The diversity of the types of informal/free-choice science programs highlighted in the book also demonstrates the vast array of informal/free-choice settings in which people engage: astronomy education, science outreach programs for young children, the use of parks and place-based education models, "teaching" the theory of evolution, programs integrating mobile computers and contrasting informal science education with environmental education. And, just so we as a field are careful not to throw the baby out with the bathwater, a chapter focused on preparing informal science educators in a formal science teacher education program. This volume also highlights the diversity of people who one can consider an informal/free-choice learning educator, by moving beyond the stereotypical adult museum educator to discuss youth as explainers on the floor of museums, scientists as science communicators, and, even a possible new frontier in which a user might be able to generate her own personal educator. Although diverse, unlike many edited volumes of this length, the chapters reinforce and complement one another

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[1] This chapter is quite similar to a recent methodological review published in *Journal of Research in Science Teaching*; as is customary, the authors were invited to write a rejoinder (53.1, pp. 65–69).

Editor Note: The following are the references for the articles to which Lynn Dierking is referring in the Foreword. The *Journal of Research in Science Teaching* article by Falk & Needham (2016) is included in Chap. 13 with permission from Wiley & Sons.

Jensen, E. A. (2016). Evaluating indicator-based methods of 'measuring long-term impacts of a science center on its community'. *Journal of Research in Science Teaching, 53*(1), 60–64.

Falk, J. H., & Needham, M. D. (2016). Utilizing indicator-based methods: 'Measuring the impact of a science center on its community'. *Journal of Research in Science Teaching, 53*(1), 65–69.

quite well, with ideas such as identity, deep learning and reflection woven in and among the chapters.

The noun, guide, as in the title of this volume, has two meanings relevant here. One is something "that helps someone form an opinion or make a decision," such as a blueprint or exemplar. The other meaning, "a person who advises or shows the way to others." In my mind, this volume has accomplished both. It offers diverse exemplars, while also gathering the collective wisdom, experience and insights of those engaged in the practice of preparing informal science educators, who point to the varied ways in which to design and implement quality preparation programs. As always, I also am hopeful that the book provides invaluable evidence for the importance of the unique and complementary aspects of informal/free-choice learning.

Corvallis, USA
July 2016

Lynn D. Dierking
Institute for Learning Innovation
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About the Editor

Patricia G. Patrick received her M.Ed. and Ph.D. from the University of North Carolina Greensboro. She is Assistant Professor in Cultural Foundations and Leadership at Columbus State University and Associate Fellow in the Department of Sociology at the University of Warwick. In cooperation with the Houston Zoo, Dr. Patrick developed a Masters of Education in Curriculum and Instruction for Informal Science Education. She has published numerous articles related to informal science learning, with a focus on sociocultural theory. Her work focuses on the importance of social interactions and the importance of those interactions within families. She published the book *Zoo Talk*. She has been a guest speaker at the Chester Zoo (England), University College London Institute of Education (England), Sao Paulo Zoo (Brazil), and San Diego Zoo where she discussed questioning skills and preparing science communicators. She has been a visiting researcher at the Museum fur Naturkunde in Berlin as a researcher on the development of a new Heinz Sielmann exhibit. Her research interests are in informal science education, preparing informal educators, and the influence of family culture and science knowledge on science learning.

Contributors

Jennifer D. Adams is Associate Professor of science education at Brooklyn College and The Graduate Center, CUNY. Her research focuses on STEM teaching and learning in informal science contexts including museums, national parks and everyday learning. She has worked as an educator and researcher in the NYC public schools and the American Museum of Natural History. She was awarded the prestigious National Science Foundation Early CAREER award to study informal learning contexts and formal/informal collaborations for STEM teacher education. Her research portfolio also includes youth learning and identity in informal science contexts, with a focus on minoritized youth, place/identity in transnational communities and environmental education. Her upcoming research will focus on the intersection of creativity and STEM teaching and learning.

Lauren B. Allen is a Postdoctoral Research Associate at Carnegie Mellon University and the University of Pittsburgh. Her research is focused on collective and community learning about socio-scientific issues such climate change and genetic engineering. She is a co-founder of the Center for PostNatural History, holds a Ph.D. in Learning Sciences and Policy from the University of Pittsburgh, and a B.S. in Biology, Spanish, and Environmental Studies from the University of Wisconsin-Madison.

Ayelet Baram-Tsabari is Assistant Professor at the Technion, where she heads the Biology Education and Science Communication research groups at the Faculty of Education in Science and Technology. She is a member of the Learning in a Networked Society (LINKS) Israeli center of Research Excellence (I-CORE). Her background consists of academic research in the fields of science education, science communication and the active communication of science in the print and broadcast mass media. She completed her Ph.D. in 2007 at the Weizmann Institute of Science and served as a faculty member at the Technion since 2008. Baram-Tsabari spent 2010 at Cornell University, NY, studying Science Communication with Prof. Bruce Lewenstein. She founded the annual Israeli Science Communication Conference and currently chairs the conference's academic committee. Baram-Tsabari's main research interests are in bridging science education and science communication scholarship, including identifying peoples' interests in science and building on these authentic interests to teach and communicate science in a meaningful and personally relevant ways.

Elaine Blake is a lecturer in Early Childhood Studies at Edith Cowan University in Perth, Western Australia. Her career includes teaching children, undergraduate and postgraduate students, being Head of a Junior School and working as an Early Childhood Education (ECE) consultant. Her Ph.D. from Curtin University, Australia, investigated a socio-cultural perspective of learning and teaching science in early learning centers. Publishing includes being co-editor of the teacher resource book, *Planting the Seeds of Science* (2010), contributing to *Journal of Teaching and Education* (2013) and *Science in Early Childhood* (2015). Elaine has studied Reggio Emilia ECE philosophy in Italy; forest kindergartens in Scotland and the development of early learning in the UK and North America. She is a Fellow of the Australian College of Educators and was presented with a Special Services to Education Award for work that encouraged new parents to read to their babies. Elaine is a grandmother of two healthy children, loves to travel, is fond of gardening, and passionate about the health and wellbeing of young children.

Brett Branco is Assistant Professor of Earth and Environmental Sciences and Director of the Urban Sustainability Program at Brooklyn College of the City University of New York. His research focuses on understanding the impacts of urbanization on aquatic ecosystems and works primarily within the boundaries of

New York City. Dr. Branco has been introducing graduate, undergraduate and high school students in New York City to urban environments for the past 7 years. He earned his Ph.D. in Oceanography at the University of Connecticut and was a National Science Foundation International Research Fellow at the University of Western Australia prior before arriving at Brooklyn College in 2009.

Martin Braund is Adjunct Professor at Cape Peninsula University of Technology in Cape Town, South Africa, and Honorary Fellow in the Department of Education at the University of York. After graduating in Zoology and Geology from Exeter University, he taught science in secondary schools for 18 years. During 1989–1991, he completed a Masters in Science Education while working as a Research Fellow for the Assessment of Performance Unit in Science at the University of Leeds. He holds a Ph.D. from the University of York focused on research in transition from primary to secondary school. Much of his work is connected with innovative approaches to teaching science and biology. Martin has published over seventy journal articles and his books and chapters in books are internationally known in the fields of transition, informal learning outside the classroom (with Michael Reiss), argumentation, teacher education and drama in science. His most recent book, Performing Science (Bloomsbury 2012), was shortlisted for education resource of the year. Martin is a member of several international research organizations and editorial boards of leading journals and was editor of Science Teacher Education. He has worked as consultant, adviser and keynote speaker in over 20 countries of Europe, Australia and Africa.

Kevin Crowley is the Director of the University of Pittsburgh Center for Learning in Out-of-School Environments (UPCLOSE), Professor of Learning Sciences and Policy in the School of Education, and a Research Scientist at the Learning Research and Development Center. His research focuses on all things informal. He holds a Ph.D. and M.S. in Developmental Psychology from Carnegie Mellon, and a B.A. in Psychology and Education from Swarthmore College.

Justin Dillon is Professor of Science and Environmental Education and Head of the Graduate School of Education at the University of Bristol, UK. He is interested in how people engage with the environment in a range of contexts including schools, museums, science centers, and botanic gardens.

Jakob Egg was Ph.D. student in the project INQUIRE—Inquiry Bases Science Education for a sustainable future at the University of Innsbruck. His research work focuses on learning in collaborative networks as a special mode of knowledge production which values knowledge that is embedded in social structures within and between individuals. He is the Chairman of the European pedagogical discourses for teachers—Changes in Education and Society, since 2007. Currently he is employed as coordinator for implementing the broadband-expansion by the Austrian federal state of Tyrol.

Dr. John H. Falk is Director of the Institute for Learning Innovation and Emeritus Sea Grant Professor of Free-Choice Learning at Oregon State University. He is internationally acknowledged as a leading expert on free-choice learning; the learning that occurs while visiting zoos, aquariums, museums or parks, watching educational television or surfing the Internet for information. Dr. Falk has authored over 150 articles and chapters in the areas of learning, ecology and education, more than a dozen books, and helped to create several nationally important out-of-school educational curricula. His recent work has focused on studying the impacts of zoos, aquariums and museums and understanding why people utilize free-choice learning settings during their leisure time. He serves on numerous national and international boards and commissions including the National Education Board of the U.S. Park Service and the National Research Council's committee on Out-of-School Learning. In 2006 Falk was recognized by the American Association of Museums as one of the 100 most influential museum professionals of the past 100 years. In 2010 he was further recognized by the American Association of Museum's Education Committee with its highest award, the *John Cotton Dana Award for Leadership*. In 2013 the U.S. Council of Science Society President's gave Falk their *Educational Research Award* for his outstanding achievement in research that improved children's learning and understanding. In 2016 NARST, a worldwide organization for improving science teaching and learning through research, gave Falk their highest award, the *Distinguished Contributions to Science Education through Research Award*. Falk earned a joint doctorate in Ecology and Science Education from the University of California, Berkeley.

Preeti Gupta Director for Youth Learning and Research, is responsible for strategic planning, program development and research and evaluation for out of school time youth initiatives at the American Museum of Natural History. Her portfolio also includes leading the summer museum residency components of the newly initiated Masters of Arts in Teaching program for Earth Science teachers. Prior to this she was serving as Senior Vice President for Education and Family Programs at the New York Hall of Science. In that role, she led the internationally replicated Science Career Ladder Program, keys initiatives in school change, teacher professional development, and family programs. She has a Bachelor's degree in Bioengineering from Columbia University, a Master's Degree in Education from the George Washington University and a doctoral degree in Urban Education from the City University of New York Graduate Center. In 1999, she was selected as one of 42 women who have contributed to the community in unique ways showcased in a photo exhibition, The Many Faces of Queens Women. In 2005, she won the Inaugural National Roy L Schafer Leading Edge Award for Experienced Leadership in the Field from the Association for Science Technology Centers. Her research interests are focused on the trajectories of youth's experiences with science in and out of school settings, the role that museums play in motivation and deepening engagement with STEM and STEM careers, youth employment and workforce development and the factors that mediate how youth identify with the scientific enterprise. She also studies the role of museums in STEM teacher preparation for both formal and informal settings.

Emily Hestness completed her Ph.D. in Curriculum and Instruction with a focus on Science Education at the University of Maryland, College Park. As an educator, Emily has worked in a variety of urban informal science learning settings and has taught university courses in Elementary Science Methods. Emily has also developed educational and training curricula at Peace Corps headquarters in Washington, D.C. As a researcher, Emily has collaborated on National Science Foundation-funded research projects in the areas of science teacher education (Project Nexus) and climate change education (Maryland and Delaware Climate Change Education, Assessment, and Research—MADE CLEAR). Emily's research interests include climate change education, environmental education, informal science education, the teaching and learning of socioscientific issues, and science teacher education.

Gary M. Holliday is Assistant Professor of Science Education in the Department of Curricular and Instructional Studies in the LeBron James Family Foundation College of Education at the University of Akron. He earned both his M.Ed. and his Ph.D. in Science Education.

His research interests are influenced by 15 years of teaching experiences in formal and informal science classrooms. To date, his research has focused on teacher professional development in informal settings (such as museums and science centers) especially addressing the learning of science, nature of scientific knowledge, inquiry, and bridging the informal and K-12 learning environments. He has published in the International Journal of Science Education and the Journal of Science Teacher Education. He has also co-authored a number of book chapters and has presented his work at professional meetings nationally and in Finland, France, Greece, South Africa, Taiwan, Sweden, and Turkey.

Christine Howitt is Associate Professor in Early Childhood and Primary Science Education at the Graduate School of Education at the University of Western Australia. Her interests are in early childhood and primary science teaching and learning, and curriculum development. Christine's research has focused on young children's science learning in both formal and informal contexts, more recently concentrating on the science teaching and learning opportunities provided within early learning centers. Christine is co-editor of the science resource *Planting the Seeds of Science*, the product of a two-year nationally funded project to develop science resources for early childhood teachers. She has been awarded various teaching excellence awards at the state and national levels.

Eric Jensen is Associate Professor of Sociology, University of Warwick. He teaches on social research methods, audience research and science communication. Jensen has conducted numerous evaluation studies of science communication, museum, gallery and public engagement activities. He has two forthcoming books with Cambridge University Press, focusing on public engagement events and engagement with wildlife conservation respectively. His research methods textbook published by SAGE is entitled 'Doing Real Research'. Jensen has a Ph.D. in Sociology from the University of Cambridge.

Suzanne Kapelari is Associate Professor of Biology and Environmental Education and Head of the Science Education Department at the School of Education, University of Innsbruck, Austria. She was the Coordinator if the INQUIRE project. She is interested in how people teach and learn biology inside an outside the classroom and how educational institution can be supported to develop their professional attitude towards teaching.

Phyllis Katz was the founding Executive Director of Hands On Science Outreach (HOSO). After more than two decades she became its Director of Research and Evaluation after completing her doctorate. She served as PI/PD on NSF and other grants. In 1999, she received the National Science Teachers Association (NSTA) Award for Distinguished Informal Science Educator. She has written science books for children and articles for adults on science teaching and learning. She worked on the Advisory Board for the Magic School Bus TV series. Dr. Katz is currently a Research Associate at the University of Maryland. She has been an active advocate for informal science education (which she prefers to call continual science learning-CSL) at the NSTA and at NARST, the primary science education researchers' association. She has presented at many conferences and remains active in creating materials and promoting science and mathematics. In recent years, she has been considering images, both drawings and photographs, as engaging ways of stimulating science and mathematics participation, and as sources of data. Phyllis lives and works alongside her husband Victor, a mathematics historian. They have three children and enjoy exploring science with their growing group of grandchildren.

Mi Song Kim As a curriculum expert and a learning sciences researcher investigating learning, cognition and knowing in authentic practices, Dr. Mi Song Kim has engaged in rich collaborations with schools, practitioners and community members in designing, implementing and scaling-up technology-enhanced curricula. Dr. Kim is currently Assistant Professor in the area of Curriculum Studies at the Faculty of Education in the University of Western Ontario. Prior to the University of Western Ontario, she researched and taught at the Learning Sciences Lab, Early Childhood & Special Needs Education Academic Group, and Learning Sciences and Technologies Academic Group in the National Institute of Education, Nanyang Technological University in Singapore. She has a strong theoretical foundation in Vygotskian sociocultural research and her research influences innovative teaching and research, which has been awarded prestigious FQRSC scholarship from the Government of Québec, the Principal Dissertation Fellowship from McGill, and the Early Researcher Award from the US National Science Foundation.

Heather King is a Research Fellow at King's College London. Her research focuses on the role and function of informal science learning institutions and, in particular, the pedagogical practices of informal educators. Prior to her current position, Heather worked in the museum sector as an educator and consultant.

Joy Kubarek, Ph.D. has worked within the field of informal science education in many difference capacities, including programmer, management, senior leadership, researcher, and evaluator. Dr. Kubarek began her career as an informal science educator working as an interpretive naturalist for the Minneapolis Park & Rec Board. Since those days, she has led teacher professional development programs, managed an education team working with schools, established the Learning Planning & Evaluation department of the Shedd Aquarium's Learning Group, and served as Vice President of Learning for the aquarium. She has served as adjunct faculty teaching biology courses and co-teaching informal science education practicums. She earned her Ph.D. in Science Education from the Illinois Institute of Technology in Chicago studying under Dr. Judith Lederman. Her research interests focus on teacher professional development with informal science institutions and assessment and evaluation practices of informal science educators. Dr. Kubarek recently completed her tenure on the Museum Education Roundtable board of directors and continues to engage in supporting the publication of the Journal of Museum Education. Dr. Kubarek has presented nationally and internationally on her research and work in this field, including a focus on evaluation capacity building for informal science educators. Her most recent presentations were at the San Diego Zoo's Symposium for Conservation Learning and the National Association for Research in Science Teaching. She is a member of the Visitor Studies Association, the National Science Teachers Association informal science committee, and co-coordinator of the Learning Science in Informal Settings strand of the National Association for Research in Science Teaching. Dr. Kubarek is based out of New England and currently works as Senior Research Associate for PEER Associates, an education research and program evaluation consulting group focused on working with environmental education and sustainability organizations.

Susan M. Land is Associate Professor and the Director of Graduate Studies in the Learning, Design, and Technology Program at Penn State University. She earned a doctorate in Instructional Systems from the Florida State University. Land's research emphasizes frameworks for the design of open-ended, technology-enhanced learning environments. Land's current research group is investigating the design of learning environments afforded by mobile technologies in everyday, informal, or classroom contexts. Recent research projects have studied the use of digital photography and mobile devices to capture everyday experiences that connect home and school learning; context-sensitive, place-based mobile learning in outdoor informal environments; and frameworks for design of mobile, augmented reality leaning.

Judith S. Lederman is Associate Professor in Science Education and Director of Teacher Education in the Department of Mathematics and Science Education at Illinois Institute of Technology, Chicago, Illinois. Dr. Lederman has a Ph.D. in Science Education, an M.S. degree in Natural Sciences and a B.S. in Biology and Secondary Education. She was the Curator of Education at the Museum of Natural History and Planetarium in Providence, RI. She taught secondary and middle level physics and biology, as well as bilingual elementary science.

Dr. Lederman is known nationally and internationally for her work on the teaching and learning of Scientific Inquiry and Nature of Science in both Formal and Informal settings. She has over 600 presentations/publications on scientific literacy. She is presently co-editor of the Journal of Science Teacher Education. In 2008, she was awarded a Fulbright Fellowship to work with South African science educators to develop research and curriculum that connects Informal sites to K-12 science classrooms. She has twice served on the Board of Directors of the National Science Teachers Association (NSTA), is past president of the Council for Elementary Science International (CESI) and has served on several committees for NARST and ASTE.

Anthony Lelliott completed his B.Sc. Hons and M.Sc. degrees at the University of Durham, UK, and holds a Ph.D. from the University of the Witwatersrand. He has worked in teacher education since 1987, joining Wits in 1995. He has held various leadership positions in the university. His research interests are science communication, informal learning in science (particularly school visits to museums, science centers, etc.), out-of-school science learning including evolution and astronomy education/outreach. He supervises Ph.D., masters and honors students and teaches on various courses in science education at undergraduate and postgraduate levels.

Bruce V. Lewenstein (A.B., general studies in the humanities, 1980, University of Chicago; Ph.D., history and sociology of science, 1987, University of Pennsylvania) is Professor of Science Communication and chair of the Department of Science & Technology Studies at Cornell University. He is also a full member of the Department of Communication. He works primarily on the history of public communication of science, with excursions into other areas of science communication (such as informal science education). He has been active in international activities that contribute to education and research on public communication of science and technology, especially in the developing world. In general, he tries to document the ways that public communication is fundamental to the process of producing reliable knowledge about the natural world.

Thomas Lister is currently studying an M.Phil. in Sociology at the University of Cambridge, and holds a B.A. (Hons) in Sociology with a Specialism in Research Methodologies from the University of Warwick.

Catherine E. Matthews, Ph.D. is Professor at the University of North Carolina Greensboro (UNCG) and teaches classes in K-12 Science Education and Environmental Education. She writes about science education and natural history topics for K-12 classrooms. She has written more than 70 practitioner and research articles that have been published in *Science & Children, Science Scope, The Science Teacher, The American Biology Teacher, Green Teacher, Science Activities, The Journal of Environmental Education and the International Journal of Science Education* and others. She spent 20 years at UNCG working with elementary education professional development school (PDS) programs focused on science and environmental education. The co-authors of this chapter are her former students from PDS teams who now work in educational fields as her colleagues.

Brad McLain is a social scientist and co-directs the Experiential Science Education Research Collaborative (XSci) at CU Boulder. Dr. McLain's research focuses on identity development in relation to STEM learning and career pathways, including the nature and impacts of extraordinary experiences and how such experiences may change our sense of self and life trajectories at different ages. McLain has served as Principal Investigator on several research and project grants funded by both government and corporate entities. He also has extensive experience in informal science education and formal science education and teacher professional development. Dr. McLain is also a research scientist with the National Center for Women & IT, participating in research, resources and strategies that organizations can use towards diversification and inclusion in workplace environments. Prior, Dr. McLain was Assistant Professor of Education at the University of Colorado Denver, an educational researcher at the Space Science Institute, a multimedia instructional designer in the online learning industry, a NASA educational lead for the Space Shuttle Program, the Office of Biological and Physical Research, and the Space Science Mission Directorate, and a social science researcher at the National Center for Atmospheric Research (NCAR). He is also an accomplished filmmaker, having produced and directed three documentary features and dozens of short films. Dr. McLain serves on the Board of Directors for the Jane Goodall Institute, STEM Space, and the Lake Travis STEM Academy. He was Co-founder of the Xperience STEM conference and www.MySTEMLink.com and is a nationally recognized speaker. His TEDx and TEDx Youth talks can be found online.

Enrico Miotto is Head of Training and Professional Development at the National Museum of Science and Technology Leonardo da Vinci of Milan. He holds a B.A. degree in Physics from the University of Milan. Before joining the museum, he worked as researcher at the Astronomical Observatory of Brera, as curator at the Planetarium of Milan, and as science teacher at secondary schools. At the museum, he was the person conceiving and developing the interactive labs of MUST in the 1990s. Today, he is responsible for all training programmes for teachers and explainers of the museum and also develops and delivers interactive education activities for a range of audiences, creates exhibitions and investigates innovative methodologies to integrate in the museum work.

Alexandra Moormann is a Researcher in the Department of Education of the Museum für Naturkunde, Berlin. She holds a diploma in biology and is a trained teacher in biology and physics. Alexandra completed her Ph.D. in Biology Education at the Humboldt-Universität zu Berlin in Germany about the development of student attitudes towards science subjects with the focus on transitions in a longitudinal design. For more than 15 years, she has worked as a freelance museum educator at a botanical garden and a natural history museum. Currently, she works at the Museum für Naturkunde Berlin as a researcher in museum education. Her research interests are participation in natural history museums and student perceptions about the nature of science in natural history museum exhibitions.

Dr. Mark D. Needham is Associate Professor in the Department of Forest Ecosystems and Society at Oregon State University (OSU), Adjunct Associate Professor in the College of Earth, Ocean and Atmospheric Sciences at OSU, and an Adjunct and Affiliate Associate Professor in the Department of Geography at the University of Hawaii. He received his B.A. and M.A. in Geography and Environmental Studies at the University of Victoria in Canada, and his Ph.D. in Human Dimensions of Natural Resources at Colorado State University. Dr. Needham's research and teaching focus on the human dimensions of natural resources as applied to forests, marine areas, wildlife, and recreation and tourism settings. He has expertise in survey research methodologies and advanced statistical analysis. In the last 10 years, he has published more than 50 refereed articles in leading journals, authored 1 book and 9 book chapters, and presented over 125 papers at local, national, and international conferences. He is also Editor-in-Chief of the international journal *Human Dimensions of Wildlife* and Associate Editor of the *Journal of Leisure Research* and *Journal of Outdoor Recreation and Tourism*. In addition, he served as Chair of the *Eighth International Congress on Coastal and Marine Tourism (CMT)*, held in Hawaii in 2015. Dr. Needham received the College of Forestry Dean's Award for Outstanding Teaching and Advising Professor for 2009, the College of Forestry Dean's Award for Outstanding Research Professor for 2007, and the Department of Forest Ecosystems and Society Graduate Students' Award for Outstanding Faculty for 2013. Dr. Needham is also an award winning wildlife photographer.

Jennifer Negron has a unique perspective on the value of Pinkerton grants. In 1998, three days after graduating from New York's high school for pregnant and parenting teens and 6 weeks after the birth of her son Joel, she went to work as an "Explainer" in the Science Career Ladder program at the New York Hall of Science —a longtime Pinkerton grantee. While there, she completed her B.A. at Queens College and went on to earn a Master's in Public Administration at Baruch College. She eventually rose to lead the 100 high school and college Explainers who guide thousands of visitors through the Hall of Science each year. Jenny has presented papers and led discussions at science education conferences at home and abroad and has been recognized as a Next Generation Getty Leadership Fellow. She brought her interest and expertise in youth programs and science and technology training to Pinkerton in January of 2012.

Sadie Camfield Payne is a 4-H Youth Development Agent with Cooperative Extension and North Carolina Agricultural and Technical University in Guilford County. She combines her love of education and the outdoors to develop inquiry-based experiential education programs for youth throughout the county in hopes of igniting the same spark in them that Dr. Matthews ignited in her as an undergraduate. She focuses her programs on urban audiences that may have very little connection to the out of doors. She hopes to continue to connect her two fields of formal education and environmental education with a doctorate that allows her to quantify the effects of environmental education on students in a formal education setting.

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Michael J. Reiss is Professor of Science Education at UCL Institute of Education, Visiting Professor at the Universities of Leeds and York and the Royal Veterinary College, Honorary Fellow of the College of Teachers, Docent at the University of Helsinki, Director of the Salters-Nuffield Advanced Biology Project and a Fellow of the Academy of Social Sciences. Books of his include: Reiss, M. J. & White, J. (2013) *An Aims-based Curriculum*, IOE Press; Jones, A., McKim, A. & Reiss, M. (Eds) (2010) *Ethics in the Science and Technology Classroom: A New Approach to Teaching and Learning*, Sense; Jones, L. & Reiss, M. J. (Eds) (2007). *Teaching about Scientific Origins: Taking Account of Creationism*, Peter Lang; Braund, M. & Reiss, M. J. (Eds) (2004) *Learning Science Outside the Classroom*, RoutledgeFalmer; Levinson, R. & Reiss, M. J. (Eds) (2003) *Key Issues in Bioethics: A Guide for Teachers*, RoutledgeFalmer; and Reiss, M. J. (2000) *Understanding Science Lessons: Five Years of Science Teaching*, Open University Press. For further information see www.reiss.tc.

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Chance Sanford joined Hunt with Heart in 2015 after 5 years at the Houston Zoo as VP of Education, and 7 years at Sea World San Antonio as supervisor then manager of education and conservation. As Executive Director, Dr. Sanford directs the organization's strategic, fundraising, and operational goals. Since beginning in 2015, Dr. Sanford successfully transitioned the organization into its first consolidated headquarters, launched a new website with online giving platform, and procured grant funding for Hunt with Heart programming. Dr. Sanford is a past Board Director for the Informal Science Education Association of Texas and member of the Association of Zoos and Aquariums (AZA) Conservation Education Committee and a committee member of Get Outdoors Houston. Dr. Sanford received his B.S. in Marine Biology from Texas A&M University, his Masters of Education in Curriculum and Instruction from Concordia University, and his Doctorate of Education in Professional Leadership from the University of Houston.

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Susannah Thompson is the Instructional Technology Facilitator for Cherokee County Schools and coaches both students and staff on effective integration of technology into the classroom. She has also worked as a high school Media Coordinator and an Educational Content Consultant. Prior to her work in the school system, Susannah spent 12 years working for the North Carolina Wildlife Resources Commission, first as a Wildlife Education Specialist and later as a Distance Learning Coordinator. She completed her student teaching in Madrid, Spain, and is certified as an Environmental Educator by the NC Office of Environmental Education. Her work has been featured by various publications including the University of NC at Greensboro alumni magazine. Susannah is an avid naturalist, conservation advocate, outdoor enthusiast, videographer and photographer; in all roles, she is a teacher.

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Maria Xanthoudaki is Director of Education & CREI (Centre for Research in Informal Education) at the National Museum of Science and Technology Leonardo da Vinci. She also teaches "Research Methods in Education" at the Department of Education, Catholic University Milan. Maria holds a B.A. in Pedagogy from the University of Crete (Greece), an M.A. in Arts Education and a Ph.D. in Museum Education, both from the University of Sussex (UK). She has carried out research on informal learning methodologies, held professional development courses in museums and universities in the UK, Italy and Greece. She began her career in the art museum field, moving to science museums in 2001.

Jung-Hua Yeh is Assistant Curator of Science Education Department at the National Museum of Natural Science in Taiwan, and has Ph.D. in Science Education. She has been working in informal settings science learning for 15 years, the Coordinator of Energy Education, Ocean Education and Social Technological Issue. Her research ranges from docent professional development, museum learning and museum science communication. She held a concurrent Assistant Professorship at National Taichung Education University for the Teacher Education Program, took in charge "Museum Teaching Design and Practice" and "Primary School Science Teaching".

Heather Toomey Zimmerman is Associate Professor at Penn State University and a learning scientist who uses ethnographic and design-based research methods. She analyzes how informal and everyday learning experiences contribute to families' and children's understanding of scientific knowledge, practices, and career trajectories. Her research interests include mobile computers as learning tools; learning in museums, science centers, and nature centers; and identity, curiosity, expertise, and interest related to science learning. Her website is: http://sites.psu.edu/heatherzimmerman/.

Chapter 1
Introduction

Patricia G. Patrick

> *Why does the sun set in the west? And why does my heart keep beating. in my chest?…I got a PBS mind in an MTV world. (Buffett & Mayer, 1999).*

> *And the end of all our exploring.*
> *will be to arrive where we started.*
> *and to know the place for the first time. (Eliot, 1971, p. 51).*

In 2013, I began a journey that led me through happiness, turmoil, and personal and professional growth, and now I have seen where I started and I know it for the first time (T.S. Elliot quote above). Prior to 2013, I wanted desperately to be an informal science educator. I was focusing my research on informal science education (ISE) and I recently had published *Zoo Talk*, in which I proposed ways formal and informal educators might think about learning in zoos. However, I still was teaching traditional science education courses for pre-service teachers. In these courses, I kept up the traditional practices of classroom pedagogy and epistemology, focusing on how to improve classroom management, questioning, and assessment skills. While I enjoyed my time with the students and was able to incorporate some lessons on informal learning, I felt pressure to follow "the code". On the outside, I forced myself to appear happy with the status quo, but, on the inside, I wanted to develop a program for informal educators. During the fall semester of 2012, the chair of my department (Education) was completing my annual review, in which I mentioned my thoughts, and she asked me, "What DO you want to do?" I was stunned. She was asking me what I really wanted to do. I described my dream to start a masters in informal science education. Her reply was "Do it! It sounds like fun!"

At that time, I felt like my real professional life started. I threw myself into the project and began developing courses and syllabi for the program. I found an ally in Chance Sanford, Vice President of Education at the Houston Zoo. We met several times and discussed what we thought would be appropriate topics for informal science educators as they began their careers. We asked: Would this degree be a fit

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for any informal educator? What should these educators know? What is it potential employers should expect of educators when they completed the program? Did they need to know about behavior management? What did they need to know about learning theory and how to apply theory in informal settings? Would it be important for them to know how to evaluate programs? Did they need practicums, which would provide them with opportunities to work in an informal science institution (ISI)? What model would the practicums follow? What teaching skills did they need to develop? What pedagogies and epistemologies would be important to informal educators? Should we focus on conservation, environmental, or general science education? These questions and many more led me to look for information about training “pre-service” and “in-service” informal educators.

I began my search by looking at well-regarded researchers in the field of informal science education, such as Doris Ash, Lynn Dierking, John Falk, James Kisiel, Tali Tal, Léonie Rennie, Susan Stocklmayer, and Lynn Tran. Even though their work and the work of many others answered some of my questions about preparing informal educators, their work prompted me to ask more questions (which research should do) about what informal science educators should know and the pedagogical and epistemological processes that university professionals should consider in an ISE course. The more I read about ISE, the more confused I became about how the ISE community was defining ISE and informal science learning and if defining them differently or using them as interchangeable terms. I asked myself, “How do we educate the informal educators?”; “What does a university level ISE course look like?” The articles, books, and conversations led me to choosing the following core courses for the Masters of Education in Informal Science Education:

- Nature of Informal Science.
- Current Issues and Research in Informal Science Education.
- Learning Theories and Curriculum Models in Informal Science Education.
- Assessing Learning in Informal Science Settings.
- Advanced Practicum in Curriculum and Instruction: Current Trends in ISE Technology.
- Advanced Practicum in Curriculum and Instruction: Diverse Audiences, Communication, Instruction, and Evaluation in ISE.

I based these courses on four main ideas:

- Utilizing learning theories would define and enhance the learning that occurs in informal institutions.
- A better understanding of how diverse audiences learn in informal settings would provide informal educators with the skills that increase their ability to interact and communicate with the public.
- Incorporating practicums that require reflective practicum journals would provide opportunities for students to expose their experiences and how the experiences influence their thoughts about informal education as well as learning.
- Students would be responsible for designing an evaluative action research project that focused on some need within the ISI, in which they were completing

> their practicum. For example, during a graduate student practicum, an institution wanted to determine how formal educators were utilizing their pre-visit activities. The graduate student found that formal educators were not using the activities and why. She redesigned the activities and this became a part of her thesis project. Another student designed a pre-, post-evaluation to measure visitors' knowledge of primates in a new primate exhibit.

Even though these courses answered the question of what the degree would include, a how-to handbook did not exist for informal educators. Based on my issues with finding a compilation of resources for my students, I decided to put together a handbook for university professionals and informal educators that could aid them in their quest to become the best at their profession. My belief is that this book has a lot to offer anyone interested in working in an informal learning environment.

I divided the book into five topics including 29 chapters. The topics are: *Defining Informal Science Education*, *Professional Development*, *Designing Programs*, *Bridging the Gap Between Formal and Informal Educators*, and *Public Communication*.

Defining Informal Science Education

The first topic, *Defining Informal Science Education*, is a singular chapter that introduces us to a new perspective on defining informal science education. Chapter 2, written by Phyllis Katz, sparks a dialog about defining ISE and sets the stage for the remainder of the book. In addition to asking informal science educators to define ISE, she poses a new term to take the place of ISE—Continual Science Learning (CSL). CSL poses a theoretical shift from informal science education as a choice to informal science as an ever-present necessity. Prior to posing this conceptual shift in defining ISE, the chapter traces the history of the term informal science education with its affordances and limitations (e.g., Bell, Lewenstein, Shouse, & Feder, 2009) and draws on educational theorists who focus on how we learn.

Professional Development

Professional Development, the second topic in the book, is an important aspect of preparing informal science educators. Due to a lack, or at least a low number, of informal science education teacher preparatory programs, informal science educators rely on the professional development provided by their institution and online resources (e.g., Association of Science—Technology Centers Professional Development [ASTC] Communities of Practice, ASTC, 2015). In 2007, Astor-Jack, McCallie, and Balcerzak (2007) completed a literature review to determine the published research about professional development of informal science educators.

They mentioned 14 studies that focused on professional development. However, most of the studies were dedicated to identifying ISI resources and fieldtrip content used by formal and informal educators. Even though educators traditionally have associated professional development with training in-service formal educators, ISIs now are viewing in-service training as an important aspect of developing effective teaching strategies. As ISIs develop training programs for their education staff, they should take into consideration the findings that workshop-based professional development is ineffective for formal educators (Darling-Hammond, Chung, Andree, & Richardson, 2009). In fact, short, focused workshops do not change teacher practice (Yoon, Duncan, Lee, Scarloss, & Shapley, 2007). Instead, professional development should include a mentor, who gives useful feedback, and should take place over time and provide long-term support for the educators as they implement their new ideas, reflect on the process, evaluate their success, and work with a mentor (Teemant, Wink, & Tyra, 2011). The five chapters in this section of the book provide a fresh look at professional development by focusing on reflective practice and identity development.

Chapter 3 authored by Patricia Patrick describes best practices through the nine dimensions of reflective practice, as defined by Zwozdiak-Myers (2012). She presents suggestions for incorporating reflection as an integral part of professional development practice.

Chapter 4, coauthored by Heather King and Lynn Tran, discusses the nature and facilitation of deep conceptual learning in informal learning contexts. They highlight the importance of reflection and consider the need for informal educators to build learning communities to support and sustain effective practice.

Lauren Allen and Kevin Crowley, Chap. 5, address the professional development of docents through discourse about field trip design. Through reflection, the docents establish how best to interact with students.

In Chap. 6, Jung-Hua Yeh portrays docent identity and how that identity forms the beliefs and theories docents have about how people learn. When informal educators reflect on their personal beliefs about knowledge and knowing, their ability to provide information to visitors improves.

As a follow up to Chap. 6, Chap. 7 defines the identity development of informal science educators who engaged in The Science Theater Education Programming System. Brad McLain shares his experiences with identity development and builds an identity-based conceptual framework that supports professional learning programs.

Designing Programs

In the third section of the book, seven chapters are dedicated to the topic *Designing Programs*. These chapters address the need for designing effective programs by offering: (1) examples of successful programs, (2) implications of gender differences on exhibit and program design, and (3) suggestions for program assessment.

Preeti Gupta and Jennifer Negron, in Chap. 8, use a phenomenological approach to describe a teen facilitator program that they designate as influential on the teenagers' science literacy. Their chapter describes the crucial components of mentoring and guiding the teenagers and provides suggestions for other museums who have or are considering a teen facilitator program.

Chapter 9 provides a view of design guidelines for integrating mobile computers into informal learning and suggests four approaches to developing science-related knowledge. Moreover, Heather Toomey Zimmerman and Susan Land recommend that technology support social interactions during the ISI visit and connect the visitors to the ISI after the visit.

Chapter 10, by Mi Song Kim, describes the development of Multimodal Mediated Modeling Activities (EMMA), which are model-based astronomy activities. The EMMA chapter focuses on the development of informal workshops that support formal educators as they develop participatory learning environments.

Chapter 11, co-authored by Christine Howitt, Elaine Blake and Léonie Rennie describe the development of a play program for young children. They express the importance of developing science-related encounters that take into consideration the audience, prior knowledge, range of knowledge, previous experiences, and how children learn.

Addressing program design from the perspective of the child, Sue Dale Tunnicliffe (Chap. 12) postulates that the gender of the child influences their interpretation of a program. Children interpret exhibits through their existing knowledge and this knowledge may be expressed in the conversations that occur during the program or at an exhibit (Patrick & Tunnicliffe, 2013). With her chapter, Tunnicliffe introduces the importance of understanding the distinct lenses males and females use to filter their ISE experiences.

Lending a particularly interesting view to the direction informal institutions might take to determine the success of their programs, Eric Jensen, Chap. 13, reviews a study completed by Falk and Needham (2011). Jensen completes a methodological review of the article *Measuring Long-Term Impacts of a Science Center on Its Community*. Based on his review of the methodology, Jensen suggests ISIs should consider a longitudinal repeated measures design that assesses the same visitors. In response to Jensen's Chap. 13, Falk and Needham's original article has been included in Chap. 14.

Bridging the Gap Between Formal and Informal Educators

The fourth section of the book, titled *Bridging the Gap Between Formal and Informal Educators*, is dedicated to the current desire to link learning that occurs in informal environments with the learning that happens in the formal classroom. I term the space between formal and informal educators the Zone of Reflexivity. The Zone of Reflexivity is the space in which formal and informal educators examine themselves and each other as educators. Within the Zone of Reflexivity, the educators explore their assumptions, beliefs, and preconceived ideas about educational epistemology and pedagogy. In order to develop a bridge between informal and formal educators, we must create within this space a link that functions as a tool to promote science learning or science literacy.

The issue of linking informal to formal learning has been an ongoing topic of conversation. In 1996, Hofstein and Rosenfeld addressed the notion of utilizing these two entities in a way that promoted a mix of learning contexts and methods. In addition to this amalgamation of pedagogy and epistemology, they called for an "integration of informal learning experiences within the formal school curriculum" (p. 107), because this combination "could make an important contribution" (p. 107) to science education for diverse audiences. Since publication of their article, many other researchers have addressed the importance of viewing formal education within the informal education lens (e.g. Eshach, 2007; Trinder, Guiller, Margaryan, Littlejohn, & Nicol, 2008; Hofstein, Bybee, & Legro, 1997; Riedinger, Marbach-Ad, McGinnis, Hestness, & Pease, 2011, Avraamidou, 2015). In accordance with previous publications, the authors in this section engage the reader by tackling the importance of making connections between the classroom and informal education programs. Moreover, the authors add to the current literature because they define ways in which informal educators may function within the Zone of Reflexivity that exists between these entities.

In Chap. 15, Jakob Egg, Suzanne Kapelari and Justin Dillon depict a training course, which they devised for a botanical garden. Their work describes the importance of developing professional, interdisciplinary learning communities, collaborative networks, and communities of practice for informal/formal educators.

In addition to the importance of learning communities, informal and formal educators also must associate informal education and educators with effective instructional techniques. Chance Sanford and Victoria Sokol state in Chap. 16 that even though informal science educators often lack the training afforded to formal educators, the informal educators may receive targeted on-the-job training that focuses on the best practices of formal educators. Their chapter provides a look at balancing university informal education programs and professional development with the needs of formal and informal educators.

In Chap. 17, Emily Hestness, Kelly Riedinger, and J. Randy McGinnis define four initiatives that melded formal science education preparation programs with informal science education internships, informal science education courses, and local informal science education contexts. They contend that informal science education is essential in building collaboration between formal and informal educators.

Jennifer Adams and Brett Branco, Chap. 18, propose the use of parks as a way for formal educators to teach science. They focus on the ways in which formal educators establish a relationship with nature in parks through place-based experiences, place attachment, and experiential opportunities. By providing formal educators with the opportunity to develop connections with parks (place), formal educators will place educational value on the parks and see them as a valuable resource for science teaching and learning.

Chapter 19 follows the experiences of a professor and two undergraduate students as they trekked through an elementary teacher education program that focused on science education and environmental education. Catherine Matthews, Susannah Thompson, and Sadie Camfield Payne co-authored the chapter as a means to explore the idea that a formal teacher education program can prepare informal educators.

Catherine Matthews continues her look at the integration of formal and informal programs in Chap. 20, with her co-author Aceng Ruyani. They describe and compare environmental education programs in North Carolina and Sumatra, Indonesia with suggestions for enhancing the informal science learning opportunities available to formal educators.

To round out this section of the book, Alexandra Moorman (Chap. 21) a researcher in the Education Department of the Museum für Naturkunde Berlin focuses on using Welcome Classes to bridge the gap between formal and informal education. Her chapter focuses on building a team composed of artists, museum educators, science educators, and social workers that use the museum resources to aid immigrant children as they integrate into society. The program termed Explorers of Nature supports children as they become discoverers through canoeing, hiking in a nature reserve, and exploring the museum.

Public Communication

This section, *Public Communication*, is becoming an important topic for scientists as well as informal educators. Public engagement in science may still follow old rules that do not apply in today's technology-driven world. Effective public outreach informs the public about current science issues and the effects of their actions, while building a shared understanding of relevant science (Varner, 2014). Within the ideologies of communicating with the public, informal educators must identify their audience and consider the institutions' relationship with the audience. This is because informal educators and their audience are part of a *system of discovery*.

In the system of discovery, the goals of the system are more obvious to the institution than to the audience. Informal educators focus on preparing and delivering their education programs; whereas, the visitors' foci are family, entertainment, a day out, and, possibly, learning. This means informal educators must develop their communication skills and abilities to interact successfully with the public. Well-developed programs take into account the idea that the system of discovery is dependent on the interactions of its parts. In other words, the educator works with partners across the organization to design a program and delivers the program that is coherent to its audience and that the audience will find mutually satisfying. The programs and the way of sharing the programs with the audience are components of the system and should support audience learning. In order to add to the literature on communicating with the public, the seven chapters included in this section identify various facets of public engagement and communication, such as science jargon, personalized experiences, exhibitry, and questioning skills.

Chapter 22 focuses on the communication that takes place between scientists and the public. Ayelet Baram-Tsabari and Bruce V. Lewenstein state that even though more university programs are providing scientists with training opportunities that focus on public communication, sufficient evaluations of the programs are not taking place. Their chapter makes suggestions for core competencies to utilize when developing effective science communicators.

Maria Xanthuoudaki and Enrico Miotto (Chap. 23) describe the methodologies they use to develop interactions with visitors at the National Museum of Science and Technology Leonardo da Vinci. They share their methodological principles for training facilitators, the facilitation process, and the *observation grid* they utilize to determine if the facilitator-applied methodology is successful.

Visitors arrive at an ISI with personal knowledge and experiences, which allow them to relate the visit to previous circumstances. In the case of Chap. 24, Michael Reiss addresses the personal views visitors have of evolution. He states that the ISI is responsible for providing information about evolution and insuring that exhibits and programs reflect evolution in a way that communicates to the public more accurately the events of change over time.

Judy Lederman and Gary Holliday (Chap. 25) relate interactions between the museum and visitors to the Nature of Science (NOS). They offer an example of how the museum can design interactive activities and communicate with the public in a way that promotes learning through the scientific process or sociocultural context of science.

In Chap. 26, Susan Stocklmayer and Léonie Rennie explain how we should utilize the discipline of science communication when interacting with the public. They define the important attributes of ISE and the skills and knowledge that informal educators must possess to communicate successfully with the public.

Patricia Patrick (Chap. 27) approaches science communication from the perspective of the audience. Through her study of middle level students' knowledge of local plants and animals, she explains why conservation educators should take into consideration the Sense of Conservation people have of their local natural community. Moreover, she describes the characteristics of Sense of Conservation and correlates them with the notion that people have emotional bonds and strongly felt beliefs about local nature that influence the value they place on conservation.

Chapter 28, by Martin Braund and Anthony Lelliott, expresses the importance of better communication with the public and promotes the understanding of discourse within dialogic space. They propose the use of good questioning skills to increase the meaningful dialog that occurs between informal educators and visitors.

Final Thoughts

As described in the introduction to this chapter, this book grew out of a need to find resources for future and current informal science educators. *Preparing Informal Science Educators: Perspectives from Science Communication and Education* shares with readers the perspectives of ISE researchers and experts from ISIs, who successfully have used theory in their practice and research. The goals are that the reader will draw meaning and usefulness from the array of professional perspectives and be stimulated to begin a quest to scaffold programs and professional development around the frameworks described in this book.

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Part I
Defining ISE

Chapter 2
Formerly ISE: Preparation for Continual Science Learning

Phyllis Katz

In order to prepare informal science educators for the future, we need to consider who they are, where they are, and what skills they need. I found myself rethinking the term *informal science education* (*ISE,* abbreviated throughout this chapter to save space, but to be read as the whole phrase) as a prelude to considering how we could prepare future educators. A memory came back to me. Years ago, when I had a bubbly three year old daughter dancing around in my kitchen, I became keenly aware and grateful for one instance of what I would call *informal science education*. She was hungry and had asked for a piece of cheese, as she had many times before. She took a bite and then, spurred on by her sister and brother, began to giggle at their antics. In seconds, the giggling changed to a gagging sound. I stopped my mixing and chopping to give her a tap on the back. The gagging did not stop. I turned her upside down and repeated the tap. No release. Her face began to change color. And then, from somewhere in my brain, there surfaced the directions and images I had seen on restaurant posters for the Heimlich maneuver. I quickly sat on a nearby step, positioned my daughter's back to me, clenched my fists and pushed up on her diaphragm. A wad of cheese spit out several feet across the room. She breathed easily and continued her play. I, on the other hand, began to shake, realizing how close we had come to a tragedy. The repeated pervasiveness of these posters—this *informal science education*—out-of-school information of the human body and emergency procedures—had probably saved my daughter's life.

This incident, real-life drama with a happy ending, is a short anecdote that compresses much of the nature and importance of continuing to learn science and to benefit from knowing how the world works. In the background were researchers studying human physiology and choking statistics, educators designing instructions, illustrators presenting clear visuals, health advocates insisting on the presence of these instructions, and my using the learning when called for. The anecdote tells

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a story of my benefitting from biology, physics, presentation skills, receptivity, policy (to make the information available) and collaboration (to display it in most eateries)—all packaged for the public. As a program developer and researcher, this event also provided me with a lived experience into the deep relevancy of continued science learning beyond schooling and an appreciation for my colleagues. Do we communicate this relevancy and offer the needed skills in this broad range of what continual science learning can mean?

The above anecdote describes a serious instance, a compelling case for *ISE*, but not the kind of example I usually read about in the literature. Much of *ISE* research has been generated from the institutions, programs/activities, and media that have been defined and been funded from the National Science Foundation (NSF). There is long standing recognition among education researchers and professionals about how important and pervasive science and public understanding are to us as participants through the course of our lives (e.g. Dewey, 1916; Kneller, 1978; National Commission on Excellence in Education, 1983; NRC, 2014; Rutherford & Ahlgren, 1990). Has this message reached the general public? That science is a human endeavor is a theme in teaching the nature of science, one that is clear in the *Next Generation Science Standards* (NGSS) and now propagated at every level of science teaching (Lederman et al., 2014; National Academies Press, 2013). Within schooling then, there are stated goals to teach students explicitly that science is indeed something we do as a natural part of who we are. Some people (professional scientists) choose to make a living doing science. The rest of us certainly need to be aware of what the scientists bring to light, and also to be aware of how we use our science skills in small ways every day no matter how we make a living (National Research Council (NRC), 2014; Tal & Dierking, 2014). What then of the messages beyond school, whose years are four to five times that of compulsory education? Enacting this encompassing perspective has enormous implications for changes in preparation, equity, policy and funding. For, instead of bemoaning the lack of science literacy, we could research and credit the science knowledge sought by everyone because we are all naturally motivated to learn what works in this world for us now and in the future. John Dewey wrote earlier in the 20th century, “The problem of an educational use of science is then to create an intelligence pregnant with the belief in the direction of human affairs by itself” (Dewey, 1916/1944, p. 225). The nature of science tells us that we must change the way we understand the natural and material world as evidence provides us with new insights. Is it not a basic goal of science education that learning how to continue to learn about the world is a key human necessity throughout our lives? And so, while I learned about the respiratory system in classes, I learned from pervasive posters that forcing air from my daughter’s lungs up into the trachea could push an obstruction out of this breathing passage, a combination of physics and physiology. The work of out-of-school science education colleagues made this possible.

I am adding my voice to a call for the perspective of continual science learning as a policy change. This will require educational adjustments in preparing both those of us who see ourselves as professionals and those of us who teach by questioning, modeling, mimicry and exploring beyond either schools or

ISE-designed experiences. This perspective—the basic human need that science fills—implies to me that continual science learning makes implicit the relationship of humans to the world, how we fit, how we adapt, and how we impact and sustain the life systems of which we are a part. The more I considered the preparation of *informal science educators*, the more I acknowledged that we are all participants, moving up and down in the consciousness of our participation throughout our lives. Therefore, future preparation for continual science learning may mean revising our vocabulary to expand and include in our vision those who do not now recognize the imperative, the opportunity, and their role in lifelong science education. In the recent NRC report, *STEM Learning is Everywhere* (NRC, 2014), Elizabeth Stage, Director of the Lawrence Hall of Science, says, "it's the vision of science learning that needs to change…If we could change that vision, we could leverage all the public investment and private and independent investment….to be a game changer" (p. 44). This chapter then, is my contribution to this discussion of "game changing" in light of what it means to prepare for teaching within a new vision.

The Challenge of Words

A new vision of continual science learning requires a starting point that communicates beyond the professional research and education community to the non-professionals who are engaged, perhaps unwittingly. I have found that the term *informal science education* has not done this. Over the years, I have asked a wide variety of people if they knew what *informal science education* was, often in connection with talking about my work. It is rare that anyone provides an explanation that I do not have to modify. I believe that part of the confusion comes from the colloquial use of "informal." Microsoft Word provides these synonyms for *informal*: relaxed, casual, familiar, easy, unceremonious, comfortable, easygoing and natural. Except for the last in the list, these words imply "unimportant" to me. And while I am making a case for *ISE* as essential and natural, grouped with the words above it on the synonym list, "natural" here suggests to me a meaning of "not requiring work or learning." It does not surprise me therefore that *ISE* has not been well recognized by those with whom I talk in the professional ISE design and research field. This seems true even when I am in an *ISE* context during our conversation. In the Yorktown, Virginia U.S. Revolutionary War re-creation, I stopped at the army's medical tent to listen to the costumed explainer speak about the medical services available in the 1770s and 1780s. He spoke about instruments, pain, medicinal herbs, bone settings, and amputations. He had studied his part to answer most questions. Did he know what *ISE* was? No, he did not. I listened eagerly to a young paleontologist talk about recent finds near a new parking lot at the La Brea Tar Pits in California. She talked about extraction methods, dating, and bone identification. She answered questions knowledgeably. After the group had dispersed, I said "hello," and asked if she knew what ISE was. She had never heard the term. After a dinner with friends, we chatted about our lives. A man who has worked in security at the U.S. Federal Emergency Management Agency (FEMA) had just retired from employment helping to control the outcomes of fires and floods across the country. He spoke about the hard work of communicating to people who had lost their homes about damage, disease, and safety. He knew both theory and practice. Did he know what ISE was? No. A young graphic designer who has moved into landscape design spoke with me about her need to learn more horticultural science to address the questions that came to her. She said to me, "I teach all day long. I teach about what plants work where because of light, elevation, and water conditions. I teach about insect and animal interactions. I teach all the time." Had she heard the term *ISE*? No.

There are those of us who advocate for an alternate term, like "free choice" (e.g. Falk ed., 2001). There are others of us who accept that *ISE* is institutionalized, but do not feel that the term encompasses the whole of what we do or all who participate. Leonie Rennie has compiled the state of informal science education in her recent section for *The Handbook of Science Education Research, Vol. II* (2014) and notes that there is not a consensus for *ISE* among those of us who design, implement, and research out-of-school contexts. Irene Rahm plainly stated, "Informal science education is a broad field of research marked by fuzzy boundaries, tensions, and muddles among many disciplines, making for an unclear future trajectory (or trajectories) for the field of study" (p. 1). If we who work and study in the field do not have a clear sense of what it is, how can we support the public's essential continued science learning?

A Little History

The work of informal science educators, separated from formal (school) science teaching has been recognized by the National Science Foundation (NSF) since the mid-1950s. There was a recognized need for funding designated to reach around and beyond the school years. Science education outside of school curricular science has also been referenced as *public understanding of science, free-choice science, out-of-school science,* or *nonformal science education.* We have developed, produced, and researched our work enough to know that it has provided many in the public with opportunities to continue to learn science beyond schooling (Rennie, 2014; Tressel, 1994; Ucko, 2010). Yet, we have struggled with how to capture and communicate the immersion we profess (Tal & Dierking, 2014).

The NSF is a major driver of the direction of science education in the U.S. The term *informal science education* was added to program definitions at the NSF in 1982. George Tressel, then Division Director of what became Materials Development, Research, and Informal Science (MDRI) briefly described the history and naming of *ISE* in an email:

> Originally, the Public Understanding of Science Program [PUOS] was administered as part of NSF's PR office…PUOS was moved into the Education Directorate where it could be

> "monitored" for vulnerable grants and activities…I kept developing a philosophy that would fit… Most people, most of the time, learn most of what they know about science outside of school, from reading, broadcasting, hobbies, museums, etc. And the principal role of formal education is to prepare for this: to establish the foundation and curiosity that makes learning possible and rewarding. I tried a number of different words: "informal," "experiential," "activity," "accidental," etc. And "informal" worked best, so I started using it consistently and it stuck. In one of our endless reorganizations, we formalized it in the Informal Science Education Program. (December 5, 2013)

I have included this quote because it tells not only the history of the ISE term, but also something of the politics and one leader's philosophy and impact. This quote describes the process of how things happen by serendipity and design at a major funding agency. In full disclosure, I tell all readers that I received my first NSF grant under George Tressel's direction and have admired and respected his vision through many lengthy discussions over the years. Certainly, he has influenced my thinking. Nonetheless, many of us who work in this field have lived, somewhat uncomfortably, with this identification ever since. It is a *not something* rather than a *something*. In introducing the *ISE* themed issue of the Journal of Research in Science Teaching (JRST), Tal and Dierking say that the field definition difficulty presented itself in thinking about the articles in the issue. The diversity of articles, they say, points "to the difficulty in defining what informal science education is, or even what science learning in everyday contexts is (perhaps even science learning in general)" (2014, p. 4).

What has always been an exploration of the world became science when the Greeks, Chinese and Arabs passed on their knowledge to the privileged in academies and made efforts to insist on evidence, separating this way of knowing from mythology and religion (Bronowski, 1978). Science has been taught in U.S. schools since the 19th century, when education broadened quickly from classical preparation for the elite to include the study of nature for a rapidly expanding participatory democracy (De Boer, 1991). With the growth of public schools, this subject was included in the curriculum along with reading and writing. As professional scientists have increased the quantity and complexity of information, science has come to be approached by many non-professionals as daunting and hard. Our participation in everyday science is less acknowledged. *ISE*, as it developed institutionally beyond school, provided science for recreation in science centers, museums, national parks, trade books, and programs. As international scores showed the U.S. to be stagnating or falling behind other countries in schooling, educators have begun to pay attention to the kind of optional science learning that some people have sought out. What was its draw? Could the answers be applied to school science? How could the resources be used? There are instances where the boundary between in and out-of-school science education has begun to blur. What of the family and its conversations and choices? *ISE* has welcomed this recognition and attention. Yes, we support schooling and do not see ourselves as leisure time entertainers. Perhaps to encourage funding, *ISE* is described in support of schooling, when it is included in documents about the state of U.S education. In 1983, the report *Educating American for the 21st Century*, stated, "The child who has regularly visited zoos, planetaria and science museums, hiked along nature trails, and built model airplanes and telescopes is infinitely better prepared for, and more receptive to, the mathematics and science of the classroom" (The National Science Board Commission, 1983, p. xii). In 1996, the same year that the U.S. National Science Education Standards (NRC, 1996) were published, the Association of Science-Technology Centers, Inc. (ASTC) released a report entitled *An Invisible Infrastructure, Institutions of Informal Science Education* (Inverness Associates for ASTC, 1996) arguing through survey research that science rich institutions support schools through providing services for both teachers and students. Within the National Association of Research in Science Teaching (NARST), the ad hoc committee on *ISE* prepared a report, later an article in JRST, summing up the committee's discussion about informal science learning.

> …learning in general, and science learning in particular, is cumulative, emerging over time through myriad human experiences, including, but not limited to, experiences in museums, schools, while watching television, reading newspapers and books, conversing with friends and family, and increasingly frequently, through interactions with the Internet. The experiences children and adults have in these various situations dynamically interact to influence the ways individuals construct scientific knowledge, attitudes, behaviors and understanding….. This broad view of learning recognizes that much of what people come to know about the world, including the world of science content and process, derives from real world experiences within a diversity of appropriate physical and social contexts, motivated by an intrinsic desire to learn. (Dierking et al., 2003, p. 109)

The Ad Hoc Committee on Informal Science Education at NARST spent time thinking about a name change in 2001, but the NSF, the NRC, and the National Science Teachers Association (NSTA), among others, have continued to use *ISE* to distinguish lifelong science learning beyond schooling from what happens in required schooling (Bell, Lewenstein, Shouse & Feder, 2009). While my work in the science education research field and anecdotal evidence among the public led me to believe that few people knew the term and what *ISE* encompassed, I designed a questionnaire to be able to research my impression in a more systematic way. This exploratory study then, was prepared with the research question, "How does the term *informal science education* communicate the field of *informal science* education, including its essential quality?"

I constructed an electronic survey and also collected some data in person using the same instrument with a dozen people. I kept the survey short to maximize responses. There were nine questions. The first was the open-ended response to the meaning of the *informal science education* phrase and the other questions asked for demographic information by U.S. Census categories or ISE participation by the NSF categories of institutions, media and programs.

After constructing the survey and examining it with another educator, I piloted it with six people whose professional backgrounds were diverse. I made adjustments to the survey from their feedback. I distributed the link by emailing it to a wide range of colleagues and personal contacts with an introduction and a request for them to distribute it with encouragement, as well as the promise of anonymity. When I scanned the data as it accumulated, I found fewer African American and

Hispanic respondents than I had hoped. I then made paper copies of the survey and went to a large regional playground. I approached African American and Hispanic/Latino adults at the playground, explained the educational nature of my work, and asked for their help in completing the survey. All consented.

These are the descriptive statistics. There were 153 respondents to the survey. They were 78% female and 22% male. The disparity between male and female respondents would require further investigation. Is it that more women are interested in educational issues and are willing to take their time for a survey? Is it that there was an inherent bias in my contacts? The age groups representation were: 8 in the 18–24 age range (5%); 69 were 25–44 (45%); 46 were 45–64 (30%) and 29 were 65 and over (19%). In terms of education levels, 2 respondents had not completed high school, 4 had finished high school, 41 had some college or a B.A.; no one selected "technical school" and 105 had graduate and/or professional school attendance. Using U.S. Census Data categories, I asked the respondents how they identified, explaining that this would tell me if I were reaching a broad audience. Although the predominant respondents were White (105), there was representation from other groups: 26 Black/African American, 7 Spanish/Hispanic/Latino, 7 Asian, 7 identified with two or more groups. There were no American Indian or Alaskan natives and no native Hawaiian or Pacific Islanders. This is a limitation of this study. However, at this point, the data do not suggest responses vary by identity.

I asked three questions about *ISE* participation. The first was about activities or programs, the second was about institutions, and the third was about media, reflecting the NSF strands within the *ISE* (now *Advancing Informal Science Learning—AISL*) program. The responses are shown in Table 2.1 by percentages of respondents. Multiple selections were allowed and therefore the numbers do not sum to 100%.

Interestingly, the category "family and friends activities/discussions" had about twice the participation of other activities. Almost all respondents had visited ISE institutions and more than half used science-related media.

I reviewed descriptions of *informal science education* from the last 30 years (e.g. Crane et al., 1994; Dierking et al., 2003; Falk (Ed.), 2001; National Science Board, 1983; Bell et al., 2009; Rennie, 2014; Tressel, 1994) and found four repeated themes describing the *informal science* field:

1. Historically, *ISE* is designed for places, programs and media in out-of-school contexts (although schools sometimes use them). It continually happens out of school without design in the course of living and communicating among families and other affinity groups.
2. Since it is not compulsory, there is some element of attraction, often called "fun" or "pleasure" in the design of these experiences.
3. Adults select environments and experiences for themselves or children and decide on the strength and length of their commitments; therefore the satisfaction or evaluation is self-determined.

Table 2.1 Participation in ISE programs/activities

Programs/activities		Institutions		Media	
Type	%	Type	%	Type	%
Non-school science classes or programs while you were a student	39	Zoo	97.8	Science reference websites? (for example, medical information, weather, science history, homework help)	85.3
Summer science-related programs while you were a student	34	Museum	96.3	Science documentary movies (such as Imax films)	70
Adult science exploration programs (including citizen science)	29	Public aquarium	95.6	Factual science information books	60
Online science programs (self-guided, webinars, videos)	34	National park	94.9	Science reference or research magazines or newsletters	53
Science activities, experiments and discussion (not a program) with your family and friends	68	Public botanical garden	91.1	Science internet videos or web-based games	44
None of these	17	Science Center	89.7	None of these	4.5
		Planetarium	90		
		None of the above	0		

4. The underlying motivation for the field is that continued science learning is essential or compelling both on a personal level for understanding “the world in movement,” (Bronowski, 1978, p. 5) and one’s own position in it (Bronowski, 1978) as well as on a national level for security and economic growth (Rutherford & Ahlgren, 1990; Bell et al., 2009).

I used these four themes and as well as “no answer,” and “I don’t know,” to analyze the responses to this question, conferring with a colleague for consensus of coding. Below are examples of how I coded the open-ended *ISE* responses. The numbers that follow the code category are the participant survey identification numbers. Sample data and analysis:

1. **Out-of-school setting recognized as informal**, #16: “Science education that happens outside the structure of a K-12 school but could be in a school being brought in by a partner group.”
2. **Out-of-school and pleasure or fun**, #76: “Fun AND educational TV program, articles, etc.”

Table 2.2 Summary data for recognition of ISE themes

No answer	No clue	Out-of-school setting	Pleasure element or fun	Self satisfaction or evaluation	Compelling need to continue to learn
15	20	89	17	21	26

3. **Out-of-school and compelling**, #109: "Building understanding of the scientific process and problem solving outside of the science classroom. Building curiosity and inquiry beyond the science classroom."
4. **Out-of-school, fun, self-satisfied/evaluated, and compelling**. #116: "Learning about the material world (not necessarily called "science") in a setting outside an institutional classroom. Done for its own sake, usually fun, no exam or formal credit."

When asked to define informal science education, 17% of my sample, as shown in Table 2.2, admitted to not knowing at all with almost as many leaving the fill-in blank. Since the purpose of the survey was to answer that question, no answer might be added to the "no clue" group, but since I cannot say that with assurance, I have separated those non responses out. Of those who answered, more than half noted an out-of-school setting. Few respondents mentioned pleasure or fun. Perhaps this is assumed. Few mentioned self-satisfaction or self-evaluation (no tests). Perhaps this is assumed. And few mentioned the inherent need to know as part of their definition. Although those of us in the field think and write about these reasons for participation, are we communicating? If anything, my survey is biased in favor of those in my mostly educated extended communities who would be more exposed to science education. Surely a larger, random sample of the general population is needed to make a statement with more certainty, but this exploratory sample suggests that *informal science education* would be less well known, not more.

ISE: Language, Teaching and Learning

What might this fuzziness about the term *informal science education* mean to science teaching and learning? Our extensive human ability to use language to communicate ideas and knowledge among each other and from generation to generation has allowed science learning to be cumulative and complex. We become excited as children learn to speak and respond to our language(s). Adults know that this is the beginning of extensive learning through the exchange of ideas. There is evidence that children begin early to recognize patterns and to categorize the things that they experience (Gopnik et al., 1999). There is evidence that the extent of early vocabulary can determine future learning and consequently success in life (Risley & Hart, 1995). As adults, our words and phrases reinforce or question our common understandings. Using the word "*informal*" with science education is confusing. It does not communicate the seriousness of our work to the public or other educators. It does not communicate the seriousness of the way learners are encouraged (or discouraged) from communicating the sense that they are making of their experiences as they interact within family and other cultural groups. Language is intimately entwined with learning science. The more I have thought about it, the more I have come to believe that the term *ISE* is counterproductive and does not help me consider how to prepare those who are engaged in it. ISE I believe is an historic term—one that helped distinguish out-of-school learning when its development needed that boundary to fund advancement and contribution to the whole science education enterprise. The phrase is now holding us back and reinforcing old boundaries that need not exist. The term is not helpful in creating a vision and plans for how we learn and teach science.

Continual Science Learning (CSL), Adaptive Core

I have argued for a language change to reflect where science teaching occurs and to reconsider how we can better prepare those who teach science. Now I want to return briefly to the adaptive quality of our learning to preface my suggestions for changes in teacher preparation. One categorization of animals that biologists make is between those that are precocial and those that are altricial. Precocial organisms operate more along the lines of innate patterns, with short adolescences and learning periods before they reproduce the next generation. We are altricial—that is, we are born with the potential to learn as we go, unlike precocial animals who are programmed by their biology to survive through inborn behavioral patterns. Physiologically, we are born with a skull structure that allows for an expanding brain. Ducks can walk and swim at birth. Monarch butterflies make a three generational migration of thousands of miles in their reproductive cycle. We cannot walk or swim at birth, even though we may need these skills for survival. Nor do we have a migratory pattern for finding our mates, even though there are cultural patterns which can determine our limits (if we accept them). Humans are the most widespread creatures. We live in all parts of the planet. We have learned to adapt to hot and cold, wet, and dry climates. We have learned to build in mud, clay, wood, stone, steel, and glass. We control our climates within these spaces. We do all sorts of things and erect all sorts of structures in which to do them. We are social creatures, living and depending upon communities (Wenger, 1998; Wilson, 1975). And, most importantly, we can pass on continuing knowledge and the learning of how to learn what we cannot foresee. This evidenced-based knowledge of how the world works and ways in which we seek new reliable knowledge is what we call science. We hope to create useful individual and collective memories as social creatures with rich cultural variations that influence how we express our learning. Science learning then, is the learning of patterns that can help us live, predict, and adapt successfully is an innate need. What we find, test and record is part of our altricial nature. We must keep learning to keep adapting, to keep living, to be the humans we are (Moss et al. 2013). My theoretical perspective, then, is that of a biologist, understanding that organisms have needs, that humans are social organisms and that we must interact with the environment in such a way as to further our survival, meeting our needs, using our well-developed human ability to discern patterns so that we may predict and prepare for what comes. Continual science learning is not an option. It is our survival strategy. Our brain capacity and structure tell us this as we learn more about learning (Krishnan & Carey, 2013). We are always taking in data and processing it. To look at learning neurologically is to call science the conscious systematic handling of all of these data. As people, our schooling is meant to give us tools to make sense of these data and to be efficient about the learning process by passing on some of what we already know in terms of facts, processes, and theories that will help us make the best choices for our own survival and success. Most references to "adaptive" learning in education have been used to describe the needs of disabled students. Bransford et al. (2005) write about "adaptive expertise" for teachers. They speak of the ability to teach while balancing efficiency and innovation. The goal in teacher education then is to develop teachers who can continue to learn to teach flexibly in educational environments—adaptively. But they do not emphasize the modeling of this attribute for students. It seems that the concept of adaptation as a driver is implied in many documents that speak to "preparing students for the 21st century," but while the notion of relevancy to student learning is a motivation concern, the development of an intentional ability to study science to change with a changing environment has not been apparent to me.

Science learning is a very old human enterprise, born of our awareness of a future for which we might prepare, and spurred by innate curiosity to ask "what if?" Therefore, continual science learning goes beyond the annals of history, although it is deduced from the results—our very existence and success as a species, living in the broadest array of environments. What we do then, is learn how to succeed through science. Science is an adaptive outcome of being human. And as such, what we have called *ISE* is not optional, not a choice, but an essential and continuing human need. Along with evolutionary biology to explain that we have survived by interacting and adapting to our environment as all living things do (or perish), there is ample evidence to suggest that play (that is, low risk experimentation and practice) is also an essential part of what we do to learn science from our earliest years (Pramling-Samuelsson & Fleer, 2009). We often engage in play as adults to flex our minds to experiment with alternatives for the pleasure using our minds brings us—and for the practice. Our continual science learning institutions offer dedicated venues for this kind of pleasure. Conversely, since these places are not required, they employ elements of play to attract us, to engage our natural curiosity. It must be fun, pleasant, engaging, or entertaining for us to take advantage of their teaching capacity.

Play is low-risk experimentation whether with our muscles or minds. We try things out, see how it goes, make mental notes that tell us things like falling can result in broken limbs, and a lack of strategical understanding of our opponent's move can lose us our queens and the game of chess. In either case, we usually survive to continue our lives, the wiser. We often associate the notion of play with children, but play occupies adults in the popularity of sports, both participatory and spectator, and more so now, video games. Jarret (1998) found a high correlation between teacher professional development ratings of fun, interest and learning potential and the intention to implement in their own classrooms. Ackerman (1999) has written about deep play, or the pleasure element that continues through life in mental and physical self-determined activity. Play is an important part of continual science learning. Our brains need to relax from high stakes work. The lower stress of play fulfills a physical survival need. The critical "what if" question can be a playful one. Play is not optional. It is interesting to note that learning outside of schooling is often called "enrichment" and its support is most often by supplementary fees. In this way, we perpetuate inequalities in learning, not only through "good" public schools that have the largest tax bases, but in the venues that enhance learning and charge for it because they cannot do their work without money. What does this say about our education policies?

A New Vision Has Been Growing

In 1983, Bonnie Van Dorn, then Executive Director of the Association of Science and Technology Associations (initially funded by the National Science Foundation in 1980), participated in the discussions which resulted in the report*, A Nation At Risk*, foreshadowing the slide which we have seen in our international standing in science education. She was especially pleased that the report recommended that out-of-school science education had a key role to play in the U.S. (National Commission for Excellence in Education, 1983). In 1985, I was a contributor to the National Science Teachers Association's (NSTA) first book on the variety of out-of-school science that was available: *Science for the Fun of It*. Marvin Druger, then President of the Association, encouraged a group of us to write about our projects and places beyond the classroom. Other authors included Don Herbert—better known as "Mr. Wizard," and Ray Bradbury, the well-known science fiction author. In 1994 Valerie Crane et al. published the first volume devoted to research in *informal science education*. The science education journals dedicated almost no space to out-of-school research. Science for All Americans, a landmark publication put into print the statement that "Even today, it is evident that family, religion, peers, books, news and entertainment media, and general life experiences are the chief influences in shaping people's views of knowledge, learning and other aspects of life." (Rutherford & Ahlgren, 1990, p. 171). The momentum was building. The report *An Invisible Infrastructure*, written by Inverness Associates (1994), provided evidence that out-of-school institutions support school learning far more than was evident. In the years that followed, researchers sought detailed insights into the links between schools and ISE institutions, mostly, but not always, in school-museum collaborations. In my research in Project Nexus at the University of Maryland where pre-service teachers chose an afterschool science enrichment internship and in research at other universities, students in teacher preparation or in-service programs were shown to benefit from experience in ISE settings (e.g. Jung & Tonso, 2006; Katz, 2011, Kisiel, 2013; Stocklmayer, Rennie & Gilbert, 2010). The linkage created space in school-centered journals. Slowly research expanded to include afterschool programs, summer camps, media (including internet), and homes/families. The Harvard Family Project collected and distributed research about learning and family, with a section on out-of-school opportunities (http://www.hfrp.org/).

Words and Actions

By redefining and communicating more clearly about what we have called *informal science education* and transforming the term to reflect the concept of *continual science learning* that is essential, pervasive, creative, and lifelong (CSL then, in our acronym prone style), I can shape a vision of science teacher preparation. Contrary to what the term *ISE* suggests, CSL is compulsory—not by law, but by our nature. We may sometimes have a choice as to where we learn, but not when. We are always learning and our minds are organized to seek learning for adaptive success. Does it not follow that support for continual science learning is a priority for us and for the nation we have created to enhance our survival—a democracy of freedom and choice for allowing a wide variety of strategies from which we can choose to survive. John Dewey told us this in the early 20th century. Democracy and education are bound together (Dewey 1916/1944). There is a need for a citizenry that is science literate enough to make democratic [and adaptive] decisions, as well as a cadre of scientists who choose to spend their lives exploring deeply (Osborne & Dillon, 2008). As social creatures, we have multiple identities within different communities in our lives, taking different roles and responsibilities within each. But we must do at least everyday science to make choices. In a very real sense, CSL educators are all of us. As with scientists, some of us will make a living at it and some of us will not. We are *continuing science learning* educators when we are parents, grandparents, aunts, and uncles, modeling interest and enthusiasm, talking to our children, choosing toys, raising questions, and involving them in skill building as we go about daily tasks. We are CSL educators in site-based and research careers that present and consider opportunities to explore the world. The current ISE institutions of science centers, space centers, zoos, botanical gardens, aquaria, national parks, and museums are very much a part of this. But we are also CSL educators when we write and illustrate books and other media about how the world works. Some of us design playgrounds, as I saw in Capistrano Beach in California, with a sturdy sign illustrating what muscles are used in climbing a rock wall. We are CSL educators when we move health information out to the public in practical ways. Yes, like the Heimlich maneuver posters in restaurants. We are CSL educators as intentional science activity participants or when we explain to consumers how their plumbing and electricity works and how to create a compost bin. A CSL educator then, is one who is aware of and uses the adaptive interests of the learners to teach science as a starting point and maintains a reciprocal understanding of her own learning and teaching in any relationship. Figure 2.1 displays the model that evolved in my rethinking continual science learning as adaptive learning/teaching.

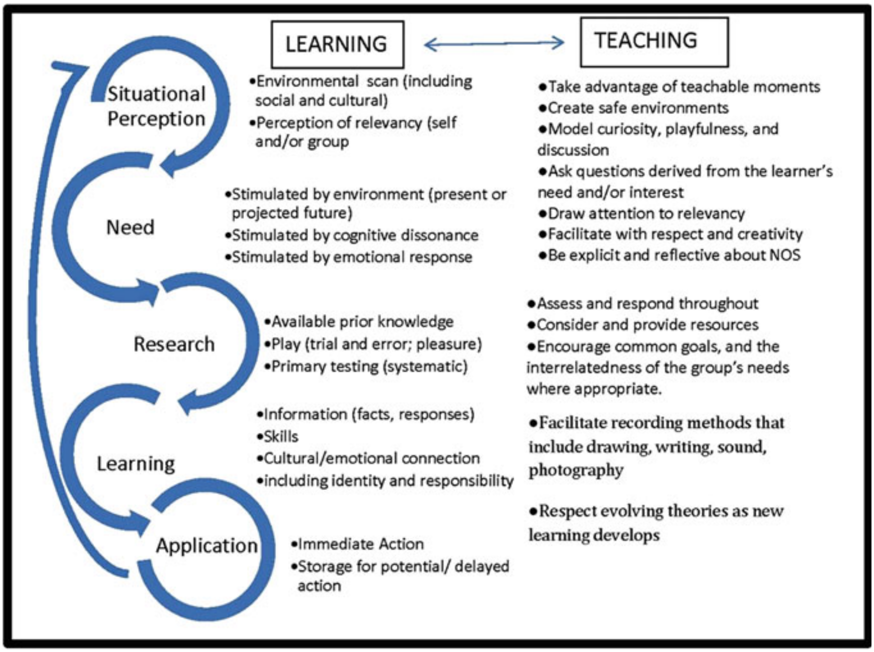


Fig. 2.1 Adaptive model of Continual Science Learning (CSL) learning and teaching

The implications of this model (all of which require research for confirmation or modification), are that:

- Learning and teaching are reciprocal ongoing activities
- Learning occurs when the learner perceives a need that is personally relevant. Can groups with which the learner identifies help create need and perception of relevancy?
- The learner is personally motivated to consider the environment and has a stake in the outcome.
- Cultural, identity, emotional and social components influence relevancy.
- The learner wants to investigate options for decision making.
- The learner seeks and assimilates the information and/or skills to protect or further him/herself at some level.
- The learner incorporates the new information by taking relevant action or banking the learning for perceived future need. In sociobiology theory, there is "proximate" or immediate need and "ultimate" (survival) needs that are filled.
- The time of this process can be short or long.
- The decision process derives from the learner. While the learning process is not optional, the participation is the learner's choice. Learners who are not "on task," in terms of a given activity, may be distracted by a competing need, or do not see the relevancy in their involvement.

- Experience is cumulative and proceeds at different rates for different learners based on their own life histories.
- Teachers provide experience, appropriate resources, safe environments, and would therefore be prepared by having their own experience in science, knowledge of research methods, community resources (as well as those available virtually), developmental psychology, and safety.

My model was certainly influenced by the work of science educators around me, many of whom struggle with the immense diversity of schooling situations in our country (e.g. Clark, 1996; Delpit, 1995; Goldberg, 1976). I believe that the *formal education* and *out-of-school education* boundaries no longer support the education of many students. It is not enough to have a scientist visit a class. It is not enough to travel to a museum as a field trip. These occasions reinforce the concept that learning beyond the school is an unusual or special event. What we have learned about learning from science can guide us. Our brains have a need for stability (homeostasis)—repeated pattern recognition on which our lives depend (Damasio, 2010.) We also have a need for creativity, given the plasticity of our brains. Creativity facilitates our adaptive need to be ready to solve new challenges as they arise in our lives (Csikszentmihalyi, 1996; Piaget, 1973). Pattern recognition and creativity are continual activities within our culture.

Science education is about how the world works interdependently. From sociobiology theory we consider that the more relatedness that is felt within a group, the more empathy or altruism is acted upon (Goldsmith, 1991). It goes beyond people. Accredited zoos no longer see themselves as exhibiting collections of animals, but as active partners in conservation, countering the spread of humans, who have dramatically and quickly changed long standing ecosystems. Biologists tell us that even small changes in the flora and fauna of the world can impact on how we humans must also adapt. Relatedness is not only about how we feel about people, but how we relate to the country we have created or the planet that sustains us.

Science education depends on and creates emotional reactions. Feelings or emotions are primal. They drive us to react for our own safety and they fill us with affordances and inhibitions in terms of safety and further learning (Damasio, 2010). Learning appears to be a mixture of memory and emotion. (Boyd, 2012). As we learn and teach we couple the emotions of trust (or distrust), kindness (or harshness), pleasure (or pain), satisfaction (or anxiety) into the memory of the experience and its outcome (adaptive or not). And then memories may be retrievable by and for our use, further molded by new experiences and emotions as we live. As continual science learning educators, our challenge is to provide memorable experiences with positive emotions that will afford the use when needed. How might this look in an out-of-school conversation?

Walking along a street after a major hurricane, a 6 year old boy turns to his grandmother and asks, “Why are some of the trees in this line of trees down and the others still standing? How did the wind choose?" He notices a curious difference—a discrepant event— in his environment. He is aware of the hurricane wind damage. He anthropomorphizes the wind with volition. He wants to know more. A continual science educator asks, "What do you think could have happened?" She is conveying to him that she is interested in his answer and respects his thinking. "Well", he says, "the wind didn't hit the trees the same, so maybe it changed direction suddenly—or maybe the roots are different." "That sounds possible," she replies, holding his hand. "Let's look around and see what has happened to other trees and then we can look it up when we get back to the house." Alternate responses might have changed the child's attitude toward inquiry. Might the grandmother have said she was cold and they should just keep walking? Might she have said that the wind just wants what it wants? Might she have told him about variations in wind direction and the strength of different kinds of tree roots, until he wandered away? We need to be prepared to give context and age appropriate responses.

Preparing Continual Science Learners: Implications for Teaching

Change in science education is often resistant, slow, and underfunded. I am therefore breaking my suggestions into two categories: "transitional," and "transformative." The first is my vision of how we could work within existing structures (whether schools, other institutions or programs) to plant seeds of a continual and adaptive science learning approach among them. The second is my own playfulness. If I could design from scratch, here is how I would do it!

(1) Where do we begin? I am going to go through levels of preparation chronologically through life, beginning with pre-parenthood and leading to the universities and beyond. Some of my ideas come from proposals or projects I witnessed or read about over the years. Where I am able to credit the source, I am happy to do so. And where I can no longer remember, I ask for the reader's understanding. Preparing educators for this vision of continual science learning (CSL) would begin with parent preparation in high school, since this is the highest level of our country's compulsory education system. As students get ready to enter the workforce and/or advanced education and take an adult role, what skills do they need to be self-sufficient people, to participate in decision-making communities, to raise the next generation, if they choose?

Transitional: Science teachers become explicit and reflective about the role of parenting in science learning. Students could journal (perhaps multi-media) about what encouraged (or discouraged) them in their own families and discuss what they would repeat or change. Science teachers focus on modeling and conversation for science learning: the asking of thoughtful questions, the active display of curiosity, the potential in the playful, "What if?" Perhaps all science teachers would modify their curricula to give credit for students who tutor and reflect on teaching techniques. Physics teachers could assign projects such as the evaluation of manipulative toys, and ask students to describe how they work, their learning and play values and any safety concerns. Assignments could include interacting with young children and reporting on the findings, giving students practice in research and reporting. Chemistry teachers could explore the chemistry of cooking and other chemistry examples within the community, perhaps using the American Chemistry Society's *Chemistry in the Community* textbook as a guide.

Transformational: Science, mathematics, history, language, art, and physical education teachers meet with parents, community planners, engineers and other stakeholders to consider what the community needs. A project is designed which benefits all and teachers design a year's curriculum that is cross-age and meets Common Core goals and more, depending on the circumstances. At The Learning Center at Linlee, a Fayette County public secondary school in Kentucky, Scott Diamond wrote about a program for at-risk high schoolers that has done something very much like this (Diamond, 2014). Working with and teaching younger children are a part of the plan. Science teachers become explicit and reflective about the role of parenting in science learning, as above. Assessment proceeds by the setting of mutual goals. All participants are credited on the new community resource.

(2) When the next generation starts to sprout, I would hope that the high school experiences in talking with younger children as mentors and reflecting on the responses would carry over into the early years of parenting. Various parent support programs around the country, among them Head Start, report success with parent education components. Many preschool settings have done a very good job of providing environments where children can explore and experience new materials and processes.

Transitional: Like Head Start, all preschools need to require parent participation so that the young children and the parents learn science together and parents become metacognitive about their roles as continual science learners and teachers. Explicit and reflective experiences considering the nature of science, safety, messiness of some science explorations, and the wide world of resources in toys, on the internet, in books and in places can be made available.

Transformational: Our society creates policies that allow parents of young children to support themselves with fewer hours of work (or gives work credit for time with children), so that parents and professional teachers can form a closer partnership to do continual science learning as a team, infusing it with cultural richness appropriate to the community. Our society recognizes that starting this early will prepare a work force that is conscious of learning how to learn about the world from early on and that this is a good investment.

(3) Elementary schools are where children have been guided to develop writing, reading, and arithmetic skills and the beginning of science, history, art, and health education. We have labelled these subjects and skills "basic." I found it (unhappily)

fascinating, that science was not as crucial as reading and mathematics in the fading No Child Left Behind Program. A generation of elementary school students had minimal science as their schools and teachers strove to do well on the high stakes tests. How did we let that happen?

Transitional: Design class projects based on student interest and connect to science education themes and skills as described in reform documents. Map activities to Next Generation Science Standards (NGSS) and discuss NOS explicitly and reflectively with children. All of us are citizen-scientists and could collect data and follow studies from a young age.

Transformational: A school talks with children, teachers, parents, and other stakeholders and decides on a school-wide theme for a year. Many years ago, I visited an elementary school in Oak Park, Illinois, that was studying the theme of *time* for the year. There were examples of timepiece technology, and the concept of time in history, as I recall. I do not remember how the school was organized, but I would envision cross-age projects and groups setting goals, planning, gathering materials, and creating presentations and displays that involve good communication skills.

(4) In undergraduate education, science courses provide content and skills to students. Those skills emphasize laboratory techniques and data analysis. In graduate programs, the research narrows and writing publishable papers is an important skill.

Transitional: Add a section to all research papers on the meaning of the research to the public.

Transformational: Make communicating science to the public an essential part of university work, either as an individual expectation or by some form of institutional assistance. Reorganize university science departments to encourage regular, cross-displinary gatherings to share research on not only science, but poetry, history, and other disciplines. Consider a theme and speak to the connectedness and contribution of these different areas of study. Consider how continual science learning is a part of all of this.

(5) Science teacher preparation is essential to this vision. Now, most universities offer programs for primary and secondary teacher candidates. They are prepared by strengthening their content knowledge and having them intern within their chosen levels. Although research has shown that experience in *ISE* settings enhances their abilities, the costs and complications of transportation limit program continuity. There are very few certificate programs for people who want to teach outside of schools. Those people usually apprentice at institutions or programs and learn how to communicate to the public through practice.

Transitional: Professors could seek out continual science learning partners and establish relationships that will benefit both parties in terms of the research-based benefits. This means that our education would include: local knowledge of educational resources and potential project resources; communication skills, team building skills, networking skills, e-skills, etc.

Transformational: I have gone so far as to design an outline for a science teacher preparation program that does not distinguish between in and out-of-school preparedness, assuming that schools become project-based and a much more integrated part of the community.

Continual Science Learning (CSL) Teacher Preparation for Career Teaching/Learning

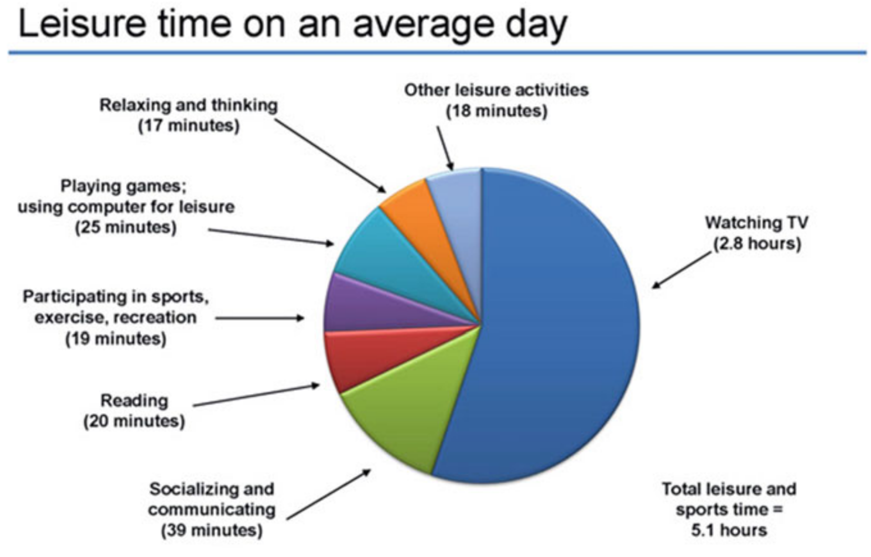
1. Program Admissions Process
    a. Writing sample to include rationale for teaching career
    b. Interview
    c. Provisional admission pending performance
2. Year 1
    a. Learning Theory
        i. Comparative Educational Philosophy among different cultures (to include developmental theories)
        ii. History of Education in the United States
        iii. Neuroanatomy and its contribution to learning (including plasticity and adaptability)
        iv. Evolution Ecology-change over time and impact of changes/projects
    b. Research Methods
        i. Print sources
        ii. Web sources
        iii. Interviews, surveys, drawings, photographs.
        iv. Cultural sensitivity
        v. Communication skills (speaking, writing, drawing, web design, clothing)
    c. Field Work
        i. Observations in which theoretical constructs are sought in the field schools, continual learning sites (museums, playgrounds, work training sites—many/any).
        ii. Group discussions (real time and/or virtual) of match or mismatch between theory and practice
        iii. Collaborative and contributive work project with one observation site
    d. Creative
        i. Year 1 project presentation evaluated on inclusion of components of a, b, c above
        ii. One alternative suggestion for teaching gleaned from Year 1 experience, presented in choice of media

3. Year 2
    a. Foundations of Science
        i. Along with an advisor, select a learning site in the community and research the science necessary for it to function at the highest level
            1. Select and succeed in two science courses related to above (assessed)
            2. Map the relevancy of the science to the learning site and/or project (assessed)
            3. Consider the adaptive quality for individual learners
    b. Science in teaching
        i. Provide an example of how relevant science could be taught to students at different ages/experience (pre-school through senior citizens)-discuss and compare among program participants
        ii. Discuss resources and relevant learning settings in the community. Begin developing a resource catalog.
        iii. Design ideal plan for implementation of one possible learning scenario —compare and assess among program participants' group.
    c. Field Work
        i. Internship at the site selected for basis of science courses
        ii. Visit alternative community sites related to science theme and compare with internship site using research methods and considering impact factors (cost, resources and so on).
    d. Creative
        i. Write media release on link between science and community
        ii. Collaborate with a teaching setting on refining or developing a science learning opportunity
4. Year 3- Repeat Year 2 with alternative setting
5. Year 4-Repeat Year 2 with alternative setting
6. Year 5
    a. Apprenticeship with science learning setting of choice (mutual assessment)
    b. Prepare a self-reflective teacher-as-researcher report in any media approved by teacher development institution—preferably a report that will contribute to setting as well as self.
    c. Certification
7. Continuing CSL certification (Frequency to be determined)
    a. Attend Science Teaching and Learning conference for networking and updates on work of others

b. Present evidence of one's own work and contribution
c. Apply for recertification among peers based on a and b.

(6) We continual science learner/educators can take the lead. Our work has given us a great deal of experience in designing engaging exhibits, meeting the public, in collaborating and communicating. We need first of all, to communicate our professional existence and importance to the public! We work in parks, playgrounds, as authors of fiction or non-fiction for children or adults. We work on films, TV shows, and videos. We work in museums, science centers, botanical gardens, aquaria, zoos, and aviaries. We are parts of projects on ocean vessels and space ships. We are writers, photographers, illustrators, explainers, actors. We are partners in school education. We are partners among our venues and projects. Our lives speak to invisible career options for the next generation, but I have suggested that in part, because of our field name and certainly by examining funding proportions over the last 30 years, we are considered optional and even discriminatory towards those who cannot afford what is seen as enrichment.

The U.S. Government surveys and publishes an American Time Use Survey (ATUS) survey each year. Figure 2.2 represents a leisure time analysis. As a start,



NOTE: Data include all persons age 15 and over. Data include all days of the week and are annual averages for 2012.

SOURCE: Bureau of Labor Statistics, American Time Use Survey

Fig. 2.2 Average day leisure time for U.S. public we can use this research to reach people where they are spending their leisure time to present the message creatively with options for continual science learning. Such tools can be made visible in teacher preparation. It appears that preparing opportunities for TV would be a good start.

Implications for Policy

In terms of broad policies, it would be protective and productive in our population if:

- All school systems and schools had incentives to become community-based science education projects that were self-determined, used stakeholder resources, parents and partners who could feel the advantages to all.
- All continual science learning places, programs, and media had incentives to connect with schools to participate in needs-based projects with their resources.
- Professional science researchers had incentives to communicate the value of their research to the public.

Implications for Funding

Increase the National Science Foundation (NSF) educational funding. It will take resources to transform our country's science education to a higher level providing an adaptive advantage to individuals and the country. The NSF is charged with funding non-medical, non-defense science research and science education. It is not the only science education funder, but it most often takes the lead and is the most clearly visible. I researched the budget for the Education and Human Resources (EHR) total budget and the portion of that allocated to *ISE*. I was unable to obtain the figures for the last four years, even though this should be on public record. The numbers in Fig. 2.3 of the chart represent the number of years from the beginning of the NSF. We spend 80% of our lives outside of schools. And yet the proportion for *ISE* is small.

If we view science education outside of school as an option and we structure its use as mostly unsupported by the public and if we make these environments charge fees for participation we insert discrimination by ability to pay. Many venues create ways to offer free days or make arrangements with schools for bulk pricing (covered by the public in the end) or work-study or other alternative means to encourage participation without regard to ability to pay. Let us think about this. Work and materials cost money. If we believe that science research leads the way, keeps us healthier, provides routes to the future, why are the only ways that people learn science beyond school poorly funded by our government, inherently (and unintentionally) discriminatory and viewed as optional? A society that values the

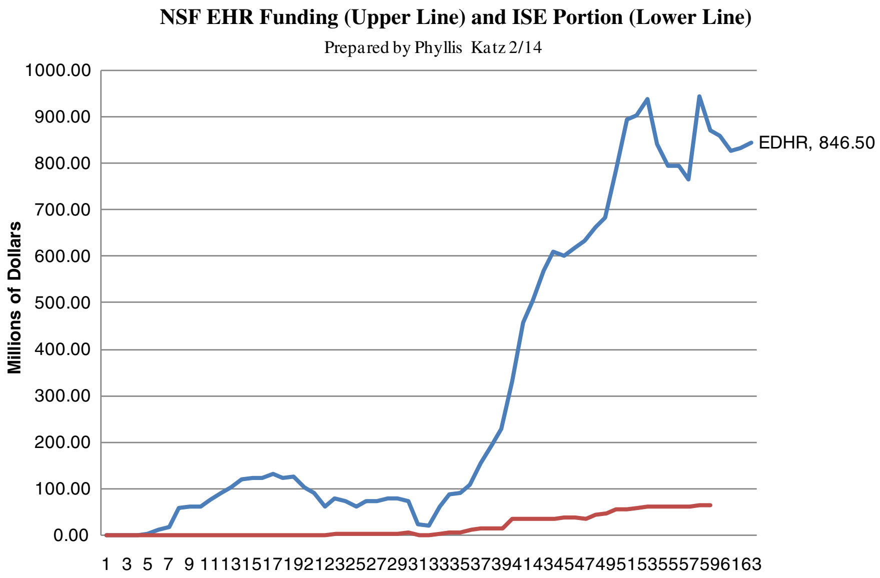


Fig. 2.3 NSF Education and Human Resources (EHR) total and ISE portion

survival of all individuals will invest in the availability of naturally occurring and designed learning opportunities. It will make these available to the population at affordable costs because its benefits to the population are critical.

- All science education projects should provide evidence of *funded* efforts to go beyond the “broader impacts” statements and entail how the projects or curricula yield better adaptiveness through in and out of school work that can continue, according to the cultural and individual interests of the participants.
- All higher education and research scientists should be funded to employ continual science learning teachers to communicate the adaptive qualities of their work to the public who may need to use their research. Researchers should be funded to learn to teach the next generation of researchers in a continual science learning approach. Too often, today’s researchers do not value teaching skills when their students need them in the job market.

Conclusion and Discussion

Living and learning are complex and cumulative. As professional scientists or continual science learners, we have no option but to engage. Most of us no longer live on farms where we participate in food production in the rhythm of the seasons; most of us do not shear, pick, weave, or piece our clothing. We do not construct our homes or even fix what breaks, now controlled by micro-chips where the engineering is less visible. And in the places where people routinely still do these things, the time consumed in doing them makes a comprehensive education of the interrelationships less likely. With the advent of electronic communication, the rate of change in our environments is rapid. Learning how to be efficient through task mastery is not sufficient. We need to be able to adapt our thinking within new contexts (Bransford et al., 2005). We need to work as individuals to enact our learning within organizations toward social change in the way that humans have always used our minds to affect our environments (Jarvis, 2006).

The message of continual science learning is critical just because of these interrelationships. Science is piecing together this puzzle of current facts and connectedness that are creating an image of a world in which bees and frogs tell us their part in the dependency of one organism on another, where wind and water movements near Africa affect hurricanes in North America, where viruses and bacteria hitch rides on airplanes with travelers from one part of the world to another in a matter of hours. We cannot stop (nor do we want to) the world from spinning, nor time to be held constant. So, we study what has been, what is, and the process of change within which we must adapt.

Continual science learning is not an option. Understanding how we come to trust information that is essential to our lives through evidence and argument is not an option. And utilizing the information is not an option. We live by making decisions based on information—making decisions that allow us to adapt to our environment (s), personal/social and material. Nor is the process of learning without cost. We need resources to purchase programs, visit special venues, and acquire equipment with which to do our own investigations. Our challenge as continual science educators is to communicate the persistent, essential, and urgent nature of continual science learning in the context of living and in a mode of communication that is targeted at the learner's zone of proximal development (Vygotsky, 1978). This is what we need to be prepared to do.

We need to be prepared to succeed in a project that would be judged not by how many academics read papers in journals, but by an impact measurement yet to be developed and tempered by the type of research, for its contribution to adaptability, and the success of its reach. "Different kinds of metrics will be needed for policy makers to be convinced of the value of cross-sector collaboration in producing such outcomes as persistence and having a STEM identity," the STEM Learning is Everywhere, report reads (NRC, 2014, p. 5).

Supporting this approach is communication. Continual science education researchers have been moving toward this approach. It is time to shift our vision, as Elizabeth Stage said. This discussion is about learning and only coincidentally about where. It is more about when, as our key interests and attention shift as we move through life from childhood to young adulthood to careers and perhaps parenting. We all grow older. We all must deal with changing bodies, and changing technology, and other changes. Perhaps there has to be a continual science educator on every project to seek understanding and opportunity to communicate to the public. This person's specialty would be collaborations and communication. This person would seek ways in which projects that prove fruitful would be offered as models and sustained, because they were maximizing adaptability. We need to be prepared to do these things.

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Part II
Professional Development

Chapter 3
Informal Science Educators and the Nine Dimensions of Reflective Practice

Patricia G. Patrick

> Teaching is like creating a work of art; like a work of art, it takes different techniques and mediums to make a masterpiece (Jenn Idema, Informal Science Education student, Texas Tech University, 2014).

People learn science at school, formally and informally, and outside school, formally and informally. However, the experiences people have during an informal learning experience with an informal science educator are likely to spark a curiosity to further explore a science topic. Therefore, informal science educators must understand the ramifications of their beliefs about teaching and how people learn. As informal educators define who they are and their notions about learning, they will shape informal pedagogical and epistemological learning perspectives.

As ISE defines the role of informal science educators within the concept of education, ISE needs to reflect on how it has grown and changed over the last 100 years and how it will evolve within the ever-changing bailiwick of formal education. Will ISE as we know it today survive the changing tide in how learning outside the classroom takes place? Preparing the future leaders of ISE (informal science educators) is an important role and all involved should take it seriously (National Science Teachers Association [NSTA], 2012; National Governors Association, 2012). As the notions of preparing informal science educators develop, university preparatory programs are needed that focus on educational theory and learning and program evaluation within ISE.

This will be difficult until universities appreciate the importance of funding such programs. Developing an education program for informal science educators is not an easy task and the numbers of rigorously trained ISE educators may not happen quickly—but these degrees are an important part of the future of ISE. An advanced degree in informal science education exposes graduate students to learning theory,

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program evaluation, and current issues and research, all of which eventually may build a bridge between formal and informal education. Moreover, as informal science educators are prepared for their roles in ISE, the informal educators should know the guidelines from which they are working. Even though the guidelines informal science educators follow will be different from those used to monitor formal educators, informal science educators should take into consideration one important aspect of formal education, reflective practice. Reflective practice is an important aspect of growth and development for formal educators and now attracts attention from ISE researchers (Allen & Crowley, 2014: Ash & Lombana, 2012; Ash, Lombana, & Alcala, 2012).

Reflective Practice in ISE

"Greater investment in an era of widespread accountability has brought greater scrutiny of whether and how science learning experiences in informal settings reach their goals" (Bell, Lewenstein, Shouse, & Feder, 2009, p. 19). This statement begs the questions: Do we have an understanding of the pedagogical skills that informal science educators need to reach the goals? Do informal science educators teach as they were taught by adopting aspects of the formal classroom in which their ideas of education first developed (Lortie, 1975)? Informal science educators do not always receive training in curriculum/program development; in fact, most likely they have strong content knowledge, but weak pedagogical skills. Pedagogy encapsulates the techniques and methods used to teach and how teachers think about them. While this may not seem an important concept in informal science teaching, research supports a much different viewpoint. For example, guided tours, which may be defined as educational by an informal institution, are viewed by visitors as too formal and boring (Charitonos, Blake, Scanlon, & Jones, 2012).

Informal science educators need to incorporate particular pedagogical practices, but not all, that university training programs teach and formal educators employ. For example, during university training, formal educators develop the skills to create lesson plans, structure lessons, write lesson objectives, differentiate between topics, implement behavior management, engage students, assess learning, and reflect on their teaching practices, which are important aspects of developing pedagogy. Moreover, authors now recommend professional development programs common for formal educators as a crucial aspect in developing the pedagogical skills for informal science educators (Ash & Lombana, 2012; Ash et al., 2012; Bevan & Xanthoudaki, 2008; Castle, 2006; Grenier, 2006, 2008, 2009, 2010; Grenier & Sheckley, 2008). However, to place informal science educators into education programs that focus on building skills that relate specifically to the formal classroom will not work either. Even though the basic skills of teaching mentioned above form a subset of the informal science educators' repertoire of knowledge, the pedagogical knowledge needed to teach in informal settings is distinct.

The best practices of classrooms are not the best practices of museums. Mayhew and Finkelstein (2009), asked university pre-service teachers to design and deliver afterschool programs for middle school children (ages 8–12). The results indicated that the pedagogical teaching skills utilized in a traditional classroom are not the same as the best practices that work in an informal after school program. The afterschool program required more subject knowledge and for the educator to feel comfortable in teaching in an informal setting. By incorporating the subject knowledge of informal science educators and formal learning pedagogies, informal science educators may better interact with their audiences and build a foundation for their teaching. One procedure often used in formal education and now considered an important part of the informal science educator's pedagogical abilities is reflective practice.

Dewey (1933) defines reflective thought as "active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends" (p. 118), and Boud, Keogh, & Walker (1985) as "those intellectual and affective activities in which individuals engage to explore their experiences in order to lead to new understandings and appreciations". Dewey (1915, 1933) suggests reflective thought as a way for formal educators to contemplate the success of their classroom performance and implementation of their lessons. In other words, educators should reflect for the sake of reflecting, but do they?

Reflective thought is a bi-directional process, as it is both a process of imposing previous experiences on the current idea and considering the immediate idea and reflecting back on prior ideas. This a natural process. Once one has a thought about an idea, one's mind builds on that idea and reasons about whether or not that idea is sufficient to answer the posed questions. In other words, one begins to infer about the place that the idea holds in one's beliefs and the inference becomes a process of reflecting on one's beliefs. When one confronts information that appears to be invalid, they reason about its existence, process their thoughts, and decide whether to accept or reject that information as valid. A similar reaction occurs when one expects an outcome that does not transpire or assumes an idea to be present that does not emerge. One then determines which outcome or idea is valid and accepts that as fact (Dewey, 1915, 1933). Even though reflective thought is a common, ordinary process, this does not mean that people reflect in a well-defined, deliberate manner. In fact, cognitive psychologists believe that while people may reflect in efficient ways they also commonly make predictable mistakes in their reflections (Kahneman & Tversky, 1979). Therefore, reflecting for the sake of reflecting is deliberate and requires directed interpretation, which makes the ability to reflect on pedagogical aspects of teaching a reflective practice. Hence, informal science educators require training in reflective practice, because focused thinking about their pedagogical approaches to teaching can provide informal science educators with a way to develop a consciousness of their teaching behaviors, performance, and impact.

Reflective practice must be considered within the context of the educator and the learner. The informal science educator must be cognizant of their place within the learning and should research how their teaching skills influence the visitors (Ash & Lombana, 2012; Ash et al., 2012). In fact, research supports the idea that training ISI educators to reflect builds a community of practice in which informal science educators have an opportunity to discuss their work with colleagues (Bevan & Xanthoudaki, 2008; Castle, 2006; Horn, 2010). In order to aid informal science educators in developing a self-awareness of their teaching, I suggest the implementation of the Nine Dimensions of Reflective Practice (Zwozdiak-Myers, 2012). I place the Nine Dimensions into three categories, which depict the modes of Theory and Research, Teaching, and Peers. Theory and Research include (1) evaluate teaching using research, (2) link theory with practice by reading the literature, and (3) critically analyze personal learning theories and beliefs. Teaching encompasses: (4) study teaching for personal improvement and reflect often, (5) be innovative by trying out new strategies and ideas, (6) maximize the learning potential of the audience, and (7) be an effective practitioner by enhancing the quality of teaching. Working with peers includes (8) utilize learning conversations with peers to discuss alternative perspectives and possibilities and (9) improve teaching by being involved in professional development and training. The remainder of the chapter describes how informal science educators may attain each of these within an ISI.

Theory and Research

Evaluate Teaching Using Research

Classroom educators believe their students' knowledge is a reflection of the educator's ability to be a successful teacher (Zwozdiak-Myers, 2012). In ISIs, the idea of student knowledge equates to the knowledge of the visitors and the behavior and attitude changes of visitors; therefore, evaluation includes assessing what the audience already knows, does not know, and their interests prior to developing a program (front-end evaluation) and evaluating learning that takes place during a program. Evaluation may take into account the interactions that occur with the guests during the program, visitor participation, level of questioning among visitors and between the visitors and the educator (formative evaluation), and memories visitors have of the experience (summative evaluation) (Friedman, 2008) (for examples of evaluations see Friedman, 2008, Lemke, Lecusay, Cole, & Michalchik, 2012; Westat, 2010). Because "all forms of evaluation play an important role in… enabling 'reflective practice'" (Dierking, 2008, p. 20), informal science educators should evaluate systematically their own teaching by gathering evidence through a diversity of sources and perspectives. Conducting research and considering the results are important aspects of the reflective process and can influence strongly the educator's perspective on teaching. One way to bridge the gap between research and practice "is by meaningfully engaging the [informal science] educators themselves in their own research pursuits, such as occurs with action research" (DeGregoria Kelly, 2009, p.30).

Visits to ISIs are social experiences and provide sociocultural interactions for visitors (Patrick & Tunnicliffe, 2013). Action research permits reflective informal science practitioners to examine the social interactions of the visitors and the connections between the visitor and the information. Moreover, the reflective behaviors embedded in action research lead to a deep, perceptual insight that progresses the development of a community of practice. When informal science educators take into account the impact of social interactions within their community of practice and with the community of learners, informal science educators will become more aware of their distinct identity in the learning process.

Action research is an important component of informal science teaching evaluation, because the informal science educator has an opportunity to "examine their own educational practice systematically and carefully, using the techniques of research" (Ferrance, 2000, p. 1). Through critical, disciplined examination of their teaching, informal science educators ask a research question, design a methodology to collect data, gather, organize, and synthesize the data, and reflect on the data to improve their daily teaching practice (Ash, 2014; Ash & Lombana, 2013). When the informal science educator identifies questions about their work, examines their performance, and considers various ways of approaching teaching, they must recognize this as a part of their reflective practice and take into account that the research will inform their teaching practice (Watts, 1985). However, educators should not take on action research as a solitary endeavor, because action research is a social process in which colleagues should propose and discuss new actions that improve their work practices. By interacting with other informal science educators within the same institution, the action researcher recognizes their research as subjective and seeks to acquire various perspectives of their teaching and audience learning from peers. Through the process of reflecting on their teaching through action research, informal science educators will "develop a deep understanding of the ways in which a variety of social and environmental forces interact to create complex patterns" (Riel, 2013, Understanding action research) and build an understanding of theory to practice (McNiff & Whitehead, 2010, 2012). Moreover, the results of action research have implications for the educator, the ISI, the visitor, and, if published or shared, for other ISIs.

Link Theory with Practice by Reading the Literature and Critically Analyze Your Personal Theories and Beliefs

Informal science educators should keep abreast of current research, practice, and pedagogy as they relate to informal teaching (Mai & Ash, 2012). Keeping up with current fields of praxis (informal science educators) may occur by reading the research literature that is produced within the field of research (ISE researchers).

However, the role of ISE researchers is to provide investigative results to the praxis field, so that other educators may utilize the findings as they plan, conduct, and evaluate their teaching practice (Folkestad, 2006). One example of how researchers and practitioners are linking their work is through the online journal *Connected Science Learning: Linking In-School and Out-of-School STEM Learning* (http://csl.nsta.org/). The promotional material from the journal states that it intends to bridge the gap between in-school and out-of-school learning settings, promote collaboration between these communities, and publish articles that support practitioners in both settings.

Moreover, informal science educators must understand, define, and question the direct relationship between teaching practice and learning theory. Learning theories vary and even contradict each other; therefore, understanding the distinctions and paradoxes relating to learning theories and how they underscore the process of learning is an imperative component of teaching practice. Most outstanding educators understand these theories and create a personal web of beliefs about learning that rely on several learning theories. Educators accomplish this web of beliefs by studying and understanding learning theories that relate to informal learning. Table 3.1 is an overview of the learning process, the learner, and the role of the educator for four celebrated, longstanding learning theories: Behaviorism, Cognitivism, Constructivism, and Humanism. Even though these learning theories have been used in describing learning in the classroom, they do have application to the informal setting. However, other learning theories exist that may be a better fit for identifying and understanding the learning that takes place in ISIs.

For example, Ash, Rahm, and Melber (2012) cited Activity Theory as a way in which to understand learning in informal settings. In 2014, Ash conceptualized her ideas about identifying and assessing learning and superimposed them over Engeström's (1999), (Ash, 2014) three generations of Activity Theory. In addition to Activity Theory, other contemporary perspectives of learning exist that may be better suited to defining learning in ISIs. As an extension of the conversation about various perspectives on learning within an ISI, Table 3.2 offers a look at Connectivism, Transformative, Biographical, and Experiential theories. A more productive pedagogical approach to identifying learning in ISIs could be to explore how and why visitors learn by applying one of the aforementioned learning theories to practice. Informal science educators may move past the pitfalls of overly simplifying teaching and learning if they take into account the various ways in which people learn. This means creating learning environments based on learning theories and working towards building the necessary pedagogical and epistemological skills that best fit their institution and audience. Moreover, informal science educators should use reflective practice to acknowledge more explicitly and honestly their sensitivity to implementing programs based on learning theory and perspectives. Because no one theory is all-inclusive, as practitioners, informal science educators should be aware of these learning theories and others, so that they may create a personal theory of learning (McDevitt & Ormrod, 2004).

Table 3.1 Long-standing learning theories and their relationship to teaching in informal science education

	Behaviorism (Skinner, 1953, 1974, 1979; Watson, 2009)	Cognitivism (Piaget, 1957; Piaget & Cook, 1952; Vygotsky, 1978; Wadsworth, 1996)	Constructivism (Anderson, 1996; Anderson, Lucas, Ginns, 2003; Anderson, Reder, Simon, 1996; Bruner, 1966, 1996)	Humanism (Maslow 1968, 1969; Maslow & Rogers, 1979)
Learning process	Learning is defined as a change in behavior. Behavior tasks result in a change in behavior by using reinforcement or punishment	Learning occurs through scaffolding of knowledge of experts. The learner builds new knowledge by scaffolding on prior knowledge. Focuses on the internal connections that are made during learning	Learning occurs through real world events that occur in everyday life. The educator is a facilitator and guides learning through problem solving. The learner reflects on past life experiences to construct new knowledge	Learning is guided by intrinsic motivation. Learning will not occur until the learner's basic needs are met
The Learner	The learner responds to a wide variety of stimuli and situations within their environment	The learner is motivated to learn when new information is linked to prior knowledge. The learner processes new information and assimilates, accommodates, or rejects the new knowledge	The learner is vested in the process, which occurs over time. This learning usually takes place outside the formal classroom	The learner chooses what they would like to learn based on the topic's relevance to their lives. The learner must have time to reflect on the information and deem it as important
Role of the Educator	To engage learners through a stimulus-response system	To engage learners to develop cognitively by allowing them to scaffold new information on existing knowledge	To engage the learner in activities that relate to their daily lives. The educator, or facilitator, provides experiences, but does not dictate learning	To engage in self-actualization. The learner is in complete control of what and how they learn, while the educator is seen as a mediator

Informal science educators must be conscious of the learning theories that relate to informal learning, take these into consideration as they design and implement programs, and ask themselves questions about their practice, such as:

- Did I take the time to respond in a meaningful way?
- Did my response foster a desire in the visitor to find out more information?
- Did my response reflect my knowledge of the subject?
- Will my work with visitors aid them in constructing knowledge or am I providing information that I expect them to memorize or remember?

By examining, evaluating, comparing, and contrasting the theoretical principles that act as a foundation for knowledge and learning, informal science educators will

Table 3.2 Contemporary perspectives of learning that may be useful in defining learning in informal science education

	Connectivism (Siemens, 2005, 2007; Tallon & Walker, 2008)	Transformative (Kegan, 2009; Mezirow, 2009)	Biographical (Alheit, 2009)	Experiential (Moon 2004; Usher, 2009)
Learning process	Learning occurs through the use of technology and social networking. Learning is based on the individual's interest. In Connectivism, the individual is a learner and a teacher	Learning occurs through a diversity of experiences and participation in a culture which allows free dialectical, informed discourse. Learners should be allowed to contrast values and ideals. Learners take action on their transformed ideals	Learning occurs when individuals relate new information to their life world	Learning occurs within the continuum of application, expression, autonomy, and adaptation. Learning is based on the experiences and interactions that occur within the continua and how they aid in defining self. Learning is socially and culturally constructed
The Learner	The learner is part of similar interest community that gathers and shares information with others through social networks, such as organizations/clubs, and topic specific social media	The learner has five forms of mind: (1) perceptual impulsive, (2) concrete/opinionated, (3) socialized, (4) self-authoring, (5) self-transforming. These forms of mind allow the learner to understand concepts of knowledge as a system	The learner self-reflects on the social activities around them and basis their decisions on their perceived life course	The focus of learning is on the learner not the educator. The motivation of the leaner informs the learning that will occur. The learner is self-motivated and interested in learning about the topic
Role of the Educator	To engage learners by connecting them to others who have similar interests. The network consists of a variety of learners	To engage learners in meaningful discourse. Provide opportunities for informative conversations between scientists and visitors. Provide examples of how the program fits into the larger picture of the organization and how the visitor might become involved in transforming the local community	To engage learners from their life perspective. Be aware of the learning environment that and how it is perceived by the visitor	To engage learners based on their personal interests and experiences. Provide opportunities to experiment alongside others that have an overlap in interest

be capable of linking their epistemological assumptions about learning to their pedagogical beliefs and practices. Determining these links will allow the informal science educators to question their beliefs about teaching (Zwozdiak-Myers, 2012). Of course, challenging these beliefs may be completed internally without discussion, but through critical discourse with a peer or mentor informal science educators will find their personal beliefs about teaching and assessment to be challenged.

Teaching

Study Teaching for Personal Improvement and Reflect Often

Examining teaching methods and reflecting on practice may occur in three ways, reflection-on-action (the past), reflection-in-action (the present), and reflection-for-action (the future) (Schön, 1983, 1987; Zwozdiak-Myers, 2012). Informal educators may capture these three types of reflecting in a narrative form through reflective journaling. Reflective journaling is advantageous, because it "can be used to prompt an awareness of new features of the situation, plan new interventions that can be implemented almost immediately, and observe the effects" (Boud, 2001, p. 13). Moreover, this type of three-way journaling provides an account of the informal science educators' experiences and allows the writer to depict their professional self in practice as well as their journey of self-awareness (Moon, 2004). Once an educator writes the reflective journal, they may self and peer analyze the narratives, and use them in depicting habitual thinking (Harris, 2005), reactions to situations, and feelings. By recording, contemplating, exploring, sharing, and making sense of their actions and using self-assessments, informal science educators will deepen their ability to use the reflective process, gain insights into their practice, and improve their pedagogy (Zwozdiak-Myers, 2012).

Even though reflecting maybe seen as a personal journey, the reflective journal is meant to be shared. By reflecting in privacy, the informal science educator's thoughts might lead to a reinforcement of their perceptions, which may not be accurate. Therefore, sharing the journal or at the least the ideas written in the journal with a partner or group will provide an opportunity to reason through personal thoughts, perceptions, and ideas. This act of reasoning out loud with others will allow informal science educators to challenge their current beliefs and critically cogitate about their patterns of teaching (Boud, 2001). In order to provide examples of ways in which informal science educators might use a reflective journal, I adapted Boud's Models of Reflection into the ISE Reflective Journal Guide, shown in Table 3.3. Specifically, the ISE Reflective Journal Guide addresses the types of interactions informal science educators might consider when writing a reflective journal. Moreover, the ISE Reflective Journal Guide provides specific examples for each element of the journal that address the reflection-on-action (what you did), reflection-in-action (what you are doing), and reflection-for-action (what you plan to do based on previous experiences) mentioned above. Reflection-on-action should take into account the learner, the context, and the skills needed to meet the goals of the project. Reflection-in-action is based on noticing, intervening, and recording information. During the reflection-for-action period, the journal should focus on the lived experiences and should provide the informal science educator with an opportunity to return to the experience, attend to their feelings, and reevaluate their experiences. By including journaling in reflective practice, informal science educators may develop deliberate, introspective habits of mind that encourage better teaching pedagogies.

Be Innovative by Trying Out New Strategies and Ideas

Teaching strategies are the learning methods informal science educators employ to bring their visitors to the desired learning objective and reflect the educator's teaching methods and educational values. Informal science educators should be encouraged to try out new ideas and teaching strategies and question their teaching style. By implementing new teaching approaches and understanding the complexities inherent in trying new approaches, informal science educators will gain a greater awareness of their pedagogical approaches and their visitors will gain a better understanding of the topic. By refining their teaching through a practice of systematic, self-reflective examination of their ideas and strategies, informal science educators will be more likely to identify those that were successful and discard those that were not effective (Zwozdiak-Myers, 2012). Even though teaching strategies exist for the formal classroom, many of these will not work for informal science education. However, there are some overlaps, such as considering the audience (diversity, disabilities, age, etc.), advanced planning, and behavior management.

Implementing new teaching strategies can be daunting for new and seasoned informal science educators. In order to implement new teaching strategies, one must know their field and their audience and how to create a learning environment. Informal science educators must ask themselves questions, such as:

- When is allowing the audience to discover more important than direct instruction (talking to them)?
- What are your expectations for the program?
- What do you want the audience to know and how can you best communicate that topic to them?

Because these questions and the audience are so diverse, no one teaching strategy will work for all visitors all of the time. However, by trying out new techniques, informal science educators may hone their skills in order to reach a larger portion of their audience.

The following are some ways in which informal science educators might approach designing new teaching practices.

- Take college courses designed for informal science educators. The courses will provide suggestions for designing and evaluating new programs.

Table 3.3 ISE reflective journal guide for informal science educators

	Reflection-on-action (what you did)	Reflection-in-action (what you are doing)	Reflection-for-action (what you plan to do based on previous experiences)
Element of Reflection	**Focus on the Learner:** Expected outcomes of an event, expectations, what the educators brings to the event (strengths and weaknesses), how the educator might be distracted	**Noticing:** Awareness of the external surroundings and events and internal thoughts and feelings	**Return to Experience:** Lived experiences, mentally revisiting and vividly living the experience, the journal writing provides an opportunity to go back and relive the experience with ease
Example in ISE	What were the objectives of the lesson or presentation? Did you meet those? Why, why not? What was the take away of the visitors' experience? What did you expect them to learn? When defining your lesson, what were the ideas that best fit your audience? What curriculum could have been used?	Write about the reaction of the visitors. Videotaping your lesson and the audience is a good way to capture the in-the-moment reactions of the visitors. How do you feel while the activity is occurring? Describe the visitors: ages, families, number of participants	In what way might you change the objectives of the presentation? What would you change about your lesson? Why? How will you use your objectives to meet the expectations of the audience? How will you change the presentation to better engage the audience? If you videotape your presentation, define specific areas of your teaching that you would change and develop a plan to implement the modifications
Element of Reflection	**Focus on Aspects of Context:** Clarify questions about the event, how do others view the event, what is expected of the educator, what are the limitations posed on you by others	**Intervening:** Actions taken to change a situation such as asking a question or listening to a visitor	**Attending to Feelings:** Focus on the feelings that were part of the experience, recognize that the feelings can inhibit or enhance the ability to learn from the experience, feelings may distort ideas and insights, for example positive feelings enhance the desire to participate, while negative feelings detract from participation
Example in ISE	Who were your visitors? What learning limitations might have occurred i.e. learning disabilities, age differences, socioeconomic, families, first time visitors, etc.?	What types of questions are you asking: lower, middle, or higher level questions? How are you interacting with visitors? Are these positive or negative experiences? Are you having problems with a specific visitor?	How did you feel during the last presentation? Did the presentation go well? How will your past experiences and feelings during the presentation support or hinder your ability to present this again?

(continued)

Table 3.3 (continued)

	Reflection-on-action (what you did)	Reflection-in-action (what you are doing)	Reflection-for-action (what you plan to do based on previous experiences)
Element of Reflection	**Focus on Learning Skills/Strategies:** Define the skills needed for the event, what strategies will the educator use during the event, ask what if questions, practice interacting with others who might be there, what will I do if the event does not go as planned	**Recording:** Write down ideas during the moment that may prompt thoughts later	**Reevaluation of Experience:** Relate new information to old ideas, determine the accuracy or validity of feelings and experiences, revisit the journal often, try to find meaning from your writing, add new ideas and extend your vision
Example in ISE	Did you have the skills needed to teach the lesson? How could you have better prepared for the lesson? How could you improve your teaching skills? What did you do that you would do differently next time? What props did you need that you did not have? Should the presentation be moved to a different area?	Write down words (just enough to prompt further thought later), times, weather, visitor reactions, your reaction, feelings, problems	Re-plan the presentation based on your journal reflections. What skills will you need to complete the presentation? What ideas will you address in the presentation? Plan the types of question that will be asked, higher level and lower level questions. Prepare for audience reactions. What is the event type? What props will you need? In what area of the institution will the lesson occur? How comfortable do you feel teaching the lesson?

Adapted from Boud's (2001) Models of Reflection

- Discuss your ideas with science and communication specialists. These interactions will provide positive gains in content knowledge and better ways in which to communicate with the public (Halversen & Tran, 2010).
- Determine if the new teaching strategy is pragmatic and will make learning easier for the audience. Do you have the resources? How long will the implementation of the new strategy take? Does the teaching style fit your epistemological beliefs and pedagogical style? What works for one ISE may not work for another.
- Define how the new teaching strategy fits within the institution's mission statement or logic model. Not all new strategies will accomplish the institution's goals and objectives. Make sure the strategies align with the learning outcomes identified by the education staff.
- Keep the teaching strategy manageable. Do not try to do too many new things at one time.

- List the teaching strategies you would like to implement and discuss them with other educators. Your peers may see immediately apparent constraints.
- Meet with educators from other institutions and brainstorm new teaching strategies. Ask other educators what techniques they use and how they work. Clearly develop and define your techniques and propose them to others.
- Use concept maps to represent a problem to address and add new techniques and ideas to the map as they evolve. Create a focus statement to address and place the statement at the top of the map as a guide (Novak & Cañas, 2006).
- Storyboard the new techniques in a large area so other educators may add suggestions. Have index cards available on which others may write ideas and add to the storyboard.

Excellent educators spend time with colleagues and discuss their ideas about best practices and teaching techniques and how those might look in the ISI. Remember a few important conditions must be meet when realizing if new techniques work, namely the external interactions that informal science educators have with their colleagues, and the internal process of reflective practice. Learning is an extensive, complicated process, which warrants a comprehensive understanding of how to adapt teaching strategies for each program.

Maximize the Learning Potential of the Audience

People visit ISIs for many reasons, such as, taking children, for fun, while on holiday, and during field trips; therefore, informal science educators do not have the pleasure of always knowing their visitors, their capacity to learn, and their commitment to the visit. Zwozdiak-Myers' (2012) nine dimensions of reflective practice encourage educators to know the needs and interests of the students, enhance the quality of the students' learning experiences, and effect behavior change. These may be difficult for informal science educators, because they do not always know the visitor (learner). Even though the ISI has demographic data about the visitors and a general description of the visitors, this does not provide the informal science educator with all they need to be successful. Formal educators are to perform based on imposed standards, which do not exist in ISE. In contrast, informal science educators have more flexibility in designing their public, non-school group programs. When designing programs, informal science educators must take into account that a single audience will have males, females, various ages, cultures, and ethnicities, and special needs learners. Moreover, informal science educators most likely will see their learners one time, which means the informal science educator must get their message across in a matter of minutes.

Another great divide between formal education and informal education is assessing learning and behavior change. The complexity and interrelationship of the visitors' variables mentioned above, which influence visitor learning, make evaluating visitor learning a very difficult endeavor. Zwozdiak-Myers (2012) suggests analyzing and evaluating what is happening within the environment during the program. By discerning and judging the environments and the interactions that are occurring among visitors and making modifications based on an evaluation of the learning environment, informal science educators will have an opportunity to reflect on the actual and desired outcomes of the program. Reflective practice, which includes taking into consideration the learner, promotes understanding and leads to better teaching approaches and strategies.

One way in which informal science educators might define the learning environment and the learning interactions that take place during a program is to videotape the program and use a rubric to measure audience engagement. Table 3.4 introduces the Visitor Engagement Rubric (VER), which informal science educators may utilize to determine the level of interactions visitors experience during a program. I based the VER on the 6 Strands of Informal Science Learning (Bell

Table 3.4 Visitor engagement rubric based on the 6 strands of science learning (Bell et al., 2009)

Strand	5 points	3 points	1 point
Strand 1 Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world.	Visitor is excited about the program. Visitor participates in the program and encourages others in their group to participate. Visitor asks thoughtful questions about the topic of the program. Visitor asks for additional sources of information. Visitor is heard discussing the program and program topic in great detail in other areas of the ISI. Visitor's body language demonstrates excitement, understanding, and/or understanding. Visitor expresses interest in the topic after the program by noticeably extending their time at the exhibit, i.e. communicating with staff, spending time in the exhibit, etc	Visitor has some interest in the program. Visitor participation is lackluster with some encouragement for the group to participate. Visitor asks some questions that related to the program. Visitor seems interested in the topic, but not in additional information. Visitor is heard discussing the program topic but not in detail. Visitor's body language demonstrates some interest, but does not express excitement in the topic. Visitor expresses their interest in the topic after the program by spending some extra time at the exhibit, but does not seek more information	Visitor is not interested in the topic and has no interest in learning more. Visitor stops with the group to listen to the program, but is not involved in the group's participation. Visitor is not paying attention to the educator. Visitor does not discuss the program with others. Visitor's body language indicates that they are distracted and are not interested in the topic, i.e. look of repulsion, rolling eyes, walking away. Visitor shows little or no interest in the topic by walking away quickly

(continued)

Table 3.4 (continued)

Strand	5 points	3 points	1 point
Strand 2 Come to generate, understand, remember, and use concepts explanations, arguments, models, and facts related to science	Visitor asks appropriate questions that represent interest outside the program topic. Visitor shares their ideas or asks questions about related topics that are not being discussed in the program, i.e. linking prior knowledge to the current topic. Visitor often uses content specific vocabulary that is introduced during the program	Visitor asks few questions that are vaguely related to the program topic. Visitor shares ideas that linked to the topic, but are a repeat of what has been presented. They do not add anything new to the discussion. Visitor uses some content specific vocabulary that is introduced during the program	Visitor does not ask questions. Visitor does not share ideas. Visitor does not use content specific vocabulary
Strand 3 Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world	Visitor asks various higher level questions that reflect their prior knowledge. Visitor interacts with available manipulatives at a high level, i.e. touching, smelling, asking questions. Visitor is conversing with their group about the program topic through higher order questioning, predicting, and observing. Visitor becomes immersed in the program through higher level physical and verbal interactions	Visitor asks some lower level questions. Visitor has very little interaction with manipulatives. Visitor is conversing with their group through some lower level questioning, predicting, and observing. Visitor has some interaction with the program through physical and verbal interactions	Visitor does not ask questions. Visitor does not interact with manipulatives. Visitor does not converse with their group. Visitor does not interact with the program
Strand 4 Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena	Visitor clearly articulates their knowledge of the topic when asked questions by the educator. Visitor often discusses the concepts with the educator and/or their group. Visitor relates their previous experiences to the program	Visitor is not sure of the topic and is not able to answer some questions. Visitor has some discussion with the educator and/or their group. Visitor relates a previous experience to the program, but does not articulate how they connect	Visitor is not sure of the topic and is not able to answer questions. Visitor does not engage with the educator and/or their group. Visitor does not connect a previous experience to the program

(continued)

Table 3.4 (continued)

Strand	5 points	3 points	1 point
Strand 5 Participate in scientific activities and learning practices with others, using scientific language and tools	Visitor willingly participates in the program. Visitor participates in the program by correctly applying the program's content language. Visitor communicates with their group using academic/scientific language that relates to the program	Visitor participates, but seems forced to participate by their group. Visitor participates by applying some of the content language, but has difficulty in apply it correctly. Visitor communicates with their group, but rarely uses academic/scientific language that relates to the program	Visitor does not participate in the program. Visitor participates but does not use content related language. Visitor does not communicate with their group using academic/scientific language
Strand 6 Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science	Visitor articulates several ways in which they might become more active in the topic of the program. Visitor discusses the program topic with their group and describes how the program topic is important to their lives	Visitor articulates a few ways in which they might become more active in the topic. Visitor discusses the program topic with their group, but does not relate the topic to their lives	Visitor does not articulate ways in which they might become more active the topic. Visitor does not discuss the topic with their group

et al., 2009) and offer it to spark conversations about how educators might best analyze the learning potential of the audience. The VER measures the social interactions that take place during a program, because the conversations and actions that occur during a visit are important aspects of engagement. The visitor must see the intellectual, social engagement that occurs in an exhibit as worthy of their attention. Moreover, the engagement, which includes the visitor contributing their own ideas and constructing new knowledge and the educator promoting a positive, relevant learning environment, leads to effective learning experiences (Claxton, 2007; Dunleavy & Milton, 2009; Taylor & Parsons, 2011; Willms, Friesen, & Milton, 2009). The informal science educator and a peer or mentor may use the VER to aid the informal science educator in reflecting on their teaching and extending their pedagogical practice. The rubric presents scores of 1, 3, and 5, but one may assign scores of 2 and 4. The best way to utilize the rubric is to videotape the program and have the informal science educator and a peer or mentor score the video. The mentor should use the rubric results as a catalyst for discourse that analyzes the audience during the program. The discussion should lead to changes in the program and pedagogy.

Be an Effective Practitioner by Enhancing the Quality of Teaching

While evaluating the learning or behavior change that takes place among visitors is an important aspect of determining successful teaching, assessing the teaching ability of the informal science educator is also vital. Informal science educators must critically reflect on the quality of their teaching and “act upon insights gained to inform future planning, improvement and development” (Zwozdiak-Myers, 2012, p. 196). Zwozdiak-Myers states that the base of quality teaching is the ability of educators to (1) use reflection of practice to improve teaching and (2) search for cause and effect relationships in the outcomes of their teaching. Moreover, research shows that educators are more effective when they evaluate their teaching, examine their work, and consider various approaches to teaching (Watts, 1985). Because teacher ability ties directly to achievement, informal science educators should evaluate their teaching and ISIs should provide professional development that addresses good teaching techniques.

Reflective practice requires the informal science educator to study and evaluate their teaching, link theory with practice, and critically analyze their teaching. In order to aid informal science educators as they develop the process of reflective practice, I developed an observation technique that incorporates video, self-assessment, and a teaching rubric. Figure 3.1 represents the informal science

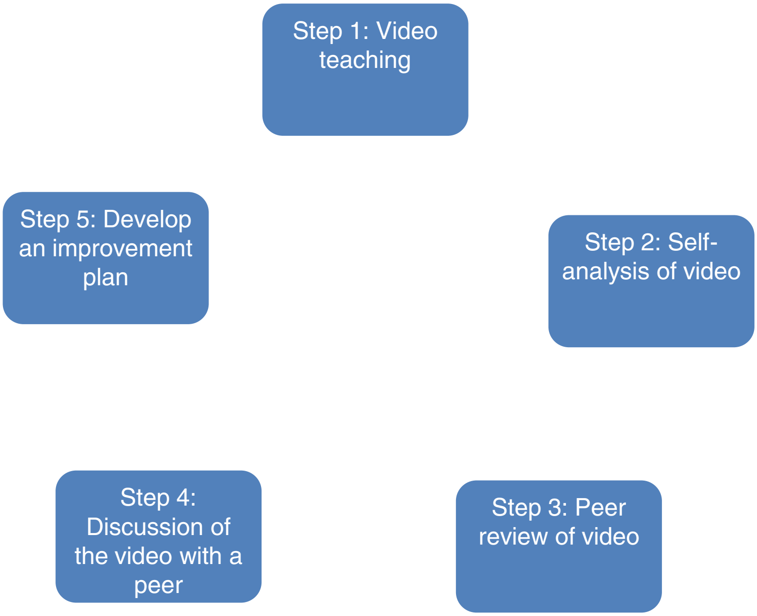

Fig. 3.1 The informal science educator reflective teaching practice cycle

educator reflective teaching practice cycle, which provides a suggestion for how peers could work together to analyze their work. Step 1: Educators video themselves during a program. Step 2: The educator views the video and identifies successful and unsuccessful aspects of their teaching. In what ways could they improve? What are they doing well? Step 3: To increase the ability of the educator to reflect on their teaching, a peer analyzes the educator's teaching and provides feedback. Step 4: The educator and the peer meet to discuss the individual evaluations of the teaching. Step 5: The meeting leads to the development of an improvement plan that focuses on one way in which the educator may improve their teaching. The ensuing conversations promote beneficial exchanges that support reflective practice and aid supervisors in determining areas for professional development, such as, questioning skills.

Peers

Utilize Learning Conversations with Peers or Mentors to Discuss Alternative Perspectives and Possibilities

In her nine dimensions of reflective practice, Zwozdiak-Myers (2012) encourages educators to engage in discourse with others in which they justify their beliefs about learning theories by considering, applying, endorsing, and rejecting the theories. These reflective peer or mentor interactions provide opportunities for informal science educators to reflect on their teaching practice and how their practice relates to learning. This cognitive apprenticeship promotes the joint construction of knowledge through active participation and reflection (Collins, Brown & Newman, 1989; Dickey, 2007; Hockly, 2000; Vasileiou & Paraskeva, 2010; DeGregoria Kelly, 2009). As the community of reflective practice evolves the newcomers may begin on the periphery, but over time move toward the center and become resources for helping new members make progress in becoming members of the community (Abu-Shumays & Leinhardt, 2002; Castle, 2006; Fischer, 2009; Grenier, 2009; Iverson & McPhee, 2008).

In addition to cognitive apprenticeship, informal science educators may be prone to apprenticeship of observation, which Lortie (1975) describes as "the protracted face-to-face and consequential interactions with established teachers" (p. 62). As a result of the interactions that occur between students and formal educators and between new and seasoned formal educators, researchers have shown that formal educators teach as they were taught (Lortie, 1975; Cuban, 1984; Matteson, Ganesh, Coward, & Patrick, 2012). In other words, educators develop their pedagogical beliefs based on the interactions that occurred in previous educational settings (Bevan & Xanthoudaki, 2008; Castle, 2006; Cox-Petersen, Marsh, Kisiel, & Melber, 2003; Grenier, 2010). Formal educators become tied closely to the teachers they perceived as 'good teachers' during their time as a student in the formal classroom. However, these perceptions are not accurate and do not take into account the everyday issues educators face in the classroom.

Cognitive apprenticeship and apprenticeship of observation explain how the experiences that informal science educators have shape their epistemological and pedagogical beliefs. Moreover, the peer and mentor interactions Lortie (1975) describes are important to reflective practice because those interactions allow informal science educators an opportunity to share their ideas concerning pedagogy and their perceptions of teaching. As informal science educators develop their perspectives of teaching and share those ideas with others, they become part of an evolving community of practice. The interactions that occur between newbie informal science educators and mentor(s) play a role in the educator's pedagogical and professional development (Watts, 1985). The conversations that result from these interactions are important in aiding informal science educators in recognizing their beliefs about teaching.

Improve Your Teaching by Being Involved in Professional Development and Training

In order for informal science educators to build their capacity to work with visitors, educators need empowerment through professional development that involves and supports risk taking. Well-planned professional development increases the understanding educators have of epistemology and pedagogy, aids them in coordinating the instructional outcomes with the mission of the institution, and reinvigorates their reflective conversations with peers (Zwozdiak-Myers, 2012). However, successful professional development should support career long learning, take into account the career stage of the educator, occur regularly and have continuity (Borko, 2004); while connecting to prior teaching and learning within the context of the ISI (Lieberman & Miller, 2008; Muijs & Lindsay, 2008). Three sources of professional development from within formal education may be applied to ISE: (1) *Within the ISI*, e.g., peer reflection groups, peer feedback, collaborative planning, observing and discussing teaching practices, sharing pedagogical practices, and working with scientists in the ISI to improve content knowledge; (2) *Within the ISI network*, e.g., partnering with other ISIs, visiting other ISIs to identify their epistemological and pedagogical practice workshops hosted by ISIs; and (3) *External Relationships*, e.g., university partnerships (i.e., Bevan & Xanthoudaki, 2008; DeGregoria Kelly & Kassing, 2013; Grenier, 2008, 2010; Grenier & Sheckley, 2008; Gupta & Adams, 2012; Halversen & Tran, 2010), non-ISI-hosted workshops, and science education conferences (Training and Development Agency for Schools, 2008).

To address the notion of professional development for science teachers, the NSTA adopted eight guiding principles and four considerations for designing professional development programs (NSTA, 2006). Even though the principles and considerations are for formal educators, the principles are relevant when developing professional development programs for informal science educators. Below is a list of the NSTA principles adapted for use in ISIs.

- Professional development should align with the mission of the institution and education department, and embed in the curriculum, instruction, program evaluation, and reflective practice.
- Professional development should address science content knowledge, epistemology, and pedagogical content knowledge.
- Professional development should have as a base the evolving needs of educators and should promote collegial, collaborative interactions *Within the ISI*, *Within the ISI network*, and with *External Relationships*.
- Professional development should engage educators in transformative learning experiences that confront deeply held beliefs, knowledge, and habits of practice and promote reflective practice.
- Professional development should focus on a few issues over time and allow for personal and institutional improvement.
- Professional development should involve educators in identifying pertinent research, exemplary teaching practices, and learning theories that relate to learning in ISIs and in applying these to observing and evaluating teaching.
- Professional development should concentrate on visitor evaluation strategies.

In addition to the seven guiding principles, ISIs should take the following considerations into account when designing professional development (NSTA, 2006).

- Planning Professional Development: A range of professional development that relates directly to evaluation, pedagogy and reflective practices is most important in developing excellent educators. The professional development must have a set of benchmarks, goals, and objectives. Embed the learning strategies into the day-to-day activities of the educators. NSTA recommends study groups, professional networks, action research, lesson study, and demonstration lessons.
- Implementing Professional Development: The professional development must fit into the educator's daily schedule. Evaluate the professional development program to determine its effectiveness and implement modifications in the program as needed. Encourage educators to attend science education conferences and share the experiences upon returning.
- Sustaining Professional Development: Educators must have buy-in and full support from the ISI through resources of funding, time, and professional materials, and unfaltering support from administration. Educators must develop partnerships with the community, scientists, universities, and other ISIs that build support for the professional development goals.
- Specific Needs of Professional Development Providers: Consider the next generation of educators. University programs that focus on informal science

> learning should prepare future informal science educators and support their pedagogical development. The significance of professional development for informal science educators is a growing research field; therefore, the ISIs involved in professional development should evaluate their professional development programs so they might contribute to the research. ISIs with the resources should take a leadership role in developing and sharing relevant, high-quality professional development materials.

When preparing professional development, consider each topic in terms of its problems, concepts, issues, and emerging trends. Professional development should arouse the interests and cognitive commitment of informal science educators and compel them to further explore their teaching strategies. Consider the entry point of each educator into the processes of observation and pedagogical evolution as the educator begins to examine their personal educational beliefs in detail. Professional development may be powerful, but also may mislead educators; therefore, reflective practice should parallel professional development. Several implications follow from this assertion. First, professional development should spend significant time on the current topic. Second, professional development should portray the topic in a way that encourages communication and interactions among peers (reflective practice). Third, professional development should permeate the educator's self-management checks and balances (reflective practice) and extend the educator's perceptions of learning.

Reflective Practice Is Critical

Reflective practice works through the meanings the informal science educator assigns to it and how the informal science educator applies the practice. Its orientation is towards the cultivation of partnerships both within and outside the ISI that allow for application of new and existing ideas within a community of shared practice. Reflective practice is the application of shared ideas within a culture of self-actualization that promotes cultural transformations within the ISI. It should not be an autonomous vocational practice that isolates educators and separates them from the vision and mission of the ISI. During reflective practice, educators recognize that learning is discursive and circuitous and reflects the interests of the audience, while defining their beliefs about how experiences and knowledge influence their pedagogical practices. As informal science educators contemplate their teaching methods and share those ideas with others, they become self-aware of the relationship between teaching practices and knowledge and become part of a confessional network of educators that share ideas. Learning about one's teaching through reflective practice is a complex topic; therefore, I present the ideas in this chapter as a basic approach to introspection.

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Chapter 4
Facilitating Deep Conceptual Learning: The Role of Reflection and Learning Communities

Heather King and Lynn Tran

Our scientific knowledge continues to grow ever more extensive and complex. Indeed, it is rare that we are able to explain phenomena by citing simple and single causes. Scientific and technological endeavor, meanwhile, occurs within social settings, and the results of such work must consider this social context. In order to support new generations of learners develop an understanding of science content and science processes, it is vital that educators develop their practice in ways that acknowledge and reflect both the nature of science and our contemporary understanding of how people learn.

Arguably, a modern education in science involves more than the acquisition of individual pieces of information in any one discipline. Instead, learners require a deep understanding of complex concepts spanning a variety of domains. They also need the ability to work with complex concepts in creative ways that leads to the development of new ideas, new products and new knowledge (Sawyer, 2006).

The task of supporting such learning, however, is not limited to schools (Papert, 1993). As researchers and policy makers have concluded, the responsibility, and even onus, of providing an education in science is no longer the exclusive preserve of the formal sector, but is more explicitly shared with resources in the community (National Research Council [NRC], 2009). Such resources include family interactions, television and media, and the Internet. They also include informal science learning environments intentionally designed to explore and communicate science, such as natural history museums, science centers, zoos, and aquariums. Furthermore, it is now accepted that engagement in learning is a pursuit that is not limited to

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children: learning occurs throughout one's life, as well as across contexts (NRC, 2009).

In this chapter, we focus on the ways in which learning may be supported in informal science learning environments. We explore the skills and components of knowledge that underpin the work of informal sector educators and consider the ways in which these skills are and may be used to support what Sawyer (2006) has termed deep conceptual learning. We also draw attention to the need for ongoing professional development, and describe the importance of reflection on the part of informal educators, and the need for learning communities to support and sustain effective practice. We begin by introducing and unpacking some of the current thinking regarding the psychological processes involved in deep conceptual learning and its facilitation.

Supporting Deep Conceptual Learning

Deep conceptual understanding refers to knowing concepts and ideas in a robust way such that learners are able to

- relate new ideas and concepts to previous knowledge and experience;
- integrate their knowledge into interrelated conceptual systems;
- look for patterns and underlying principles;
- evaluate new ideas, and relate them to conclusions;
- understand the process of dialogue through which knowledge is created, and examine the logic of an argument critically;
- reflect on their own understanding and their own process of learning. (Sawyer, 2006, p. 4)

Organizing Knowledge into Mental Models

In understanding and thereafter facilitating deep conceptual learning, it is firstly important to note that learners do not come to new experiences as empty slates. Rather, they have their prior knowledge and previous experiences organized in the form of mental models (Getner & Stevens, 2014). Such mental models vary in terms of their complexity, and also in their consistency with canonical thinking. They serve to help learners address new and existing ideas. By organizing and storing various pieces of knowledge as mental models, learners reduce the strain on their working memory. Such organization is essential as humans are only capable of processing 5–7 units of information at any one time (Miller, 1956). This processing may involve comparing, contrasting, or organizing content. Without mental models, which may be viewed as one piece of information, we would be less able to deal with new incoming information.

Over time mental models become part of our long-term memory freeing up our working memory and leading to greater expertise. For example, an expert chess player is able to use mental models stored in his or her long-term memory to recognize a particular mid-game position (Gobet & Simon, 1998). A novice player, on the other hand, has no access to accumulated models and must rely on his or her working memory to make sense of what may appear to be a randomly positioned set of single chess pieces.

For mental models to become part of long-term memory, it is necessary for the learner to see such models as useful, and that these models do not clash with existing models. As Posner, Strike, Hewson and Gertzog (1982) have argued, for new conceptions to be accepted they must be perceived to be intelligible and more plausible than prior less fruitful notions. This process of collecting, assessing, sorting and systematizing new ideas—many of which will be piecemeal and simple—into larger and more integrated wholes or mental models requires considerable effort by the learner. This process has been termed active construction (diSessa, 1988; Smith, diSessa, & Roschelle, 1994).

The Value of Externalizing and Reflecting

To aid full understanding of especially the more complex ideas, learners benefit from opportunities to externalize and reflect on their thinking. Externalizing is written or verbal articulation of ones' evolving understanding, which allows learners the opportunity to share their unformed ideas with others (Sawyer, 2006). The importance of externalization stems from Vygotsky's (1978) notion that higher mental functions have social origins, meaning that they are first expressed *between* individuals before they are internalized *within* the individual. In other words, meanings are rehearsed and made explicit as a result of conversations and interactions, including writing or drawing, before becoming internalized. Reflection is the act of thinking about the process of learning as a means to detect inconsistencies in ones' thinking and help to identify connections between existing mental models (NRC, 2007; Davis, 2003). Reflection includes a broad range of processes, including monitoring, detecting incongruities or anomalies, self-correcting, planning and selecting goals, and even reflecting on the structure of one's knowledge and thinking (Gelman & Lucarriello, 2002). Both externalization and reflection may be supported by interaction with others. For example, research has shown that students (from K through 12 to university) exhibit greater understanding when they engage in collaborative dialogue with peers, wherein they offer explanations as part of arguments and justifications, and in so doing reflect on what they themselves have understood (Mercer, Dawes, Wegerif, & Sams, 2004; van Blankenstein, Dolmans, van der Vleuten, & Schmidt, 2011; Veenman, Denessen, van den Akker, & van der Rijt, 2005; Venville & Dawson, 2010) Indeed, students who were given the opportunity to talk, argue and defend their ideas have been found to exhibit positive changes in their understanding of difficult and complex concepts like evaporation (Tytler & Peterson, 2000) and climate change (Mason & Santi, 1998).

Learning as a Social Process

The importance of externalization and the need for reflection underscores the notion that learning is an inherently social affair—it is not only something that happens within the individual, rather it is an activity involving people, the words they speak, the things they use, the cultural context in which they operate (Bransford, Stevens, Schwartz, Meltzoff, Pea, Roschelle et al., 2006; Rogoff, 1998). Learning is thus a feature of a social environment, but social environments are also the units of learning. Peer groups, the family context, and larger social networks enable social interaction and thus engender learning. For example, we learn by imitation: watching other people is ubiquitous among humans across the whole of our lives (Bransford et al., 2006; Meltzoff & Decety, 2003). We also learn from collaborating with people: learning is the result of a community coordinating to build a common understanding (Dillenbourg, Baker, Blaye, & O'Malley, 1996). And we learn by our efforts being guided by others: instruction is the process of more knowledgeable individuals helping less experienced learners to make meaning of new experiences (Vygotsky, 1978; Wood, Bruner, & Ross, 1976).

In concert with the notion that learning is social, learning is best enabled if it is situated in a context which provides learners with a reason to understand (Greeno, 2006; Kolodner, 2006). By situating new information in an authentic everyday context, learners understand the nature of the discipline by making connections to the real world and to their everyday social lives. Providing a clear context for the new information can also provide learners with an appropriate frame of reference with which they may organize and reform their existing mental models. Moreover, by assessing their mental models in specific contexts, learners are able to generalize their knowledge to a wider range of conditions (Kolodner, 2006). Authentic contexts—those in which the content that is needed and the reasoning that is required actually relate to the setting—help learners form connections between new and old information, which lead them to develop better, larger, and more associated conceptual understanding (Blumenfeld, Kempler, & Krajcik, 2006; Kolodner, 1993; Schank, 1982).

Learning Requires Effort

As noted above, in order to create connections between ideas, learners need to expend considerable effort. Such commitment requires various types and levels of engagement to learn. *Behavioral engagement* refers to the ways in which learners participate in learning experiences (Fredricks, Blumenfeld, & Paris, 2004). The concept includes learners' conduct, for example attendance and adhering to rules of the environment, and levels of involvement in tasks characterized as attention, concentration, effort, and contribution. *Emotional engagement* refers to learners' affective reactions (their feelings and emotions) to the learning context, which may be influenced by their interactions with the people and context involved; their interest in the subject matter; and how they value the subject matter (Fredricks et al., 2004). *Cognitive engagement* refers to learners' psychological investment in learning—their motivation—and also the cognitive learning strategies, or methods they employ (Fredricks et al., 2004). It incorporates thoughtfulness and willingness to exert the effort necessary to comprehend complex ideas and master difficult skills. Motivation to participate may be affected by learners' feelings of competence in being able to succeed and be driven by their learning goals, for example to fully master and understand the task, or just to complete the task (without attaining mastery). A key driver for motivation is interest, which may be prompted by the environment (situational interest) or be more deep-seated (personal Interest) (Hidi & Renniger, 2006). Understanding the breadth of learner engagement and commitment is important, for as Blumenfeld et al., (2006) have argued, conceptual understanding is enhanced when learners are committed to building knowledge and using their learning strategies.

In summary, learning involves active construction of new information into mental models and is engendered and facilitated by social interaction and supported by opportunities for context specific and situated learning. Effort on the part of the learner is required, but such effort may be minimized by the use of learning strategies. Such strategies include opportunities for articulating and externalizing one's thinking, and for reflection. In externalizing their thinking by rehearsing, elaborating, and monitoring, learners identify patterns and connect and organize ideas into mental models. In reflecting, learners evaluate their thinking and become conscious of their own learning motivations and interests, which in turn fuels further learning. We now turn the discussion to a consideration of how informal educators may work most effectively to support deep conceptual learning.

Examining the Support for Learning in the Informal Sector

The body of research examining the educational practices of informal science educators is small but growing. Cox-Peterson, Marsh, Kisiel and Melber (2003), for example, in their study of docent practice at a natural history museum in California, found docents to be didactic and non-receptive to learners' needs. Tal and Morag (2007) were similarly critical of the educators that they studied in four different natural history museums in Israel. Additionally, Davidson, Passmore and Anderson (2009) in their study of zoo docents found that the content assumed by docents to be interesting and engaging was, in fact, unappreciated by the visiting students. In contrast, however, Tran (2007) found her sample of educators to be highly receptive to learners' needs and noted that they consciously employed a variety of strategies to facilitate learning. Likewise, Castle (2001), in her study of educators in a history museum, an art gallery, and a nature center, found that educators selected from a range of supportive approaches in their work with visitors.

In reviewing the above findings, it became clear to us that the practice of informal educators varied immensely and that the profession as a whole lacked a conceptual framework. Thus, we sought to identify the key aspects or components of knowledge that educators require in order to support learners most effectively (Tran & King, 2007). Our original proposal was part of a larger argument for professional recognition of informal educators and the need for practitioners to have a distinct body of knowledge for their educational work in museum settings. The six knowledge components that we initially proposed were not intended to be conclusive, but were put forth as a framework to be discussed. The six components were: an understanding of context; the support for choice and control; a knowledge of content; an appreciation of the unique role of objects; an understanding of research on learning; and facilitation of 'talk' (a term we used to refer to all forms of mediation). Below, we revisit these knowledge components and explain how they serve to scaffold the deep conceptual learning processes outlined above.

Context

The context in which informal educators do their work has social, physical, and temporal aspects. Visitors often attend informal institutions within social groups (e.g., as a family, in a school group, with friends) and for varied social reasons (e.g., family vacation, school trip, night out). As discussed above, learning is social, but negotiating these varied social groupings to best facilitate deep conceptual learning requires educators to be able to engage with both adults and children simultaneously, and to select the appropriate strategies that support learners as they build their own mental models. The physical aspect of many informal spaces, be they national institutions or local marshlands, must also be acknowledged by the educators. Visitors may experience feelings of awe, novelty or visceral excitement that in turn may affect their behavioral, affective, and cognitive engagement. The temporal context of an informal setting refers to visits being either repeat or first-time experiences. Time spent in a particular gallery or part of the informal setting, meanwhile, may be measured in hours or just seconds. The temporal context further reminds us that learning is life-long: learners' mental models build over time; motivations change over time. In short, recognizing the impact of context on a learner provides educators with a frame or backdrop upon which to organize subsequent facilitation efforts.

Content

In order for educators to be flexible and confident in supporting the diverse range of learners that come to their institutions, educators need to have deep conceptual understanding of the subject matter. This knowledge needs to go beyond the disparate facts pertaining to a discipline or related to an object, but be at the level of understanding disciplinary core ideas, concepts that cut across disciplines, and the nature and practices of a domain (NRC, 2012). In parallel with the arguments within formal K-12 education in the U.S. for teachers and students to develop deeper conceptual understanding of science, we would similarly argue that educators in informal science environments must also have deep content knowledge.

Objects

Informal learning environments feature objects as a part of their institutional work and mission. We use “objects” broadly to include, but not limited to, artifacts, specimens, artworks, live organisms, and interactive exhibits. In supporting learner engagement with objects, educators need to acknowledge the constructivist perspective on learning. This perspective notes that an individual’s mental models are created as the result of combining and consolidating prior and personal information. The informal nature of the context with its lack of prescribed assessment structures means that the range of meaning-making from objects in a museum context can be extensive. As Rowe has argued,

> One important implication of constructivism [in the informal context] is that the meanings people make as a result of the negotiation of different knowledges and ways of knowing cannot be judged according to authoritative standards of what is “correct” or “incorrect” as is often the case in more formal learning settings. (Rowe, 2001, p. 21)

It is important to note here that the opportunity for multiple representations and interpretations of objects can provoke affective connections among learners and lead to greater engagement. In short, objects offer a vehicle for very personalized learning. For educators, then, an understanding of objects involves the ability to highlight their attributes (scale, size, age, provenance, and so on) in order to help learners make personal connections and mental models of the objects and the knowledge they represent. If the educators support affective engagement with the objects on the part of learners, a deeper motivation for further learning may occur.

Choice and Motivation

Informal science institutions have been described as free-choice learning environments (Falk & Dierking, 2000) wherein learners have freedom to choose their learning pathways, activities, and agendas without the levels of accountability and scrutiny experienced in schools. While institutions design the learning spaces, learners may pursue their own agendas and navigate the learning spaces in their own ways. This personal agency enables learners to follow their interests and therefore fosters motivation and engagement. The role for informal educators, therefore, is to develop mechanisms for nurturing learner interest and willingness to exert effort. Blumenfeld et al., (2006) argue that levels of cognitive engagement may be described by four factors: value, competence, relatedness and autonomy.

Value refers to the usefulness that learners place on the subject matter, skill or task to be learned and may be intrinsic, instrumental (i.e. a perception of how the task is related to future goals) or attainment-based. To increase value judgments, educators may emphasize the novelty or incongruity of an object in order to "hook" their learners' interest, which may transition to "hold" learners' attention thus sustaining interest over time.

Competence pertains to learners' feelings of efficacy regarding their ability to succeed and has positive influence on their effort, persistence, and use of higher-level learning strategies (Wigfield, 1994). To support learners attain competence educators are advised to scaffold the thinking process, by breaking down the tasks into smaller, more manageable chunks. However, it is important to note here that given the nature of the informal environment, with its lack of formalized assessments, learners can also "mess around" with their ideas. In such instances, the educator's role becomes one of encouraging learners to engage with new ideas and to express and reflect on this thinking.

Relatedness is the learners' sense of belonging in the community, and has been found to enhance learners' interests, participation, and academic effort (Wentzel, 1997). As learners usually visit informal environments in their own familiar social groups, e.g., family, friends, and classroom, informal educators can foster notions of relatedness by choosing to select objects with particular cultural associations or community relevance.

Finally, a*utonomy* is the perception of a sense of agency, which occurs when learners have opportunities for choices and for playing significant roles in directing their own activity. Again, the lack of formal sector constraints means that informal educators can facilitate learner autonomy which, in turn, fosters behavioral, emotional, and cognitive engagement (Ryan & Grolnicka, 1986).

Learning Research

A knowledge of learning research refers to an educator's understanding of the situated context, social interaction, and the active process of knowledge construction, as discussed in the first part of this chapter. It also refers to an educator's knowledge of how best to support learning. Our review of both the literature and our own studies of educators (Tran, 2007; King, 2009) would suggest that in many instances this knowledge of how best to support learning is only held implicitly and that there is a need for greater reflection on practice to make the implicit explicit, enabling changes and developments to be made as necessary (Ash & Lombana, 2012).

In addition, we acknowledge the changing zeitgeist within informal practice and calls for the sector to move away from conceptualizing the role of the informal educator as one of increasing visitor understanding towards one of enabling visitor engagement (Schäfer, 2009). Content is no longer something to be acquired, but rather something that represents a particular social or cultural practice, and something for whose meaning or significance must be negotiated:

> The contemporary museum seeks, therefore, a negotiation between the knowledge and culture sedimented in objects, exhibitions, spaces and tools, on the one hand, and the knowledge, memory, emotions, and socio-cultural background embodied in the visitor herself, on the other. (Bevan & Xanthoudaki, 2008, p. 110)

Our understanding of the outcomes of learning have also developed in recent years. Increasingly, contemporary theorists study learning and engagement through the lens of identity construction (Butler, 1999; Tan, Calabrese Barton, Kang & O'Neill, 2013; Fields & Enyedy, 2013). From this perspective, the manner by which learners engage with new content or ideas is linked to how they see themselves and how they are constructing their identity. Thus a 'geek' may happily engage with a content-rich lecture, whilst a young woman keen to present a hetero-feminine image may overtly reject such material in order to stand in stark contrast to the geek (Wong, 2012). The challenge for informal educators thus becomes selecting objects, content matter, and relevant cultural references that recognize the importance of identity formation and foster learner engagement emotionally, affectively, and cognitively.

"Talk"

The final component that we identified is that of "talk." By talk we refer to opportunities for discourse between visitors and educators, and between visitors themselves as a way for learners to externalize their thinking, to rehearse new ideas and demonstrate understanding, and to reflect on and organize their conceptions. As many have experienced in their own learning and teaching, conversation plays a key role in facilitating social interactions and can help learners develop more generative thinking, not least by asking and answering questions.

In prompting talk, informal educators utilize a variety of techniques, some of which are also used in formal contexts. For example, informal educators have been found to repeat and rephrase learners' contributions, and to emphasize particular comments (King, 2009). Such techniques have been identified in classroom settings (Mortimer and Scott, 2003). But in contrast to teachers who may also employ writing activities as scaffolds and extend an experience over several lessons, an informal educator may only have talk at their disposal. To be effective they must employ the right prompts within a relatively limited timeframe and do so judiciously in order to maximize the affordances of the object, content and context.

Examples from Practice

In combining the above elements, we argue that the pedagogical practice of an informal educator thus involves mediating the interaction between the subject matter (embodied in the object, content and context of the informal institution) and the learner by providing opportunities for choice and control, and using talk within a frame bounded by an understanding of learning research. A tall order, perhaps, but as the examples in the next section illustrate, informal educators can and do apply these elements to provide support for deep conceptual learning.

In their analysis of educator practice, Forman-Peck and Travers (2013) described a staged process comprising particular talk techniques underpinned by an understanding of learning. They found that educators firstly ask an open question in order to gather the group's initial intellectual and emotional ideas about the content or object under discussion. This technique helps the educators to understand their learners' levels of engagement and motivation. Next the educator uses key verbal prompts to focus the visitors' attention towards a particular topic, for example the attributes of an object. To do this effectively, the educator must have a deep understanding of the object and its associated ontology, epistemology, provenance and aesthetic merit, and significance. The prompts encourage learner articulation of their prior knowledge and may raise questions about existing mental models leading to reflection. The third stage of talk involves exploring the significance of the ideas to support the meaning-making. The educator may also make links to other objects, or displays to help individuals follow and develop any interests triggered.

The stages of talk identified by Forman-Peck and Travers were similarly found by King (2009) in an analysis of educator practice in a natural history museum. This study identified distinct verbal (and non-verbal gestures) used by the educators to encourage learners to firstly observe the natural history specimens and then secondly compare them. The educators' aim here was to equip learners with enough information to articulate and reflect upon the connections between specimens. The third stage of meaning-making involved the educators encouraging students to reason about the function of particular features or the relationships between specimens. The prompts involved in the whole process would sometimes involve placing particular specimens in close proximity in the hope that visitors would notice the similarity of features. Other times, the educators would 'model' curiosity and examine, discuss, and reflect on the specimens in an exaggerated manner to attract attention and promote similar engagement behaviors amongst students.

In supporting learners to articulate and externalize their understanding, informal educators create opportunities for learners to exercise a degree of agency and the development of a particular learning identity (Barton & Tan, 2010). For example, and with respect to the above example, in encouraging educators to articulate the ways in which natural history specimens are connected, and in rephrasing these contributions for the benefit of the wider group, the informal educator is encouraging the learners to adopt the language of natural history—a register rarely used in schools. As a result, the learners may feel more comfortable in the world of natural history and even see themselves as natural historians.

Our discussion, thus far, has focused on the knowledge and skills that informal educators employ to support deep conceptual learning, but such knowledge and skills are not necessarily widespread and uniform. Researchers have long noted the deficiencies in informal educators' practice (Cox-Peterson et al., 2003). Research indicates that while informal educators are cognizant of, and indeed attempt to accommodate, their learners' interests, abilities, and needs (King, 2006, 2009; Tran, 2007), their strategies tend to be didactic and dominated by their own agendas rather than that of their learners' (Cox-Peterson et al., 2003; Tal & Morag, 2007). Such gaps and limitations may be due in part to a paucity of preparation and training (Tran & King 2007). Indeed, as Allen and Crowley (2013) have noted, many informal educators who interact directly with the public may have been only minimally prepared in the theories of learning and pedagogy. Fortunately, many professional development programs designed explicitly for informal educators are now emerging.

Professional Development for Informal Educators

Professional development opportunities for informal educators are available online and in-person, and involve participation in discussion forums (e.g., CoP forums hosted by ASTC), short-courses and workshops, institution-based programs (e.g., REFLECTS from Museum of Science and Industry in Tampa, FL), and graduate degrees (e.g., from University of Washington, Oregon State University, and Texas Tech University). In some cases, the programs are designed with the intention of broader dissemination; in other cases, the programs are individual institutional efforts to support staff development (Bernstein, Tran, Aichele & Tinkley, 2014). In many, if not all of these programs, an emphasis is placed on the importance of reflection, be it at the individual, group, or institutional level.

Reflection—the ongoing learning for and about ones' practice in which professionals engage in order to increase their expertise and skills—helps practitioners to better understand what they know and what they do. As Loughran (2002) has noted, it is a critical aspect of many professions (nursing, medicine, law, science, and teaching), as it develops practitioners' sense of understanding how they do their work and informs the profession about aspects of the practice. In addition, and as Day (1999) has argued, reflection is necessary in order to effectively exercise professional judgment. In the field of education, reflecting on practice is learning about one's own teaching. Reflection is also about thinking how one and one's colleagues teach and think about teaching and learning. Moreover, reflection is "a stance, a willingness to question our teaching. It is a purposeful process used to inform our decisions and help us improve the learning experiences we provide to our students" (Serafini, 2002, p. 4). It requires a deliberate process of framing and reframing practice in the context of ones' actions, principles, beliefs, values, expectations, and experiences. Importantly, the process of reflection also involves taking action as a result of reflective thinking (Dewey, 1933; Schön, 1983; Serafini, 2002).

In addition to reflection, researchers have noted that in order for professional development programs to have a meaningful effect, the learning must relate to authentic practice. Furthermore the learning must be situated within a community that supports it (Garet, Porter, Desimone, Birman, & Yoon, 2001; Webster-Wright, 2009; Wei, Darling-Hammond, & Adamson, 2010; Wei, Darling-Hammond, Andree, Richardson, & Orphanos, 2009). For example, learning that is situated within the professional's workplace engages individuals in actively working with others on genuine issues within their professional practice (Burbank & Kauchak, 2003; Lave & Wenger, 1991; Wenger, 1998). Situating the learning in real world contexts provides learners with a reason to understand (Greeno, 2006; Kolodner, 2006) and facilitates the connecting of research to practice (Tran, Halversen & Werner-Avidon, 2013a; Tran, Werner-Avidon & Newton, 2013). In describing professional learning in this way, we can clearly see parallels with the process of deep conceptual learning described earlier in this chapter.

Building Professional Learning Communities

In the formal education field, the continued learning among teachers has been conceptualized as participation in a professional learning community (PLC) (DuFour, 2004). Whilst only a handful of studies have investigated the effects of PLCs, the findings to date suggest that participation in a PLC is valuable for developing teacher practice and supporting student learning (Hollins, McIntyre, DeBose, Hollins, & Towner, 2004; Louis & Marks, 1998; Phillips, 2003; Strahan, 2003). While there is no agreed definition of what a PLC is, there appear to be some fundamental assumptions and essential characteristics. It is presumed that there is professional knowledge situated in the day-to-day lived experiences of educators, which is best understood through critical reflection with others who share the same experience (Buysse, Sparkman, & Wesley, 2003; Wei et al., 2009). It is also assumed that actively engaging educators in a PLC will increase their professional knowledge and increase their learning (Louis & Kruse, 1995). Moreover, from the work of Hord (2004), Newman (1996) and Stoll, Bola, McMahon, Wallace and Thomas (2006), we can draw out a series of recommendations for the development of successful PLCs:

1. *Share values, visions, and norms* about how children learn, institutional priorities, and the proper roles of major stakeholders.
2. Develop *a consistent focus on*, and collective responsibility over, *student learning*.
3. *Promote reflective dialogues* about curriculum, instruction, and student development.
4. *Make practice public*.
5. *Collaborate* in developing activities, curriculum, and materials to develop a sense of interdependence beyond superficial exchanges of help, support, or assistance.

Given the positive impacts of PLCs for practice, and for the purposes of building greater collegiality, the PLC construct has also gained appeal among informal educators as a way of organizing professional development programs and imbuing greater reputability. In the final section of this chapter, we share how the design of the *Reflecting on Practice* (*RoP*) program developed by researchers at Lawrence Hall incorporates these five characteristics of successful PLCs for supporting the teaching practice of informal science educators.

Reflecting on Practice—A Professional Development Program for Informal Educators

Reflecting on Practice (RoP) is a professional learning program that immerses novice and experienced science educators at informal science education institutions in discussions about, reflections on, and applications of research and theory on learning and teaching science (Tran, Halversen et al., 2013; Tran, Werner-Avidon et al., 2013). Mid-career educators participate in a Coaching Workshop to learn the program. These educators, in turn, use the written *RoP* curriculum as a guide to implement the program with colleagues at their institutions over a period of 6 to 12 months. All informal science educators at an institution can participate in the program. The program also builds capacity of experienced educators, as they are challenged to reflect deeply on their practice and model and mentor novice colleagues

RoP participants engage in 14 two and half-hour-long interactive sessions, to explore the six knowledge components outlined above. These interactive sessions deliberately relate research to practice as they juxtapose new knowledge with prompts for increased thoughtfulness about an educator's current habits and understanding. As the educators talk about research and articulate their practice, their mental models of effective practice develop and evolve. Moreover, they begin to consciously think about their new understandings and the way in which they incorporate it into their practice becomes explicit (Tran, Halversen et al., 2013; Tran, Werner-Avidon et al., 2013).

Participants also undertake a variety of reflective tasks. These tasks involve creating videos of educators' practice, and thereafter viewing them with colleagues. Video-supported reflection enables educators to develop specific comments about aspects of their practice and have been found to be more useful in prompting reflection than notes made from memory post the mediated session (Rosaen, Lundeberg, Cooper, Fritzen & Terpstra, 2008). Participants and facilitators of the program also reflect on and discuss their practice with colleagues by writing journals and online social activities, such as discussion forums and blogs. Writing, like speaking, is a process of externalization and a product of critical reflection. The slower pace of writing is also significant in that it can mediate recall (Wells, 1999). Thus the written discussion forums slow down the interchange, and allow participants time to process, review, and organize their thoughts before posting an idea or responding to someone else's ides (Garrison, Anderson, & Archer, 1999; Vaughan & Garrison, 2005)

The design of the *RoP* program follows the recommendations for PLCs described above. For example, the *RoP* offers a prolonged opportunity for participants to discuss, develop and determine their *shared visions and norms* about how people learn. In exploring ways to support learning in the light of institutional goals, a *consistent focus on visitor learning* is developed. The ideas and tasks in the program promote *reflective dialogues* about the design and goals of educational offers, and in so doing create and strengthen a shared knowledge base and professional language among educators within an institution. As they discuss their understanding and application of research into practice in the interactive sessions, and talk about their actions with others in the reflective tasks, the educators are supported in developing a habit of *making their practice public*. Finally, with the emergence of a shared language and a shared understanding of research and their own practice, *collaboration* between the educators within the institution extends beyond superficial exchanges of help.

In essence, the *RoP* program supports participants to articulate or externalize their practice and reflect on their thinking. The learning context is authentic—it refers to the participants' daily work—and moreover is social in that the context involves group discussions. Motivation to continue learning, meanwhile, is fostered through the increased levels of autonomy such learning confers. In short, the *RoP* program supports the deep conceptual learning of informal educators so that they in turn may support deep conceptual learning on the part of visitors.

Final Words

The discussions of ideas, issues, and practices that we have explored in this chapter have all been underpinned by our original premise: if we wish to equip learners with the knowledge and skills to engage with the contemporary nature and practice of science, the role of an educator must be one of supporting deep conceptual learning. But, in discussing the psychological processes involved in deep conceptual learning and noting the foundational knowledge components and skills required by educators to facilitate such learning in informal contexts, we have also highlighted the need for educators to participate in programs of ongoing professional learning. Such programs will necessarily be more efficacious if they build on elements that are known (and indeed documented in the first part of this chapter) to support learning. That is, such programs should provide opportunities for participants to engage in the processes of externalization and reflection, and ensure that the support and motivation to learn, and the accompanying effort required to learn, remain high.

The central focus of the *RoP* program described above is reflection. Participants are encouraged to articulate and contemplate their practice using videos and other tools, and also to relate their practice to the findings of recent research. Thus far, more than 40 institutions have adopted the program across the United States and over 400 informal educators have participated in its courses. In their evaluation of the program, however, Tran, Halversenet al., (2013; Tran, Werner-Avidon et al., 2013) noted that the widespread implementation and sustainability of the program was largely affected by three factors: (1) an institutional commitment to professional learning, (2) an institutional culture open to change, and (3) a program champion in the institution's leadership.

Here, then, appears to be a key challenge for the field. As Brink, Vourlas, Tran and Halversen (2012) have argued, if institutions strive to offer quality learning experiences for their visitors—which we would assert to involve the support of deep conceptual learning—'then institutions need to support the quality learning of the educators that provide it' (p. 33). In other words, informal science institutions need to become places that value and support their employees' learning and growth. The institutions need to become professional learning communities and reflect the importance of continuous learning across the whole institution.

In this chapter, we have summarized key aspects of the research on the facilitation of deep conceptual learning. We have outlined the unique knowledge and skills that informal educators apply to foster such learning. And we have discussed the nature of professional learning programs that can support informal educators in their role. The next step is arguably one of advocacy and sector-wide policy change. Professional learning about learning needs to be embedded within all informal science institutions. We look forward to addressing this challenge in the future.

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Chapter 5
From Acquisition to Inquiry: Supporting Informal Educators Through Iterative Implementation of Practice

Lauren B. Allen and Kevin Crowley

One December day in Pittsburgh, the project team for museum/school collaboration gathered in the basement of the Carnegie Museum of Natural History to debrief a visit to the museum by Pittsburgh Public middle school students. The team included the science curriculum coordinator for Pittsburgh Public Schools, the newly appointed director of museum education, a new museum educational program designer, and three learning researchers from across the street at the University of Pittsburgh. The team also included eight seasoned museum docents. The docents were typical types for a natural history museum: They were mostly retirement age, well educated; they loved the museum, and had backgrounds in (or strong personal commitments to) science, nature, or education. They all wanted to give something back, to share their interest in the museum and its collections. But on that day, the docents were not in a good mood:

> Ninety percent of the problems—and there were problems—on the November 22 tour had to do with the audience. They simply were not there… I spent more time being distracted by getting them to listen and pulling them away from taking pictures… For God's sake don't let them bring cell phones. It is the single most destructive invention for education! (Steve,[1] 16 December 2011, meeting transcript)

The docents were talking about school trips they had developed using the existing museum practice of writing their own personalized tours around a small set of general, high-level objectives given to them by the museum. In this case, the objectives came directly from a federal grant that funded this project.

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[1] All personal names are pseudonyms.

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Elizabeth agreed with Steve's assessment of the students: "They had an inability to focus" (Elizabeth, 16 December 2011, meeting transcript). Other docents agreed that the students were difficult to manage, and felt that their chaperones and teachers did not have disciplinary control over student behavior in a way that allowed the docents to feel comfortable. While the rest of the docents in the room nodded emphatically, Steve explained: "The teachers have to understand that it is not our role to impose discipline. I have a lot of trouble doing it. There has to be a clarification of what their role is before they get here, and they have to stick to it" (Steve, 16 December 2011, meeting transcript).

After about 15 min of listening to the docents air their frustrations, the school districts' science curriculum coordinator leaned forward in his chair and, in a quiet, reasonable voice, changed the whole direction of the project:

> You know, [pause] this is the student and teacher population that come to us in this public system. We should not orient our conversation in a direction that has us thinking about aspects that are not in our control. What is in our control is to make the tour as engaging as possible. If our students have electronic devices, then we should use them. To say that these students cannot focus is inaccurate, there is evidence that they do focus on things in their lives, but we need to meet them where they are and engage them in the type of learning that fits them (Tim, 16 December 2011, meeting transcript).

The Challenge of Professional Development for Part-Time Informal Educators

We ask a lot of museum educators. School trips are still the primary way that schools and museums interface, and for many students, the school trip may be the only time they visit the museum. Docents, tour guides, or museum educators are typically the only point of human contact between students, teachers, and the museum. Across all of the school trips in all of the museums in North America, this adds up to millions of contact hours per year with students.[2]

Yet, despite their central role as informal educators, museum docents face a number of difficult challenges and are often poorly supported in terms of professional development. Docents are often part time, usually untrained in contemporary science education pedagogy, and accustomed to a fair amount of autonomy in their work. If they had any formal training or experience as educators, it may well have taken place decades ago when knowledge-focused, teacher-centered didactic approaches were the norm. Many may have made their minds up about the nature of quality education long before people began advocating for inquiry or using mobile devices as tools for educational engagement (Grenier, 2005, 2006).

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[2] There were approximately 55 million students attending public and private schools in the US in 2014 (NCES.ed.gov/fastfacts). If 10% go on museum trips, which typically last an hour, museum education will account for about 5.5 million student contact hours this year.

What do we know about how museum educators are prepared for this important role in our science education infrastructure? Docent training typically entails lectures from curators, readings, and shadowing more experienced docents (Abu-Shumays & Leinhardt, 2002; Castle, 2006; Grenier, 2005, 2009; Grenier & Sheckley, 2008). There is a common, yet paradoxical discrepancy between the participatory theories of learning espoused by docent trainers, who are usually full-time staff in a museum's education department, and the knowledge acquisition-based theories that docent trainers actually use in practice (Grenier, 2005). "Without training reflective of engaging programs that encourage questioning, interaction and experimentation, docents will likely continue to lead tours in a manner that mirrors their prior learning experiences in schools and in docent training" (Grenier, 2005, p. 6).

Prior research has demonstrated that for students on school trips, museum educators expect students to apply prior knowledge, make connections to real-world situations, and have a positive experience that sparks enthusiasm for learning in museum environments (Tran, 2006). These are quite different expectations when compared to those classroom teachers have for measurable improvement on exams or standardized tests, mastery of skills, and completion of curriculum-based instruction. Despite these distinct expectations and priorities for students, museum educators tend to utilize a limited set of strategies for engaging school-trip students, and as a result, their educational practice appears very similar to that of formal classroom teachers. Researchers argue that museum educators need to develop a shared professional language and museum-specific pedagogy to support the affective and student-centered learning objectives that museums are uniquely suited to serve (Allen & Crowley, 2014; Tran, 2006).

In this chapter, we describe a project that addressed the unique professional development needs of docents. The vignette that opened the chapter took place about a year into a NASA-funded school trip project at the museum, at a point when the leadership on this project had undergone a complete turnover, and new leaders were attempting to understand what was happening with the project and what was necessary to move it forward and ensure its success. Elsewhere, we describe the nature of docent change in more detail (Allen & Crowley, 2014). Here, we expand upon the processes our project followed to encourage docents to embrace an inquiry-centered approach to learning. For this work, we draw from transcripts of meetings with the docents, open-ended survey results from a brief written satisfaction survey conducted after a docent training, and the results of one-on-one, semi-structured interviews conducted with seven of the most active docents on the project. The first author conducted these interviews after the spring semester when the first round of new school trips were tested and implemented.

A New Approach to School Trips to the Natural History Museum

The vision for this project was that students on school trips would encounter the museum as a museum. Within a general frame, students would able to follow their own interests, seek out exhibits, interact and converse with each other, and document their own observations in ways that made sense to them. This vision for school trips contrasted sharply with the existing condition. Traditionally, docents led groups of approximately 10 students and one chaperone on a tour of various areas of the museum, while explaining different concepts related to the exhibits the docent decided for themselves that the group should visit. The docents felt comfortable with this format, because it allowed them to maintain control over the content and conversation that occurs during the tour. The format also fit with how they tended to conceptualize learning, as the transmission of information from the more knowledgeable expert to a less knowledgeable student (Allen & Crowley, 2014).

Traditionally, docents were accustomed to receiving in-depth content-laden lectures from relevant curator and perhaps reading several articles on science content to prepare to lead school trip groups. And this approach had been fine with the docents, who often view themselves as life-long learners in pursuit of facts and content. After all, many of them chose to get involved with the museum because they valued its collections and because it fit with their own personal identity and desire to be around others who connect deeply with museums and content. For example: “I’ve always been a museum person” (John, 13 June 2012, interview); “I’ve always loved museums and always wanted to be involved in archeology… I really like working with the people here. Overall, they’re the kind of people I want to interact with” (Naomi, 12 June 2012, interview); “I have a degree in biology… and I’ve always loved the museum. I like the people.” (Lucy, 13 June 2012, interview); “I’ve been coming here since I was a kid, I mean, this is the greatest place” (Clara, 15 June 2012, interview); “I wanted to continue learning new material, to be with an intellectually stimulating group of people and environment” (Steve, 13 June 2012, interview).

But as should be clear from our account of the December 16 meeting that opened this chapter, the business-as-usual approach was not sufficient for the docents to “meet the middle school students where they were,” and was instead proving frustrating for both student and docent. We needed to come up with an alternative.

Iterative Implementation as Professional Development

We use the phrase “iterative implementation” to describe our process of reflectively working to actualize a newly designed educational program, or a program that is new to a particular context. Through iterative implementation, practitioners identify something that is not working during a cycle of implementation, new ideas are discussed and tested, and, if more successful, are implemented into the next version of the program.

We see iterative implementation as part of the same family of research/practice approaches as design-based research (Barab & Squire, 2004), and design-based implementation research (Penuel, Fishman, Cheng, & Sabelli, 2011). Iterative implementation is different from these other development methods in that it is a less resource-intensive and more reflection-based process that facilitates professional development and successful program implementation in situations where institutional constraints may impede design processes that include practitioners in the role of full on co-designers. Rather, the leadership team conceived the learning principles and approaches of the new school trips, and the docents (who did not have the time to be full participants in that process) acted as beta testers, who had the authority to tinker and customize within the broad parameters of the new structure. This reflective process facilitated the development of the new, untested design into a program with which educators are familiar and believe in, because they have worked to see its successful implementation over time (see Nunnery, 1998 for an example from formal education). The most important part of iterative implementation is reflection and conversation among implementing educators: they must have opportunities to share successes and challenges from each iteration, while also sharing and vetting ideas and strategies for improvement to be tested in the next implementation.

The primary venue for reflection and conversation among the docents on this project was the debrief meetings held within a few days after each of the school trip implementations. The first author facilitated these meetings, encouraging docents to share specific examples from their recent school trips, and discussions of how to utilize successful strategies, and how those connected to the guiding principles for inquiry-based learning. The debrief meetings gave docents the opportunity to continue to share their experiences, both good and bad, with one another and with the leaders of the project, in an effort to make their work on the new school trips as successful as possible.

Guiding Principles for Inquiry-Based Learning

The new school trips were structured using three guiding principles for inquiry-based learning from learning science and educational psychology research: learner autonomy, conversation with reflection, and deep investigation. Throughout this report, we refer to “inquiry” as the incorporation of these three principles into learning experiences. These principles were not only useful in structuring docent-student interactions during the project, but also served as principles for the professional development and learning taking place among the docents throughout the process of iterative implementation. The project leadership intentionally provided opportunities for the docents to experience learner autonomy, conversation with reflection, and deep investigation within the iterative implementation process. We strove to provide consistency between the learning experience docents were asked to provide and the type of learning leaders were asking docents to engage in themselves (see Grenier, 2005). Below we explain the background for the three guiding principles for learning, including how they applied to students on the school trip and to docents in their process of professional development through iterative implementation.

Learner Autonomy

The principle of learner autonomy is important for motivation for learning and engagement (Ames, 1992; Linnenbrink, 2007; Pekrun & Linnenbrink-Garcia, 2010; Ryan & Deci, 2000), particularly in informal and museum settings (e.g. Barton & Tan, 2010; Falk & Dierking, 2000). Inquiry-based learning hinges on learner autonomy, positioning the learner as the decision-maker and encouraging learner-centered choices on the part of the teacher, facilitator, or (in this case) docent. By highlighting learner autonomy as a guiding principle in this project, we hoped to encourage docents to foreground learner-centered pedagogical choices, leveraging the advantages of free-choice learning provided by the museum. In contrast, the structure of traditional docent tours provided little opportunity for learner autonomy, and based on docents' reaction to student behavior at the first project meeting, we found it likely that middle school students would benefit from more autonomy, and that docents would benefit from thinking of autonomy as an important support for learning, rather than a detriment (Allen & Crowley, 2014). Early in the project, docents pushed hard against the idea of giving students autonomy on the museum floor. For example, after the second training session in mid-March, Elizabeth wrote on the open-ended survey: "Perhaps my issue with this is the autonomy idea. I can effectively guide an entire tour group through exploration to collectively learn" (Elizabeth, 18 March 2012, survey). However, by the end of the project, she was able to acknowledge that there was some benefit to allowing more autonomy to students at the museum, saying in an interview:

> Through my struggles with this [I] have found… I'm even looser with the way I do a tour. But guided and allow them to come up with their own conclusions, with a proper answer though… allowing for more observation, more conversation—I'm finding a lot of success with that because if your children are really excited, they go to an exhibit and they start chattering, that's your avenue (Elizabeth, 14 June 2012, interview; also quoted in Allen & Crowley, 2014).

The process of iterative implementation also provided autonomy to each of the docents as they implemented the new school trip design. Docents were charged with identifying where and how they would model the observation and analysis technique that students were asked to learn and document. Additionally, the docents were in charge of their own learning around the driving content questions and learning objectives for the school trip, and would share articles with one another over email and have informal discussions about how to address content-related questions and ideas before and after school trip implementations, unfacilitated and unprovoked by the project leadership team. Having autonomy in their work at the museum was something that docents identified as valuable: “One of the things that attracted me to the museum is the autonomy, really. There’s lots of stuff, support, and things to learn here, but when it comes to how you do it, you can pretty much do what you want to do” (Lucy, 14 June 2012, interview).

Conversation with Reflection

Conversation and reflection are important complementary learning behaviors that lead to deeper engagement and are often described as foundational in studies of museum learning (Ash, 2004; Barron, 2003; Crowley, Callanan, Jipson, Galco, Topping, & Shrager, 2001; Leinhardt, Crowley, & Knutson, 2002; Palmquist, & Crowley, 2007; Pierroux, 2010). Students were already engaging in conversation with one another, albeit it to the earlier chagrin of docents. As dual principles for inquiry, conversation and reflection were important in providing docents tangible scaffolds for students’ learning experiences through their natural exploratory behaviors, such as asking questions, making observations, and talking with classmates (Allen & Crowley, 2014).

Conversation and reflection were the two most important aspects of docents’ professional development through the process of iteratively implementing this new program. The main way that docents generated new ideas and strategies for successive iterations of the school trip were through the facilitated debreif meetings after each implementation, where docents would meet with one another and at least one member of the leadership team to discuss the successes and challenges of the most recent school trip. Steve found the debreif meetings to be essential to his and his colleagues’ development:

> I think the debriefings after each tour were absolutely invaluable… when a docent begins to have an individual approach within the framework that has been established, that is a very, very positive sign (Steve, 13 June 2012, interview; as quoted in Allen & Crowley, 2014, p. 93).

In these conversations, docents learned from each other’s successes and struggles, and were given the opportunity to spend time reflecting on their own experience with their colleagues, receiving feedback, and often learning that collectively they were experiencing the same challenges. These realizations enabled docents to more readily work together to come up with new ideas for how to address challenges in future implementations.

Deep Investigation of a Few Concepts

Finally, deep investigation of a few concepts, as opposed to shallow exposure to many facts, was our third principle for inquiry-based learning. This principle was targeted to help docents and teachers from feeling pressure to make sure students “see as much as possible”, a common challenge for facilitators of museum learning experiences (Bitgood, 1989; DeWitt & Storksdieck, 2008; Kisiel, 2005a, 2005b; Orion & Hofstein, 1994). For students, deep investigation meant the opportunity to engage with an area of the museum in a way that allowed time and space to ask questions, record observations, have discussions, and re-visit ideas and exhibits without pressure to see everything (Allen & Crowley, 2014).

For docents, deep investigation was the opportunity to continuously engage around and improve a program being implemented for a large number of students over the course of a semester. This meant that they had the opportunity to try variations on the same design, tweaking their strategies based on what they learned in prior implementations. This is similar to a practice in formal teacher development called ‘lesson study’ (Hiebert & Stigler, 2000). Museum school trip programs are an ideal opportunity for informal educators to engage in deep investigation of a single program, because museums usually offer a small number of programs to schools for trips, and those programs are utilized many times over the course of an informal educator’s tenure at the museum. By intentionally providing the space and time for group reflection during debrief meetings as part of the iterative implementation of this project, docents were able to deeply investigate how this new school trip worked, was improved, and how it could inform all of their work at the museum.

The Leadership Team and the Core Objectives

We, the authors of this chapter, were two of the learning scientists at the December 16 meeting. The first author was one of the primary leaders of the new school trip leadership team, along with Roselyn, the museum’s education director, who was trained in youth development in learning, Tim the school district’s science curriculum coordinator, trained originally as a physicist, and Jordan, the new program developer, who trained as a paleobotanist. At the conclusion of the December 16 meeting, the leadership team made a commitment to re-think the format of the NASA-funded school trips in light of the experiences the docents had shared and with the goal of capitalizing on the learning behaviors that the students were already engaging in at the museum (such as taking photographs). We made ‘meeting the students where they are’ a priority for the new school trip design.

Roselyn was brought on by the Carnegie’s then newly hired director when the project was already under way. One of her priorities was to increase interactive and inquiry-based experiences on the floor. She pushed for more opportunities for visitors to engage with hands-on natural history objects, and for more thought-provoking exhibits that would encourage conversations between visitors and museum education staff.

Tim, the science curriculum coordinator for Pittsburgh Public Schools, made it clear that the school trips provided by this project should prioritize students' opportunities to engage with real science. In this case, the NASA-funded project was for creating experiences that integrated satellite data and authentic objects from natural history collections. He emphasized that students do not have the chance to do engage with real scientific data and authentic objects from natural history collections in their classrooms, and that this school trip could potentially be students' only opportunity the entire school year to have a non-classroom style science experience. In particular, learner autonomy was an important aspect of these school trips for Tim: "Put a protective boundary around students if they are really pursuing their interests, that should be a priority. Don't pull them away if they are engaged. How can you protect that time and space?" (Tim, 29 March 2012, debrief meeting transcript).

The first and second author served a dual role as advisors to the project, recommending principles and ideas from learning research, suggesting new approaches, and helping to collect evidence to document impact. Bringing learning research to the table helped to legitimize the new pedagogical structures that docents were asked to implement during the project, important for docents who were initially skeptical about the emphasis on pedagogy and inquiry in the project's objectives and training sessions.

Finally, Jordan, a recent hire in the education department, served on the leadership team designing and implementing both the new school trip and the in-class session that preceded each school trip. The docents trusted Jordan because of her graduate training in paleobotany and her commitment to rigorous science content. Jordan, Roselyn, Tim, and the first author were the main developers of the new school trip structure that docents iteratively implemented between January and May of 2012.

The leadership team worked to generate a clear set of driving questions and learning objectives that would give the docents, teachers, and students a clear understanding of the learning expected on their school trips. These learning objectives, presented in Table 5.1, were designed to fit the same format as the curriculum and standards used by Pittsburgh Public School science teachers, allowing teachers to see the value of trips for their students, and allowing docents to connect with teachers immediately and easily regarding the goals of the trip in a format that made sense to both docents and teachers.

The new design for school trips for this project was grounded in the three guiding principles for inquiry-based learning (learner autonomy, conversation with reflection, and deep investigation). In addition, the original project grant stipulated that these school trips would include a classroom visit from a science educator from the museum, usually Jordan. Prior research on school trips has revealed that the more closely connected classroom learning and museum learning are, the better students perform on assessments in either venue (Gennaro, 1981; Orion & Hofstein,

Table 5.1 Driving questions and learning objectives

Driving questions		*Learning objectives*	
How are climate and biomes connected and what happens when they change?	Knowledge I can describe in my own words	Skills I can	Disposition & Participation I will
What are biomes?	Earth's biomes, using features such as precipitation, temperature, and vegetation	Utilize NASA data to identify and describe different biomes	Explore weather, climate, and biome data based on my own interests
What's the difference between climate and weather?	The differences and connections between weather, climate, and climate change	Identify and use scientific evidence (maps, fossils, photographs, etc.) to describe current and past climate change	Have conversations about biomes, climate change, observations and evidence with peers and adults
Do climate and biomes really change?			
How will humans respond?	Why it is important for people to understand climate science.	Ask questions and connect experiences to my own life.	Identify the parts of my school trip that are of personal interest to me.
How do scientists study change?	How my school trip site is part of climate science research and education	Access scientific evidence and learn through authentic objects, data, and living collections on my school trip	Recognize my school trip destination as a valuable part of my city—a place where I can visit, learn, have fun, volunteer, and find a job
What does NASA have to do with this?			

1994; Sturm & Bogner, 2010). Even though docents did not conduct the in-school visits, they were able to know what students had experienced in their classrooms immediately prior to visiting the museum, which was never the case for traditional school trip tours. The in-school visit introduced students to the main driving questions and learning objectives using hands-on activities with the two main tools students would also use while at the museum: a field notebook for recording observations, and NASA satellite data maps depicting the different biomes of the earth (Allen & Crowley, 2014).

On the museum floor, instead of leading groups to exhibits of the docents' choosing, as in traditional tours, docents were asked to direct the students on "expeditions" to two or three areas of the museum, where students would use the tools that had been introduced in their in-school portion of the program to engage with the exhibits on their own, punctuated by opportunities to ask questions and engage in conversation with docents and other students. Scaffolded opportunities for students to experience each of the guiding principles were described as follows: learner autonomy meant students had opportunities to choose which exhibits they would observe and how they would document those observations, e.g., they might choose to draw what they saw in an exhibit or use a mobile device to take a photograph. Conversation with reflection opportunities were encouraged by docents throughout students' visit to the museum in the form of questions and answers as well as more open-ended opportunities to engage in conversations with peers and teachers. Each school trip ended with a reflective conversation where students discussed their favorite exhibits in the museum and how they connected biomes to climate. Finally, deep investigation meant that docents and students would stay in one or two areas of the museum to engage with them for more time, rather than rushing through to try to see more of the museum, even though it meant some students did not see all the exhibits.

Inside Iterative Implementation

The leadership team introduced the iterative implementation process, guiding principles for inquiry-based learning, and new school trip structure to the docents in a classroom-based training on January 26, 2012. That training included, at the docents' request, a lecture on climate science, and a long discussion about how to talk about climate change while 'avoiding controversy'. The questions and concerns voiced by the docents at this training mainly focused on their discomfort with the topic of climate change, and logistical concerns regarding the new structure and how to coordinate timing the new activities. The first training presented the docents with a great deal of information, and asked them to implement the new structure the following week.

The first school trip implementation of the new structure took place on February 2, 2012. Nearly 200 students from one of the district's largest middle schools attended the school trip, and approximately 12 docents were involved in two 'rounds' of the school trip. This first school trip included several unexpected logistical demands—the first author ended up helping several groups who had been separated from their docents to find them on the floor of the museum, and locating missing equipment (e.g. clip boards and pencils for students and chaperones). During this trip, we observed that docents were not confident in the new structure they had been presented with the week before in training, and in the midst of a crowded and chaotic day at the museum, they fell back on the traditional structure of the docent-led tour, where the docent did the majority of the talking. Students were observed to be mostly compliant but not highly engaged with the content of the docents' lectures (see Fig. 5.1).

At the first debrief meeting of our new school trip season, the discussion predictably focused on logistics and smoothing out the rougher edges of our first attempt to implement the new structure. In particular, docents needed to have more information about where the different stations would be located on the museum floor—they wanted to make sure they could bring their groups to the touchable objects and data exploration stations within the tight time frame of a 90-minute visit to the museum, and feel that they had covered the driving questions and learning objectives that had been established for these school trips.

Fig. 5.1 Students on the early February school trip to Carnegie Museum of Natural History sit and listen (or not) as a docent as she gives a lecture in front of a bear

In this first debrief meeting, the docents began to realize that they had experienced autonomy on the floor in the museum, and that it was something valuable to their work:

> Mary: Are you going to tell us that we have to go from here to here and then here?
>
> Lauren: Do you want that?
>
> Mary: NO!
>
> Lauren: I think we want you to have a set of examples of how climate and biomes interact that you're really comfortable talking about with students (8 February 2012, debrief meeting transcript).

The docents were not yet comfortable implementing the new structure for these school trips, but they were also not ready to give up on the idea of making changes in their practice to ensure that students were engaged and reaching the learning objectives that had been agreed upon by the museum and the school district.

After the initial school trip implementation, the leadership team met to re-group and assess the finding that docents had not fully understood what the new structure could or should look like on the museum floor. We planned an 'on-the-floor' training for docents, which included the full 45-minute in-school session in a classroom in the museum, so that they could experience what their students would have in school within a few days before coming to the museum. The docents resisted putting themselves in the role of the student during this training, but afterwards provided mostly positive feedback on the training experience, citing conversations with other docents during the training and being able to talk about examples on the floor as very valuable.

Following this training, the first author distributed a survey asking for docents' feedback on the training format and content, and their overall enthusiasm for the new school trip structure. The survey responses indicated that many of the docents were still very much focused on 'knowing more facts' as a result of their training, and put pedagogical training at a much lower priority, for example: "While pedagogical theories about learning are interesting, docents need to continue to be trained on scientific facts and recent findings" (Marco, 19 March 2012, survey). Since we had only engaged in one school trip/debrief meeting cycle, after this training, docents had not yet had a chance to see how their subsequent implementations of the new structure might change over time. However, one docent indicated that she understood these particular school trips would evolve and depend on the students who attended them: "I think this will be a tour that is constantly revising itself especially dependent on the school groups we get" (Joanna, 19 March 2012, survey).

Over the course of five more iterations of the school trip and follow-up debriefs, docents discussed their experiences, what they would like to see change and what went well for them, and how they would adjust their strategies next time around. Their concerns moved from almost entirely about logistics and coordination to deeper questions about student learning and strategies for engaging students in the new school trip structure. Once they realized that they had some control over how they iterated and tried new ideas after discussing them in debrief meetings, they became enthusiastic about debriefing and reflecting on their own processes. For example, Steve noted in one debrief that the structural changes were not something that came easily to him and his colleagues: "There is a lack of comfort with the different format, so if folks are also uncomfortable with the content, they fall back onto their more comfortable format of lectures—this is how we were trained" (Steve, 29 March 2012, debrief meeting transcript).

When students responded positively and engaged readily with the new format, docents were able to see that what they were implementing was working. The docents began to recognize and value the three guiding principles for inquiry-based learning. Autonomy became very important: "the students respond well to having free time on the floor, this format works better than regular tours" (Paul, 29 March 2012, debrief meeting transcript). As well as conversation and deep investigation: "There were really dynamic questions from students, when they get interested and have time to engage, there was lots of conversation. Docents shouldn't whisk students away if they are engaged, it breaks down the good conversations that are beginning" (Steve, 29 March 2012, debrief meeting transcript).

Towards the end of the iterative process, the docents collectively came to the conclusion that they were improving in their work. Docents at first attributed the improvement in students' behavior and engagement to a higher level of student preparation. The project's leadership team encouraged the docents to think about themselves as learners and consider the possibility that they could be the ones improving in preparedness:

> Lucy: These field trips have been really interesting and different every time. This most recent group was the best group, most fun and engaging students so far.
>
> Paul: These tours have been successful because the students are very well prepared, both with their knowledge and willingness to be engaged.
>
> Jordan: How well prepared the students are varies from school to school. Could it be that the conversational aspect of these field trips is why we are observing these successes?
>
> Steve: The kids are better and better every time we do these trips. Something is changing that's making the trips better and better.
>
> Roselyn: Do you think that you docents might actually be getting better and that's why it feels like the trips and students are getting better and better?
>
> Aaron: These debriefings that we do after every trip help us docents to improve our 'product' (7 May 2012, debrief meeting transcript).

This exchange was followed by a flurry of exclamations around the room. The general sentiment was a realization that the hard work of trying new things and reflecting on them regularly could pay off in a tangible way. The iterative implementation process helped docents to grapple with logistics early on and later become comfortable with a new way of working with students. After several iterations, they began to spontaneously engage in sophisticated examinations of what learning really is, and how it can take place in the museum:

> Lucy: I don't know if the students learned much on this trip.
>
> Lauren: What do you mean by "learned much"?
>
> Lucy: I don't know if they left with some new information in their heads about climate change.
>
> Steve: We can reinforce things that they already know, that is also learning.
>
> Lucy: I would not include that in my definition of learning.
>
> Andy: The teacher might give a verbal definition of a biome that students can regurgitate, but it might not be meaningful. Coming to the museum and seeing the biomes helps them understand what biomes are in a real context, and how that information is useful.
>
> Lucy: I still see a distinction between affirming something that's already known and getting new information.
>
> Lauren: Maybe we can think of it as students learning the skill of using their knowledge.
>
> Roselyn: Learning is reflexive, people are always revisiting what they learn. Coming to the museum is rich and emotional for kids, this is a good opportunity for learning because affective experiences lead to stronger memories.
>
> Steve: Here they can see and touch and make more enduring memories (7 May 2012, debrief meeting transcript).

In this conversation, Lucy was questioning whether the project team, docents included, were really justified in their excitement about the more recent iterations of the school trips, which had been deemed very successful in debrief meetings. She challenged her colleagues about the definition of learning, and project leaders as well as her fellow docents bring up different kinds of learning and how the museum is an important venue for them. Compared to their earlier insistence that learning can only be the transfer of ‘factual knowledge’ from one person to another, this conversation is a big step toward embracing the types of learning in informal environments that have been identified as valuable by the field (Bell, Lewenstein, Shouse, & Feder, 2009).

By the end of the iterative implementation period, the docents recognized that they had made iterative changes in their educational practice on an individual level: “Every time I worked on a tour [for this project] I did it a little bit differently” (Lucy, 14 June 2012, interview);

> …as I went through with the next group and saw where they were stumbling, I knew which questions to ask the second time around to make it easier for them to get what I wanted them to get out of the exhibits… I’ve learned something with each particular group (John, 13 June 2012, interview).

In addition to these individual iterative changes, the docents had begun to develop into a community of practice (Wenger, 1998) around implementing the new inquiry-based principles for learning, and reflected on their changes as a community:

> The debriefings after each tour were absolutely invaluable. You could see what was working… I could sense that we were getting more comfortable with the idea that we were getting better at it… When the docent begins to have an individual approach within the framework that has been established, that is a very, very positive sign (Steve, 13 June 2012, interview).

Steve, like other docents, had been particularly skeptical and resistant to the new school trip format early in the project’s trajectory, but as we reported in Allen and Crowley (2014), he became one of the project’s strongest advocates, even using the inquiry principles to re-create one of the museum’s most popular docent-led tours into a more inquiry-based exploration. Several other docents agreed that the new format was valuable, even though the change was not intuitive or easy for them or their colleagues:

> In the initial training, I was skeptical as to how this was going to work. I thought, oh I don’t know. I’m not used to doing tours in this manner where there’s so much freedom to explore. I thought I would lose control, but I was really surprised that given the opportunity, it works really well… we need to update the way we do [all the] field trips… I think the docents can be flexible. We’re all not young so sometimes it takes a little arm-twisting to get things to change. But change is important and that’s what life is all about (Naomi, 13 June 2012, interview).

In a similar vein, Clara recounted how she shared her feelings about the project’s value with a colleague:

> I was just saying to another docent the other day, there were things that came out of our training that we will use. You might not realize you’re using it because you did it on the NASA trips, but I think you do… there was a lot of learning for everybody that came out of it, I think (Clara, 15 June 2012, interview).

The process of iterative implementation helped the docents to see that change was possible, and not necessarily a negative aspect of their work:

> I was surprised at how much it [the trip] changed… each time out it was like, okay, we're going to do this. The [field] notebook changed. The stations changed. So I did like that about it, that it was actually changing as we did it… I don't think the end result was where everybody wanted it to be, but it was heading in that direction. And I think people listened to each other a lot. When the transition came, the docents were defensive about the whole thing, some of those changes made the docents feel threatened, but then the docents came around, we were like, we shouldn't feel threatened, we should contribute. Everybody worked together (Clara, 15 June 2012, interview).

Conclusions

The docents at the Carnegie Museum of Natural History progressed in their ideas and opinions about the students from Pittsburgh Public middle schools, which we documented in the opening vignette of this chapter. By the end of the iterative implementation process, even though the students they were working with were simply a few months further along as seventh graders, the docents' perception of them was entirely different. The project leadership team provoked the docents into considering that the new school trip approach could have something to do with how much more successful their school trips were.

The iterative implementation process allowed the docents to grow and develop professionally in facilitating an inquiry-based school trip program. Iterative implementation also provided a streamlined process for taking an untested school trip design and turning it into a program that educators and docents were comfortable offering. Many of the details of the new school trips were dictated by the grant that funded the project. However, the docents and educators decided to offer the new school trips not only to the students who were covered by the grant, but also as one of the available programs offered to schools from other districts that come for museum visits. The grant did not provide an abundance of funds for staff development on the new school trips, but the new format required that docents be supported as they learned how to engage students in the inquiry-based process. We found that by encouraging reflection and providing the space of the debrief meeting after each school trip in the first six months of the new structure's implementation, which used relatively few resources but provided an important space for professional interaction and conversation through which docents grew and developed their practice.

This project required us to address the question of how we would get the docents to implement a new school trip design about which they were initially very skeptical. In the case of this project, not only was the inquiry-based pedagogy challenging, but the content area of the school trips was also something around which the docents had experienced discomfort and conflict—in part because not all of the docents had the same opinions about climate change.

The new design and content of this project set us on a course of disrupting the existing system of docent-led and docent-centered tours. Although the docents were resistant to the new pedagogy and the challenging content, iterative implementation provided space to have a conversation with project leadership and one another. The iterative implementation process allowed docents to maintain autonomy in their practice, and deeply investigate the new school trip design. By providing the space for docents to reflect together as a regular part of their process, they were able to collectively develop their understanding of learning from one strongly focused on acquisition to one that more clearly articulated and acknowledged the value of inquiry.

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Chapter 6
Museum Science Teaching: Museum Educators' Personal Epistemologies and Created Learning Experiences

Jung-Hua Yeh

A report by the Center for Advancement of Informal Science Education (CAISE) described how public engagement with science (PES), in the context of informal science education (ISE), can provide opportunities for public awareness of and participation in science and technology (McCallie et al., 2009). Natural history museums, zoos, botanical gardens, aquaria, and nature centers or parks are well known for informal science education, and they expand possibilities for science learning. In Taiwan, to encourage students' science learning, teachers and administrators from 3-year-old to 15-year-old arrange field trips to such places as science museums or centers. Beyond the expectation of encouraging science learning, science museums offer docent guided tours and educational activities for schoolchildren. Several studies on schoolchildren's field trips have reported that few took advantage of museums' unique offerings (Bartels, Semper, & Bevan, 2010; Bell, Lewenstein, Shouse, & Feder, 2009; Bevan et al., 2010; Falk & Shepard, 2006). Other studies have suggested that docent guided tours tended to appear more as formal learning enacted in an informal setting (Cox-Petersen, Marsh, Kisiel, & Melber, 2003; DeWitt & Storksdieck, 2008; Kisiel, 2005a, b).

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Introduction of NMNS

The National Museum of Natural Science (NMNS) emerged from the 1970s energy crisis, which prompted the world to place greater importance on the environment. This museum serves as a traditional natural history museum, collecting and investigating natural specimens and anthropological relics. In the area of education, the museum's missions are to raise public knowledge of science, cultivate reasoning and independent thinking, and encourage people's curiosity about natural phenomena. Every year, the museum welcomes nearly two million visitors. The main building and the Botanical Garden have a combined area of 132,132 m^2; the main building includes the Space Theater and Science Center, Life Science Hall, Human Cultures Hall, and Global Environment Hall. Currently, the museum has a staff of 332, including 123 permanent employees (science curators, 55; education curators, 8; technicians and office workers, 60), 127 contracted employees (presenters, 65 and exhibition service staff, 62). NMNS established a volunteer support program in 1986, and the volunteers work in five major areas: visitor services, education, inquiry response, administrative support, and specimen collection, and these areas exclude student groups, corporate groups, and high school student volunteers. As of 2013, the number of volunteers exceeds 1,400.

The employed docents divide into four groups: (1) Commentary, guided tours for groups with scheduled commentary for each exhibition (standard duration, 40 min); (2) Activity, providing hands-on science events in the museum and science-event outreach for primary schools in other cities (standard duration, 40 min); (3) Classroom Theater, 12 small rooms with teaching aids and multimedia that introduce specific, scheduled science topics (standard duration, 40 min); (4) Naturalist Center, a free admission area that provides various all types of specimens and microscopes, allowing visitors to explore nature; it is sometimes reserved by schools to introduce nature events (no more than 90 min).

Although during the past decade in Taiwan, no research has identified the benefits that schools received from guided museum tours, from personal contact with our museum educators, most employed docents in our museum make guided tours as simplified version of science lectures. There is an assumption that the quality of the guided tours could be improved by decreasing the group size as this would lead to an increase in the visitors' concentration. This assumption has meant that most of our employed docents have put efforts into memorizing the notes, which the science curators have provided for the docents in the in-service training. At the NMNS, there are 56 guided school group tours and educational programs on the schedule each. From 2001 to 2006, each guided tour had 45–50 persons per school group (one class counts as one group); since 2011, this number has decreased to only 22–26 persons. The declining birth rate has caused the total number of first graders (6-year-old) in Taiwanese elementary schools to decrease 25% in total every 5 years (National Institute of Educational Resources and Research, 2003, p.118). This means that each guided tour has only half the number of people compared with past years. When observing school groups, I have noticed that before 2006, each group had 8–15 students who paid attention during the group tour; after 2009, however, only 3–5 students have been paying attention. From my observations, decreasing the group size has not enhanced the school children's deep engagement. These observations have led to the development a new education program.

Learning Happens Through Interactions with Exhibitions or People

Since the 1990s, several studies investigated how learning occurs in museums. Falk and Deirking (2000) suggested a context model, that is, museum learning results from interaction among the social, personal, and physical contexts. From interactions between visitors and exhibits, Stocklmayer and Gilbert (2002) proposed the personal awareness of science and technology (PAST) model. Other researchers have grounded their notions about museum learning in constructivism (Russell, 1994; Hein, 1998). They believe that museum learning results from direct (face-to-face) interaction with staff members or indirect interaction (staff members' thoughts manifested through exhibits). The perspective of constructivism for learning considered that conversation (when interacting with exhibits) was evidence of learning, and suggested that museum learning was the collaboration with exhibits (representation of knowledge), identity, and learning environment (Abu-Shumays & Leinhardt, 2002; Leinhardt, Tittle, & Knuston, 2002; Leinhardt & Karen, 2004). These studies affirmed that museum learning occurred while visitors interacted with exhibits, museum staff, or their peers.

In most science museums, docents serve as the point of human contact for visitors, especially for school trips when docents routinely guide student groups through the exhibitions (Cox-Petersen et al., 2003). That which school groups receive from docents is part of their museum learning experience how and what they learn. Most school groups express satisfaction with the docents' guided tours, but do not see the field trip as a learning experience (Cox-Petersen et al., 2003; Davidson, Passmore, & Anderson, 2010; Kisiel, 2010). Some researchers advised educators (docents and teachers) to meet and prepare prior to field trips, to build a bridge between school science and science museum exhibitions (Davidson et al., 2010; Jarvis & Pell, 2005; Kisiel, 2010; Tal, Bamberger, & Morag, 2005). Davidson et al. (2010) and Patrick, Matthews, and Tunnicliffe (2011) highlighted the influence that teachers who involved themselves in pre-visit preparations had on students' awareness of learning. Cox-Petersen et al. (2003), Kisiel (2010), and Tran (2007) suggested that docents' pedagogy and their goal for science learning contributed to students' learning. These studies concluded that the docent's personal interest in science and their museum-learning experience diversified their teaching practices.

Social Identity, Personal Science Epistemology, and Staff–Visitor Interaction

After the mid-20th century, simple tests inquired about how people separate their identity from others (Kuhn, 1960; Zurcher, 1977). In this research, the identity of self included the physical self (physiological features), social self (a particular social position or status), reflexive self (personal characteristics or personality description), and oceanic self (global statements that fail to differentiate oneself from others). As an important index, the social self helps individuals behave correctly according to their social category. Social identification includes two processes: self-categorization and social comparison, which are context dependent. The interaction contexts could highlight one social category over others or as an underdog, and the same social category might be reversed in another context (Abrams, 1999). For example, employed docents in a science museum clearly know that they are not scientists and they have lower status than the science curators in discussing scientific knowledge; however, docents believe they have much more information about the science exhibits than visitors. The docents are the main source of information for visitors to the guided tours; therefore, the docents have higher status than the visitors. Several studies have stated that guided tours can be didactic and lecture-oriented or exciting and engaging, depending on how docents view themselves (Ash, Lombana, & Alcala, 2012; Kisiel, 2010; Tran, 2007, 2008). Tran suggested that docents with personal interest in science can introduce much creativity, complexity, and skill in teaching science; however, they also need to connect the museum's educational agenda with school science curricula and treat school visits as part of a long-term science learning experience. Several studies have argued that students felt that they gained no learning during museum visits because docents were not concerned about the connection between the exhibits and school science courses (Cox-Petersen et al., 2003; Davidson et al., 2010; Kisiel, 2010). Ash et al. (2012) found that science museum docents could change their practice by transforming their social identity from that of a one-way presenter into an educator. These studies found that how docents' perceive their identity in teaching science affects their pedagogy.

The identity to which Ash et al. (2012) and Kisiel (2010) referred is how docents approach their role in guided tours and as an educator. Neither study described how one identifies an educator's duty.

The present research drew on a personal science epistemology approach to interpret docents' identity in museum education, including how they think about science and what they think is important for teaching and learning science (Hofer, 2004). According to social identity theory, docents choose their teaching material based on their science-teaching role, which then shapes their pedagogical practices. When interacting with a docent, schoolchildren receive their museum experience through that docent's specific pedagogy. A docent-science educator needs to define important science events (knowledge) and methods of teaching science (knowing).

These individual beliefs about knowledge and knowing are the docent's personal epistemology.

During the last two decades, many studies on personal epistemology have addressed the theories and beliefs individuals hold about knowledge, and how such epistemological perspectives are related to academic learning (Hofer, 2004; Hofer & Pintrich, 1997; Schommer, 1990; Schommer-Aikins 2002). Schommer (1990) suggested that in different domains, personal epistemologies might be independent of each other. Furthermore, Hofer and Pintrich (1997) provided a quasi-theory framework for personal epistemologies in different domains. Hofer (2004) examined first-year college students for domain-specific personal epistemologies in the context of introductory chemistry, revealing how personal epistemologies influenced students' perception and learning behaviors and how their epistemologies kept changing during academic learning. Personal science epistemology may be ascertained from the following dimensions of scientific knowledge: its stability, structure, source, speed of its acquisition, and control of its acquisition (Schommer, 1990). Personal science epistemology is a multi-belief, complex system, each dimension is somehow independent of the others, evolving and changing according to personal experience (Schommer, 1994). Examining an aquarium staff's collaboration with an elementary school, Kisiel (2010) found that the collaboration raised staff members' understanding of the classroom setting and teaching as a career. Ash et al. (2012) provided evidence that changing how explainers viewed their identity caused changes in their practice. Therefore, this study reveals how social identity and personal science epistemology lead to differing science instruction.

Methods

This study drew upon qualitative approach to inquire two senior docents' self-identity, personal epistemology, and pedagogical practice. These two docents patriciate an activity which expected to help teenagers learning by objects. The study combined observations of the docents' preparation process, practice teaching, and interviews to provide multiple evidentiary sources and data triangulation.

Methodological Framework: Case Study Approach

The framework for this research uses a case study method (Stake, 1995; Yin, 1989). Yin noted that case studies are advantageous approaches to research projects that address explanatory and/or descriptive questions in a real-life context; they are particularly appropriate when the researcher has no control over events. A case study's goal is not to provide generalizable results, but to reflect on museum education practice through the perspective of personal science epistemology. This case study draws on interviews, observations, and pedagogical artifacts to develop an interpretative understanding of the relationship between museum practice and docents' beliefs.

The two participating docents were in their tenth year of museum work at a mid-scale natural history museum. Mei (pseudonym, female) is an employed museum presenter, and Yan (pseudonym, male) is a volunteer. They enrolled in a task force to develop inquiry-based learning activities for school tours. They both earned credit for their routine work in the museum and for participating in the study.

Mei is an experienced presenter in the National Museum of Natural Science (NMNS). She began her career at the museum almost 20 years ago. She had taken guide tour for zoology, archeology, and biodiversity, despite having earned her college degree in applied science. She gained her knowledge of various scientific subjects from the museum's science topics commentary training.

In 1992, Yan joined the museum's learning sheet task force as a volunteer. He is an experienced science teacher and active instructor for the pre-service teacher training program at his school. Having earned a college degree in earth science, Yan taught 8th grade physics and earth science. In 2002, he retired as dean of a downtown public junior high school, continued his voluntary participation at the museum.

This study also considered audience opinions. Sixty-six students participated in the study. Of these 66 students, all were in their first semester of 7th grade at a medium sized municipal senior high school in Taichung City, which they had entered directly from elementary schools in nearby school districts. There were 26 females and 40 males in the study, with an average age of 13.5 years. The ethnic background of the students represented a cross-section of the high school, with 64 Taiwanese and 2 Taiwanese Indians. The students were in two classes, but they had the same science teacher. This high school is a partner school to NMNS and is a 10 min walk to the museum. About once a month, the 7th grade science teacher brought the students to the NMNS, where they participated in a 2 h science class in the Exhibition Halls. These students came to the museum to participate in education programs, such as speeches, demonstrations, guided tours, and new educational program tryouts.

Observations

This paper primarily focuses on the two docents' teaching plans, which provided high contrast in terms of underlying epistemological assumptions. Observations were centered on teaching goals for museum learning, organization of learning material, importance of specimens in teaching, and role of the educator. An observational study is shaped by a particular purpose that guides what is obtained and how such information is used. My primary goal in these observations was to examine how beliefs about knowledge and knowing are communicated in the museum program and how they are situated in teaching behaviors.

The observations offered rich understanding of how the docents prepared their guided tours so that interview questions could be contextualized within common practice. Observational notes were written as running field notes. In addition, the pedagogical artifacts docents prepared, such as the fragments of implements or potteries came from archaeological findings which they used in teaching, PowerPoint introductory presentations, and photos were collected. The written field notes were interpreted, in accordance with the dimensions of epistemology identified in an earlier literature review (Hofer & Pintrich, 1997), by identifying examples of practices and incidents that might be classified as indicative of simple knowledge, certain knowledge, the source of knowledge, or justification for knowing. A discussion with docents of such situated practices furnished a potentially contextualized, phenomenological understanding of their personal epistemology.

Interviews

The docents were interviewed at three points: after a lecture, after their teaching plans were presented, and after a session of practice teaching. The interviews used open-ended questions that provided a framework and were guided by an interest in hearing individuals "use their own words to express their personal perspectives" (Patton, 1990, p. 277). The semi-structured interview protocols included questions that explored general personal epistemology through questions adapted from existing interview protocols that tapped the four dimensions suggested in the literature (Hofer, 2001), and questions, pertinent to instructional practices, that docents answered after their practice teaching.

Analytical Process

Early analysis of the observational notes provided incidents and topics for interview questions; accordingly, the observations were read for suggested evidence of the four hypothesized dimensions of personal epistemology. Interview analysis was an ongoing, iterative process, facilitated by note taking at several points. To begin the coding process, each question on the three interview protocols for the dimension(s) guided the writing of the questions. For example, a question about how a docent thinks of archeological practices was hypothetically coded as "simplicity of knowledge."

The practice teaching was video-recorded and the audio portions were transcribed according to time spent on each learning experience. The duration of different teaching behaviors were calculated based on the different learning experiences. Periods of talking, student discussions, and specimen observations were calculated, respectively. The percentage of time spent on student discussions and specimen observations could be an index of how the docent's personal science epistemology affects the pedagogy. These videos of test teaching were also coded by episode to clarify the following: whether the docent treated the specimen as a source of research data or academic evidence; whether the docent thought learning occurred during discussion or listening; and the docent's assumed identity during the exploration activity.

The final methodological step was to consider issues of verification. I employed "member checking" (Creswell, 1998; Stake, 1995), an accepted means of establishing credibility in a qualitative study, by providing an early draft of this paper to the participating docents.

Study Background

Since the NMNS Life Science Hall opened in 1988, the science education curator has planned in-service training for experienced science teachers to develop learning sheets for primary and secondary school students. Teachers involved in the learning sheet task force met regularly with the education curator and brought their students to the museum to test the new learning sheets. They voluntarily participated and could discontinue at any time. Until 2002, this group consisted of about 15–20 teachers per year and produced 20 learning sheets for 12 different exhibition galleries. Each permanent exhibition gallery had at least one learning sheet, and the museum planned to renew some exhibition galleries that had been open for over 10 years.

In 2002, according to educational statistics announced by the Republic of China's Ministry of Education, the number of first graders would decrease by 50% every 5 years. Faced with the impact of a low birth rate and the competition from Internet science learning resources, the museum's department of science education tried to create new attractions for visitors, especially school groups. In 2009, the task force for editing the learning sheets changed goals to develop a "new exploration program," and only five experienced science teachers remained. While attempting to develop this new program, after discussions with these five teachers, we reached consensus that the program would adapt these approaches: learning occurring through interaction, staff as facilitators of learning, and learning from objects.

Based on constructivism, this exploration program would implement the notions of "learning from the object" and "learning by the visitor-self." In Taiwan, visitors highly rely on the docents' guided tours to learn about the exhibition galleries, and the new program developers hoped that the docents would act as facilitators to encourage learners' observations and reasoning. Because the employed docents would conduct the new exploration program, they were invited to engage in the development process.

Development Process

During the exploration program development, we requested that the collection managers help find educational materials for the program. The archeology department provided some artifacts from three different sites in central Taiwan: Niu-ma-tou (middle Neolithic, BC 3700–BC 3500), Ying-Pu (late Neolithic, BC3500–BC2000), and Fanzaiyuan (late Iron age—AC 400). Most of these were small pieces of broken pottery, but some were made of stone, and all were left safely untreated with any toxic chemical solution. Visitors were allowed to touch all these artifacts, which thus became direct evidence for constructing knowledge, because different ages of pottery are easily recognized through the sense of touch. After the pottery was provided, I showed it to the learning-sheet editor/teachers and the employed docents, inviting them to engage in developing a new exploration activity. Yan responded to my invitation immediately, and Mei joined us later.

During the six-month research period, I observed how the docents interacted with the pedagogical and archeological museum staff, how they prepared the topic, how they chose teaching materials, and their practice teaching. For the first four weeks, we met once a week to introduce inquiry-based learning and teaching. For the next four weeks, the archeology curator lectured on the three pre-historical archeology sites studied by museum archeological staff, and then for two weeks, we visited the archeology studio. After these preparations, Yan provided his teaching plan, and we arranged three sessions of practice teaching and post-teaching discussions. In those meetings, Mei approved the plan as "excellent," but her practice teaching drew on a totally different plan. In the post-teaching discussion, Mei claimed that she could not implement Yan's teaching plan. Each practice teaching was video recorded and transcribed by the minute.

Results

According to models of personal epistemology, all data analysis suggests that individual theories about knowledge and knowing comprised multiple dimensions that can each be expressed as a continuum (Hofer & Pintrich, 1997). In addition, personal epistemology's dimensions clustered into two central areas: (1) the *nature of knowledge* or what one believes is knowledge is. The nature of knowledge includes two dimensions: certainty of knowledge [a progression from believing that absolute truth exists with certainty to the position that knowledge is tentative and evolving] and simplicity of knowledge [viewing knowledge as an accumulation of facts to seeing knowledge as highly interrelated concepts] (Schommer, 1990). (2) The *nature or process of knowing* or how one comes to know. (1) The nature of knowing consists of the knowledge perceived and the justification for knowing. The source of the knowledge perceived originates outside the self and resides in external authority or is constructed by individuals in interaction with the environment and others. Justification for knowing is how individuals justify what they know and how they evaluate their own knowledge and that of others (King & Kitchener, 1994). This analysis is not focused on profiling participants' personal science epistemology, but aims at examining their practice from the cross-section of personal science epistemology.

Personal Science Epistemology Reflected in the Learning Process

Both docents verbally agreed on the social constructivism perspective for learning, which the science education curator introduced in the regular meetings. They also agreed that the events they guided in the museum were for education; their role in the museum was that of an educator:

Mei I think the teachers who reserve the educational program have the purpose of education, not entertainment. They (the students) came into the museum with the expectation of obtaining much more knowledge. My duty is to give them enough and correct knowledge. Just like the teacher in school, the docent and the teacher are educators.

R (researcher) What do you mean "correct" knowledge?

Mei The lectures in the museum provide us scientific knowledge reviewed by those "doctors" [curators] in science departments. They [curators] are careful and professional in science. That knowledge would not go wrong.

R Do you think that "correct knowledge" needs to be renewed, and sometimes the science curator might not catch on?

Mei Yes, science is progressing. We don't show things as uncertain in the education program. Those science curators provide the "truth" that all scientists agree on for us to teach in the museum.

This interview quotation reveals that Mei felt that science knowledge as "static" came from the scientist, and the scientist provided all things for learning. However, Yan reflected from his teaching experience:

Yan The role of docent is as the teacher in the museum. But there is not a certain concrete content knowledge that should fill in each program hour. We could do much differently from school science.

R How is that?

Yan People have different expectations for school, after-school tutorial classes, and the museum. You don't expect to visit a science museum today and get A++ for a science test tomorrow. Students come to the science museum to see some different aspects of science; those who do not adapt to examination and seem interesting. Or they hope to know how "to do science." We can give students much opportunity to observe, think, and reason.

R What do you mean, "To do science"?

Yan Things that adults want students to keep in their memory exist only in the science classroom. Science knowledge is changing. I mean most science information renews every few years. They [students] aren't interested in it,

> and they do not understand it, really. Things meaningful to students are those they are interested in, can talk to, and are used in life. I don't mean to expect students to act like scientists. But they need to have a chance to connect the hypothesis, observation, and reasoning. Scientists producing knowledge also repeat this process. In my opinion, the science process is much important than scientific facts.

Yan believed that the museum should provide different aspects of learning from those provided by schools. He emphasized the process of making knowledge: he saw students' interaction with peers as a useful path for science learning. Yan felt that although scientific knowledge is changing, the schools focused on merely feeding students more information. Thus, most important for the museum was creating a different learning experience for the students.

Mei enjoyed the curator's lecture much more than the educational issues discussion. In the archeology lectures, Mei busily wrote notes, whereas Yan jotted down just a few words. Mei felt that in the first lecture, the archeology curator gave a very clear picture of the three archeological ages. And the next three lectures featured related research in other Taiwanese locations. After each lecture, Mei asked the curator to provide her several photos to use as teaching materials. She felt that the curator had provided a full introductory vision of archeology.

> The curator is very nice. He provided much knowledge about archeology. And there are lots of photos of pottery in different ages; they are good to use in teaching. His lecture was very useful to help me prepare for teaching.

After the first lecture, Yan came to the interview with some references about these archeological sites and asked for leave to miss the next three lectures.

> The lecture provided several keywords for the three archeological layers. And I found these references [some seminar proceedings, journal papers]. These are from creditable sources. It is enough for me to design a teaching plan. And… [personal reason for leave for the next three weeks].

Obviously, these two docents favored different learning processes. Yan was an active learner who recognizes key concepts and tries to find more information by himself. Mei relied on authority to provide information. Both docents were present in the archeology studio visit and interacted with the staff there. Mei listened to the introduction carefully and asked questions to ensure that she had noted all the details about how to process the artifacts—washing, drying, marking, documenting, and categorizing. Yan observed the three piles of artifacts from the three different archeological layers. He asked questions to understand how archeologists construct knowledge from specimens, but the staff could not answer most of his questions. During the second studio visit, an archeology curator made a presentation and deeply discussed with Yan how the artifacts supported forming a supposition and how further relics provided proof or disproof.

Teaching Goals

During their preparations, Mei and Yan presented different and interesting plans. Mei focused on how to conduct archeological excavations. Yan focused on how the archeologist constructs knowledge from artifacts. Their designs for the education program reflected their differing interests.

> There is too much content knowledge fed to students in school science. I think the museum should provide a different style of learning. The education program should give many chances for observing, thinking, and reasoning. We have a good topic. These archeology sites are located around the city, most students have heard about them. They would be interested. And things from three different archeological layers could provide the chance to distinguish objects according to age, their function, and then help restructure life in that age. The best thing is when children do these explorations, they don't have to use expensive equipment. The experience is directly from their fingertips and about past life appliances.

Yan presented the education program's goal very clearly, and he aimed at engaging students in the process of doing science. Mei did not present her idea for the education program. She said that Yan's idea was good and fit for the museum's situation. She mentioned in the meeting that we should include more information for archeological excavation. But according to her interview, she cared very much about the quantity of knowledge provided in the education program.

Mei I think the teachers who reserve the educational program have the purpose of education, not entertainment. They (the students) came in the museum with expectation of obtaining much more knowledge. My duty is to give them correct and enough knowledge. Just like the teacher in school, the docent and teacher are educators.

She emphasized providing scientific knowledge correctly (quality) and amply (quantity), but she did not clearly state her overall goal.

Teaching Plans and Materials

Yan's proposal included two activities, both using real archeological pottery as material for inquiry. The first set of pottery included three pieces that came from three different archeological layers. His activity was a closed-end inquiry that asked visitors to classify the pottery's age by touch. The second activity provided each group a set of artifacts and asked visitors to guess how people lived at that time, according to the specimens they had. The ending was a summary that focused on reflective thinking during the process. Yan's teaching plan is presented as Table 6.1.

After Yan's second practice teaching, Mei claimed in the group meeting that she had another idea about the topic. Mei's proposal was an outline of an introduction to archeology, with, as she asserted, some inquiry factors in the process. Mei's

Table 6.1 Yan's teaching plan

Time estimate (min)	Teaching protocol	Personal science epistemology attribution	Pedagogic concern
1	Students assigned in 3–5 persons group	Knowledge came from personal exploration and peer interaction	Learner center
1	Brief introduction the concept of archeological layer and age		Operational principle
10	Sorting the 3-piece potteries by their archeological layer	Application of knowledge from authority	Practice
10	Group reported their answer Docent response	Justification for knowing through the evaluation of evidence	Docent as facilitator to enhance the dialog between groups with different answers
15	Each group had one set of heritage Each group needs to predict which archeological layer they belong to and provide an assumption for the life of that age	Source of knowledge as actively constructed by individuals in interaction with the environment and others Simplicity of knowledge by seeing knowledge as highly interrelated concepts	Docent as facilitator to enhance the in-group fruitful conversation
20	Group report Docent response	Justification for knowing through the evaluation of evidence	To remind students to recheck their conclusion according on their specimen
1	Conclusion		

teaching plan is presented in Table 6.2 and shows she used lecture with no exploration activities. We asked her to include some exploration opportunities. She replied that she would find some questions to lead students' thinking and reasoning during her practice teaching.

Table 6.2 Mei's teaching plan

Time estimate (min)	Teaching protocol	Personal science epistemology attribution	Pedagogic concern
10	Explaining the concept of archeological layer	Source of knowledge comes from external authority	Docent as the representation of the expert
15	Introduction how to research the archeological site		
25	Explaining the standard operation procedures of the archeology heritages taken from the archeological studio		
5	Show students the heritages from three different archeological layers	Justification for knowing by the assessment and integration of the views of experts	

Roles of Teachers, Learners, and Objects

Figure 6.1 displays a comparison of the two docents' teaching behaviors during practice teaching. Mei taught in lecture style, employing many photos of the archeological excavation process. Yan spent more than 80% of the time on students' observations, discussions, and communications of their different ideas.

In the post-teaching meeting, both docents gave reasons for their behavior. Mei thought her plan provided adequate knowledge to satisfy seventh-graders' expectations. And she also had some comments about Yan's teaching:

> I've watched [on the video-recording] his teaching twice. And I don't understand what he wants to give to students. The students' discussion wasted too much time. After the program, students know no more archeology than before. We should offer more knowledge to students. I did not know what the teacher should do when the students discussed or did not discuss.

Mei believed lecturing is the most efficient teaching method. To make students concentrate and engage, she had them answer questions she had mentioned earlier. According to observations of the practice teaching, Mei viewed the docent's role in teaching as being the source of knowledge. She believed that students could not obtain knowledge from discussion and observation; they could accept academic knowledge only by listening. In her teaching, the student was a passive receptor, and she believed that was best. In Mei's teaching, the objects were decorative.

> The specimens of archeology are rarely seen in other places. They are good for attracting schools to reserve this program. The pottery could make the students feel real knowledge

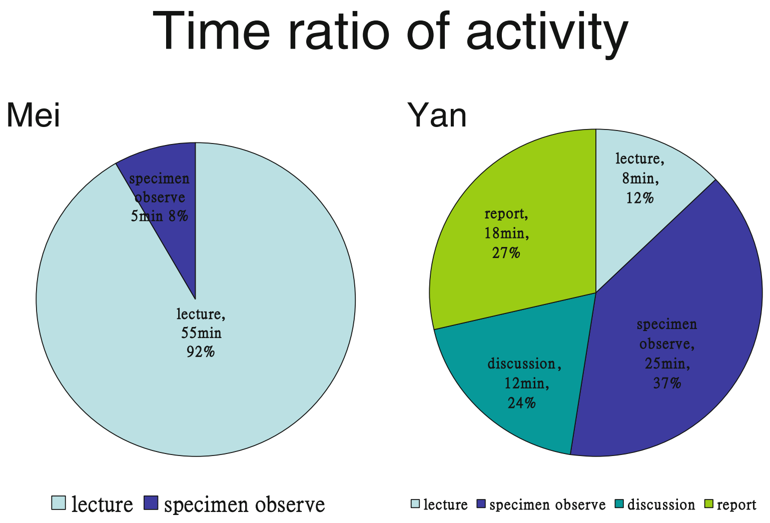

Fig. 6.1 Percentages of time allotted to activities in each docent's teaching plan

> introduction in the program. They are not archeologists it is impossible for them to gain any knowledge from observing those potteries.

Mei felt that the museum's education program should use real objects to attract visitors and that the artifacts' reality and age would interest laypersons. But the specimens did not play a leading role in her teaching; instead, they ornamented her program's conclusion. Yan respected Mei's choice. He said that it was usual for educators to have different pedagogical practices. But he also said he came to the museum to implement authentic learning:

> We need something different from school science that could help the public understand there is another choice in learning science. It looked like a waste of time to let the students observe and discuss. But they could get the spirit of science from the process. Though the result is rough, needs more evidence and examining, the program creates a new trial for museum science learning.
>
> There are two leading roles in my teaching, the students and the objects. I gave students simple guiding, and they applied it in the first activity. They could find achievement in it, and feel that knowledge could be manipulated. Then mind engages in what is possible. The object is the second lead. It acts as evidence to produce knowledge, on the one hand, and is novel to arouse curiosity.

Yan did not cast himself in the program's leading role. Instead, he acted as a facilitator. During the students' group discussions, he hung around between the groups and encouraged students to express their arguments. In this manner, the students became the center of the program. Yan supposed that the students were active learners and that the objects provided a ground for constructing knowledge, thus becoming both evidence and attraction.

Students' Feedback

Two classes (N = 66) of seventh-graders participated in the practice teaching, and both classes took both Mei's and Yan's programs. One class (Class A, 33 students) took Yan's program first and then Mei's; the other class (Class B, 33 students) first took Mei's program and then Yan's. The teachers collected the students' after-visit diaries, and all 66 reported interest and positive responses to both programs.

Yan's program made a deep impression on the Class A students, with thirteen of them mentioning that they were excited to access the artifacts and try to do an archeologist's job.

> The program made us experience what the archeologist does. It's the first time I feel myself that I could take a scientist's job. The program made me feel interested in how the archeologist found these potteries. I was very attentive in the second section. (Student A02)

Although the Class A students said that they were attentive during Mei's program, there was no further description about Mei's teaching, content, or photos. Of the Class A diaries, 9 mentioned that Mei's program introduced the process of archeological excavation and 5 of them felt that excavation was a difficult job.

Typical feedback of two types came from Class B (Mei's program first): The first program was a little bit boring, and the second one was interesting; they mentioned their actual experience only in Yan's program:

> The first session was the same as a history lecture in school. There were lots of photos to show how to do archeological excavation. The second one was really funny. He [Docent Yan] gave us some pottery, and we had lots of time to discuss. The questions in the program needed to be answered according to our evidence [pottery]. The docent did not pronounce our answer as right or wrong. He showed us the principle to check whether we needed to fix our answer. (Student B29)

This quotation reveals the student's feelings about the two programs. Mei's program seemed very similar to school and Yan's program engaged them in the process of learning.

> It was interesting. I accessed more archeology things in the second program. I have not taken a program like this before. We did a similar process with a scientist. I enjoyed in the program. (Student B03)

Most of the students' diary entries resembled that quoted above. Of the 33 students in Class B, 12 commented positively on the visit and wrote much related to Yan's program. There were 11 students (Class B) mentioned both programs, the first as an introduction to archeology and the second as a hands-on activity. The other 9 diaries (Class B) mentioned only the second program: Yan's program had student discussion, observation of artifacts, forming hypotheses as an archeologist. In Class B, 8 diaries had detailed descriptions about the process and content of the whole process of this visit but the descriptions of Yan's program contained much detail.

> This visit included two programs. The first one was an introductory lecture of archeology. The second one was an activity to experience what archeologists do to the things they dig out. The docent asked us questions, and we needed to answer according to the artifacts we had. At the beginning, we felt nervous because we were not good at archeology. The docent suggested to notice some differences between the things, and soon we knew how to answer. This was the first I felt the time went so fast in a museum program. (Student B19)

The 8 Class B diaries all included a brief description of the two programs, deep impressions of the docents, and their positive emotions toward the program. They were most impressed with Yan coaching them on how to develop their argumentation during the discussion, and reminding them that their report of reasoning should align with the evidence (artifacts) in the feedback.

Reflections from the Docents

At the last education meeting with the two docents, we read these diaries together. Before the meeting, I selected diaries that described the visit with at least a completed paragraph.

Yan was excited because the students liked his exploratory approach, but mentioned room for improvement:

> I am glad to know students liked this program. And most of them felt they had done the things archeologists do. In the program, it is necessary to supplement some materials to quickly introduce how we get these potteries.

On the other hand, Mei felt frustration and a little anger that few students had talked about her teaching. She attributed this to Yan's program being akin to a game with activities; children would rather play than learn:

> I chose a good topic and organized the content well and so many photos to help them know all the details about how archeologists work. They preferred to play rather than to learn. If the test teachings were separate at different dates and the students were independent, they would show how deep their impressions were for this content.

Mei noticed that most students did not express any understanding about the archeological layers or sites introduced in both programs. She believed that although most students liked Yan's teaching, no effective learning occurred.

> Though I have watched his teaching [video] 3 times, I see no learning happening. If we created a test for the ages of the three archeological layers, the locations of the site, and the difference of the life style, my program could help them to get higher scores than yours [Yan's].
>
> How can you (the education curator) accept his program as an education program? It teaches nothing to the students. The activities are vivid and novel for the museum, but teachers expected us to bring them more knowledge. We should not have spent almost 1 h on the scientist role-playing game.

Mei cared very much for the quantity of knowledge, and her criterion for successful learning was a paper-pencil test for recalling terminology. This might be a limitation of her personal science epistemology. Mei believed that knowledge comes from scientists, and only scientists can judge what is important in the field of science. In this meeting, she argued with Yan about whether students could learn from discussion, believing that the discussion's educational function is to evaluate or apply previously learned concepts. And she felt it strange that Yan's program promoted the students' interest in her program.

Mei How can they learn from discussion? They know nothing about archeology; it is impossible for them to discuss and provide an answer.

Yan There are two durations for discussion in the program. Before the first, I explained the concept of archeological layers and provided them a simple principle—the better controlled the fire, the finer the pottery feels. They adapted the principle in predicting the age very well.

Mei Yes, the first discussion is the evaluation of the concept of archeological layers. But they are not archeologists. How could you ask them to recover life in that age? Their conclusions must be wrong.

Yan While they were discussing, I heard them guessing each piece pottery as what kind of tackle. And they knew the characteristics of the Stone Age, Neolithic, and Iron Ages in school, so they are capable of making a reasonable guess.

Mei How can students get anything from talking to each other? There is no expert in their group.

Yan I think the learning did happen when they made their reasoning agree on the artifacts they had. Students got the chance to practice the process skills of science. During the program, they observed, reasoned, and provided hypotheses. If we aroused their interest in archeology, they could open the computer and Google some keywords which they learned from the program.

Conclusion

During the conversations, we found that the two docents had different educational goals. Although they both identified their role as that of an educator, their criteria for good education differed. Mei insisted that acquiring academic content knowledge is the core goal for a learning program. Yan wanted to provide students a chance to practice science process skills; his goal focused not just on emotion, but also on the experience of doing science. In Yan's program, discussion served to inspire learning; Mei's program treats discussion as evaluation or application for concepts the learner has gained in the lesson. Because Mei believed the appropriate way to receive knowledge was from authority and the scientist was the authority, in the museum (or classroom), the docent (or teacher) should be the scientist's representative. Yan's personal science epistemology about the source of knowledge came from interaction with persons or the environment, and he believed that discussion among peers could offer positive learning experiences.

Discussion

The research finding presented two docents who had different personal science epistemologies, which led to different decisions about their pedagogy practice. They study revealed the fact that docent embedded different personal science epistemologies with different practices. On the point of view of the science museum, we need to take into consideration the value of different epistemological beliefs and pedagogical practices. Schommer (1990) stated that personal science epistemology is a kind of belief system. Belief is rooted deeply in one's mind and difficult to change. According on these findings, the discussion paid attention on the value of two different pedagogical practices and how to have the docents capable to appreciate the practice which based on different personal science epistemology.

The Mission of Science Museum

The introduction of NMNS stated that "the museum's missions are to raise public knowledge of science, cultivate reasoning and independent thinking and encourage people's curiosity of natural phenomena". Education is one of the human activities in society. The thought of quality for education is changing from passive accepting to active engaging. In the 1990s, there was a debate for "presenting science as production or as process" in science museum (Aronld, 1996; Morton, 1997). The viewpoint of "presenting science as a production" is easy to find significance objects for collection, and these advanced science findings implicated in objects also quick step into "outdated science". A science museum conveys its mission of education could taking the role as a new information provider or sharing the sense that science as a process with visitors. The science museum practice often take the role as information provider. Yan's program provides a choice: to facilitate learners reappear the process of science knowledge product. The program of Yan includes the personal science epistemology vision: knowledge is tentative and evolving; knowledge embedded in interaction with peers or environment; knowledge is interrelated rather than discrete piece; and individuals justify what they know through observation. These science epistemological believes are rare appearing in school science. And Yan integrated his personal science epistemology in pedagogy by these events: group discussion, open end learning task, finding answer from observation, treating students' misconception as the start point of learning and response by answers come from evidence reasonable. This case provided an opportunity for learners to access science argument in a short period.

The Professional Development for Docents

Though Schommer (1990) referred to personal science epistemology as belief and hard to change. Some studies found that students' personal science epistemology during academic training changed (Hofer, 2001; Tsai, 2008). Brownlee and Berthelsen (2005, 2008) made an elaboration for the correspondence between personal epistemology and pedagogical practice, and confirmed the contributions to help teachers reflective their pedagogy on personal epistemology. In this research, Mei could not agree there was learning taking place in Yan's program because of the her strong personal science epistemology: science knowledge comes from the scientists only (students could not acquire science knowledge by peer discussion); science knowledge is independent in different field (there are no connection between chemistry, physic, biology and archaeology); only the authority could judge whether you get knowledge or not (all teaching material should organize by science curators). Mei's practice was typical case of science museum learning activity.

Brownlee and Berthelsen (2008) presented a view of learning in relation to change in epistemological beliefs drawing on the 3 P Model of Learning (Personal presage factors, Perceptions of the environment-personal epistemological socially constructed, and situational presage factors) proposed by Biggs (1993), and suggested a model for relational pedagogy that is socially and contextually situated which tried to extend teacher's vision of personal epistemology by pedagogical practice. Brownlee and Berthelsen (2008) referred to change in teachers' thinking about their practice is required by the increasing recognition that teaching is a complex and multifaceted process, teacher education courses need to stimulate reflective and critical thinking about practice as necessary preconditions for effective learning outcomes. It is useful for the professional development of docent.

Ash et al. (2012) drew on the sociocultural frameworks, followed the idea of zone of proximal development (Vygotsky, 1987) to promote docents' capable to scaffolding in their teaching. Allen and Crowley (2014) offered case studies which explored how part-time museum docents engaged in reflective practice through iterative implementation and some of their approaches to learning and teaching in the museum changed. Both research ground on sociocultural frameworks and sent their docent professional development practice through the theory of situated learning (Lave & Wenger, 1991). It looks a potential training framework for museum educators. And Ash et al. (2012) drew on the scaffolding in the zone of proximal development; their work provided a much clear framework to enable docent changing their practice. We will follow the same framework to improve the professional development of our employ docents and examining whether they would accept the parallel personal science epistemology in practice.

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Chapter 7
Informal Science Educator Identity Construction

Brad McLain

The notion that professional development for informal science educators should pay special attention to identity development is still considered a somewhat innovative and foreign idea. When we originally proposed an ambitious project on precisely this subject to the National Science Foundation, it took over two years of scrutiny of the included precepts and methods and revisions before it was finally funded. However, the world of informal science education is changing. For over a decade now there has been a sustained and growing interest in professionalizing the role of "informal science educator" and with it, the entire field. Identity, it turns out, is a central concept in this effort.

In this chapter, I will share what we learned about the identity construction of informal science educators engaged in a project called STEPS (The Science Theater Education Programming System). Perhaps more importantly, I will share an identity-based conceptual framework for considering how professional learning programs and environments for informal science educators may be re-invented as vehicles for self-discovery in order to tap into the full potential these individuals bring and the quickly evolving field they comprise.

Why Professional Identity?

What do we know historically about the professional lives of informal science educators? On the positive side, we see that they work in a wide variety of alternative learning environments (museums, science centers, community and school outreach, online, etc.), they serve audiences that are in "recreation mode" and

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therefore present opportunities for innovative educational programming, they represent a wide variety of pathways into the profession (there is no commonly travelled route or background), and by necessity these educators cover a wide range of science content areas. Bailey (2006) investigated science museum educators' self perceptions and found that they typically bring a strong set of values that not only attracted them to the work, but also sustains them in it. Notably, this includes the desire to be a change agent, to "make a difference," as it were, in the world. In this regard, informal science educators are not unlike their formal educator counterparts. Bailey further found that they enjoy the flexibility, social nature, and variety of their work but also cite the need to be well versed in the science. This includes being drawn to creative challenges, a love of life-long and a rich combination of teaching, presentation, science content, and project management.

On the negative side, informal science educators are often isolated from the larger community of the field. They often lack growth opportunities as education professionals (Sutterfield & Middlebrooks, 2000). They have limited pedagogical skills development opportunities and they typically have relatively low status in terms of title, salary, perceived skill sets, and job security. These status markers, positive and negative, are in fact explicit and powerful indicators of identity, akin to badges or certificates and other professional and personal identity monikers.

There is also high turnover among informal science educators, especially for front-line staff. Together, these challenges indicate a need for better and longer-term professional development including ongoing interaction among colleagues, at the very least. However, if we expect to actually professionalize the field and clear barriers to recruitment, retention, and elevate the field's professional standards and growth, it demands we re-think who informal science educators are, what they do, and what kind of professional development training they require.

Past research on similar issues facing formal classroom educators has specifically linked quality professional development to the sense of professional identity. Enhanced professional identity in formal education has long been known to translate into increased job satisfaction, higher quality educational programming, and staff retention. Museums and science centers, in particular, struggle with many of the same challenges as they try to balance effective staff recruitment, training, and retention with quality educational programming and increased visitorship. Meanwhile, multiple, varied, and indirect career pathways leading to informal education jobs (often considered a strength of the profession) can in fact complicate the sense of professional identity and may result in such employees regarding their positions as transient or as "means to other ends." I speculate that many, if not most, in the profession did not enter it thinking that it would be a "destination career," if there is such a thing in today's world.

Within this context for the STEPS project, we began with two simple questions: Given that the role "informal science educator" covers a lot of ground, can efforts to better articulate and enhance the professional identities of informal science educators lead to similar benefits as those seen among formal educators? And if so, what might those efforts look like in terms of professional development? However, in order to even approach the subject, we had to draw upon the larger (and mostly unknown to the informal education world), sociological field of identity theory.

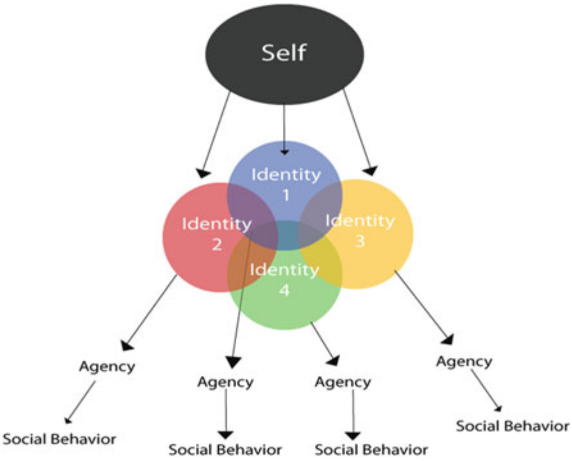
What Is Professional Identity?

Professional identity, concisely put, refers to a person's self-perceptions as a contributing member of a larger group of colleagues and as part of an extended profession, with goals, methods, ideals, behavioral ethics, and other values held in common to a great degree (Ibara, 1999). Professional identity is set within the larger context of identity theory, which in very general terms, considers the self as a highly complex, pluralistic, and fluid idea. "Self" is systematically unpacked into identities as dynamic psychological constructs or schemas that emerge, grow, compete, evolve and/or disappear over time. Such identities are directly related to the sense of personal agency, behavior, choices, performance, and relationships (personal and professional).

Identities exist in the mind of the individual and together give rise to the sense of self. Self is defined as a person's consciousness of his or her own being, and although usually co-located with one's physical body, it is a mental, psychosocial construct. Self allows each of us to reflect on and evaluate ourselves as both subject and object, planning and modifying on this construct in efforts to bring about desired future states. Because we can each assume different positions or roles within society, the self reflects these by way of identities. Therefore, we each have multiple identities, each one an agent capable of behavior, choice, and role taking (e.g. parent, friend, teacher).

These identities may overlap and be arranged in dynamic hierarchies, which can change moment-to-moment and certainly evolve over the years of our lives. Therefore the notion of such identities is distinct from the person owning them, but

Fig. 7.1 Total sum of the identities of self



describes avenues for behavior and transactions within society and the external environment. That is, the self assumes agency through identities, and is in part comprised of the sum total of those identities (Fig. 7.1). In this capacity, "professional identity" (an "informal science educator" for instance) is a role-based designation, endowed with all the expectations and responsibilities one understands it to mean. This subjectivity, of course implies a wide range of content for the informal science educator identity across individuals—reflecting the wide range of roles within the profession. That is where identity-based models of informal science educator professional development must begin.

Identity and Professional Development

Professional development (or professional learning) efforts traditionally center around the construction of new knowledge in what can generally be referred to as the constructivist model. For informal science educators (or even formal science educators for that matter), such training typically includes two levels: content knowledge and pedagogical content knowledge. That is, respectively, knowing the science content and knowing how to teach that science content. The latter component includes the broad spectrum of learning scenarios that may occur within informal education environments (presentations, classes, workshops, activities, exhibit design, multi-media design, encounter carts, dramatic performances, etc.). Such training seeks to continually develop employees, ideally through strategically progressive steps that construct more knowledge and expertise in the form of mental constructs or schemas, and ultimately leading to increased capacity (Piaget, 1926; Zemelman et al., 1993). The reality, often due to resource limitations and staff turnover, is typically much more uncoordinated, sporadic, and opportunistic than strategic.

Alternatively, invoking identity theory shifts the focus from content and skills acquisition to include a specific consideration of the learner of that content—the informal science educator him or herself—as a holistic individual. What does this shift do? Viewing professional development through the lens of identity theory, we acknowledge that the learning of new things can go beyond their incorporation into internal frameworks or schema, to actually inform, modify, and become integrated into a person's identity or identities. Therefore, this perspective intentionally links professional development experiences (such as those we designed for the STEPS project, discussed below) to identity and the use of tools and techniques intended to promote identity building, agency development, and behavioral outcomes in concert with content and skills development.

In short, this perspective says that the construction of new knowledge can sometimes, in fact, *be* identity construction. Incorporating the self into the learning equation in the form of the relationship of the knower to the known becomes an essential element to professional learning that includes meaning making, personal relevance, motivation, agency development, actions and future choices. Viewing informal science educator professional development as a medium for identity construction purposively promotes personal ownership of the science-related and education-related substance of the training, connections to other identities or elements of the self (often through emotions for example), and may allow for important linkages to identity growth and modification in unintended and unexpected areas.

Taking it one step further, once an identity of "informal science educator" is personally articulated, developed, and established through professional development that is designed to do so, an individual will likely then act to verify their conceptions of who they are, depending on the salience of the identity (Burke & Stets, 2009). That is, the new identity becomes a platform for continual cognitive and behavioral growth if the identity is personally and professionally important. Herein lies the secret to sustainable (and often self-driven) capacity building—both for individuals and for the institutions they collectively generate.

But how do we do this? What does informal science educator professional development that enhances professional identity look like? And does it produce the intended outcomes? That was the subject of the STEPS project.

STEPS

An Experiment in Professional Identity Construction

The Science Theater Education Programming System, or STEPS, was a four-year informal science education project funded by the National Science Foundation (award #1043060). The STEPS project created a unique network of professionals to collaboratively develop several innovative deliverables, including a new system for the development of multi-media enhanced theatrical science presentations. This network of professionals was designed as a geographically disperse hybrid (online and in-person) community of practice (CoP) as defined by Lave and Wenger (1998). The network was comprised of informal science educators from small and large museums nationwide, software designers, writers, artists, performers, scientists, and others. Partner organizations included:

- Bishop Museum (Honolulu, HI)
- Chabot Space and Science Center (Oakland, CA)
- Farmington Museum (Farmington, NM)
- Kansas Cosmosphere (Hutchinson, KS)
- Montshire Museum of Science (Norwich, VT)
- North Museum of Science and Natural History (Lancaster, PA)
- Science Museum of Virginia (Richmond, VA)
- Space Center Houston (Houston, TX)
- Association of Science-Technology Centers (Washington, DC)
- Astronomical Society of the Pacific (San Francisco, CA)
- Challenger Learning Center of Colorado (Colorado Springs, CO)
- Children's Museum of Indianapolis (Indianapolis, IN)

- Colorado School of Mines (Golden, CO)
- NASA Astrobiology Institute (nationally distributed)
- National Optical Astronomy Observatory (Tucson, AZ)
- SETI Institute (Mountain View, CA)
- Del Padre Visual Productions (East Longmeadow, MA)
- Institute for Learning Innovation (Edgewater, MD)
- The Space Science Institute (Boulder, CO)
- UXR Consulting (Baltimore, MD)
- University of Colorado at Denver (Denver, CO) professional identity study

Note: Several organizations that were not part of the development team adopted STEPS during or shortly after program completion. This group included The Pacific Science Center (Seattle, WA), The Omaha Children's Museum (Omaha, NE), The U.S. Space and Rocket Center (Huntsville, AL), and McWane Science Center (Birmingham, AL).

The STEPS project established five main deliverables:

1. Museum Partnership Network: A community of informal science educators working towards a common goal. Small and large museums were paired together for mentorship opportunities.
2. STEPS: A unique and innovative suite of software tools for science theater programming and a set of online professional development operational tutorials.
3. Astrobiology Theater Shows: A set of three performance shows with the STEM content focus of astrobiology and a set of online professional development astrobiology tutorials.
4. Professional Development products for informal science educators, including in-person workshops, online tutorials, and inter-museum interactions
5. Evaluation and research focused on understanding informal science educator identity construction, capacity building within institutions, and the relationship between professional identity and multi-institution collaborative networks.

We chose astrobiology as the STEM content for the initial theater shows because it was popular with public audiences and multi-disciplinary in its science content, giving the team ample room for theatrical creativity. Three astrobiology theater shows were developed by the educators varying in purpose, length, and theatrical components. Generally, these museum theater shows were comprised of on-stage educator/actors performing scripted stories using props, science demonstrations, interactive multimedia components and characters projects on one or more screen, and audience participation elements. These shows and their components (including special effects, virtual characters, and science-embedded plotlines) were all built from scratch, as was the software STEPS generated to create additional shows beyond the time of the project itself.

A substantial portion of the project was dedicated to an exploratory investigation of the network's collaborative model. Given this wide-ranging collection of organizations and individuals, we wanted to create a collaborative model that intentionally promoted professional identity enhancements, if we could. Two central precepts we were concerned with were control and risk. For control, we wanted to afford as much self-direction and self-determination as possible into the model without sacrificing functionality, not knowing where such a balance point might reside. As it turned out, this balance point was a moving target and different for each individual collaborator. For risk, we wanted to encourage professional risk-taking throughout the project. We asked the participants to intentionally select work groups and sub-teams that were often outside of their comfort zones and to consider STEPS as a growth opportunity rather than just another project to crank out. Once again, the balance point between such risk-taking and work efficiency proved to be a moving target requiring frequent adjustments.

Prior to the project launch, we designed an innovative collaborative model to promote both control and risk-taking within a supportive structure. We combined Team Leadership Theory (TLT, described below) within the structure of a hybrid community-of-practice for the explicit purpose of enhancing the professional identities of the informal science educators involved. The assumption being tested was that affording participating educators a high degree of personal leadership and responsibility as well as opportunities for risk-taking, would have a positive impact on their professional identity development.

As part of this effort, the study also investigated the relationships between professional identity impacts of individual educators, their institutional capacities, and the capacity of the network formed by the project. Figure 7.2 shows this nested structure, embedding the idea that individual identity is at the heart of both institutional and network capacity.

Prior evidence had suggested promise for our collaborative model. The community-of-practice element generated structure for an extended network of professionals, an important social component to professional identity. Successful

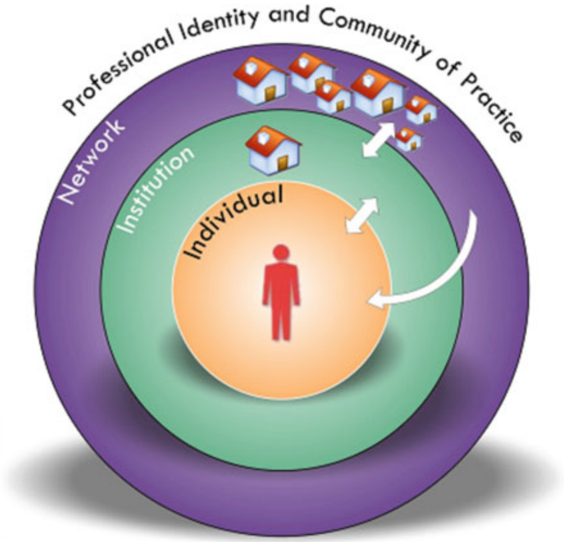


Fig. 7.2 STEPS professional development impact model

communities-of-practice combine three essential elements: Domain, Community, and Practice. The Domain—A shared domain of interest defines the community's identity and membership in the group implies a commitment to the domain. For STEPS, the domain was informal science education through interactive theatrical presentations. The Community—By forming relationships that facilitate learning, people form communities. STEPS created a partnership network of small and large science centers for informal educators to interact and learn together. The Practice—Members develop a shared practice over time including shared resources such as experiences, stories, tools, interventions, and skills (Wenger, 2006). STEPS incubated a shared practice through collaboration on an innovative project, within a partnership network, thus creating a community of practice for the professional development of participants.

As articulated by LaFasto and Larson (2001), Team Leadership Theory (TLT) is a model of distributed leadership in which participants have a high degree of freedom and responsibility regarding the decision-making, scheduling, and general leadership of a project in which they are engaged. The LTT is a model of leadership that is "from the ground up" rather than the more familiar and traditional "from the top down" models that emphasize command and control over collaboration. In developing this framework, LaFasto and Larson studied 6,000 work teams in organizations worldwide. Their research indicated that team leadership lends itself to greater productivity, more effective resource use, better decisions and problem solving, higher quality products and services, and increased innovation and creativity. Most of their studies involved groups that worked in a single organization, however, and often the same building with regular face-to-face interactions and one-year time frames for projects. STEPS was one of the first studied examples of TLT applied across a geographically distributed team, utilizing online communication technology extensively and over a four-year project period.

Importantly, LaFasto and Larson described eight characteristics for TLT excellence, which we adopted for STEPS. In Table 7.1, each characteristic is listed with a brief description of how it was actualized in the STEPS project (excerpted from the STEPS Summative evaluation, Koepfler 2011).

With this collaborative model in place at the outset, STEPS was intentionally designed as a vehicle for individual and institutional professional development via identity building. Additionally, we should note that the challenge of Museum Theater itself puts a high stake on individual informal educators. The success of interactive presentations for communicating science to the public depends heavily on the quality of the presenters, their content knowledge, facilitation and communication skills, and fluency with the format and technology. Further, Museum Theater has the advantage of synthesizing many things museums aim to do by integrating presentations, multimedia, hands-on activities, and social audience interaction. Rising to such a challenge demanded a higher level of professional development for individual educators and their institutions, thus allowing for greater impacts (positive and negative) on individual educators, institutional capacity, and collaborative interactions within the network.

Table 7.1 Team leadership theory framework adapted for the STEPS project

LaFasto and Larson TLT	STEPS TLT
(1) A clear and elevating goal	The team was tasked with the creation of deliverables that were challenging and required a multi-disciplinary team. The software and shows were novel and out of the comfort zone of the educators, but the project overall was perceived as valuable to the group with the inclusion of professional development opportunities, the STEPS software system, the astrobiology shows, astrobiology tutorial, and associated evaluation and research products
(2) Results-driven structure	Application of TLT through subteams and a “network whip” working across multiple, parallel timelines. Each subteam had a timeline and set of milestones to achieve. This framework was the nuts and bolts of the collaborative structure.
3) Competent team members	The project required and brought together informal science educators, software developers and multimedia professionals, scientists knowledgeable about astrobiology, a leadership and management team, and theatrical expertise
(4) Unified commitment	At the individual level, the team established a unified commitment to the project at the kickoff meeting by drafting and signing three governing documents: a Declaration of Collaborative Excellence, a Collaborative Framework, and a Collaborative Agreement. At the institutional level, the PI obtained buy-in from the leadership (e.g. Museum Director) as well as the informal science educator who would participate in the project.
(5) Collaborative climate	A collaborative climate was created through the use of web-based communication tools; a schedule for communication to happen face-to-face and online; shared leadership so that there was room for multiple voices to be heard; and ongoing encouragement for subteam leaders to take control of the project rather than a top-down structure
(6) Standards of excellence	The standards of excellence were set forth in the Declaration of Collaborative Excellence and carried out in practice through the process of collaboration and the creation of products for dissemination.
(7) Principled leadership	On the part of the PI, there was an explicit commitment to TLT, announced at the kickoff meeting and reinforced through monthly teleconference meetings. On the part of the participants, they agreed to the shared leadership model and the responsibilities and assigned tasks that came with it
(8) External support	External resources were in the form of financial support from the National Science Foundation, scientific review from a team of advisors, and product development support from technology and media, and evaluation and research consultants

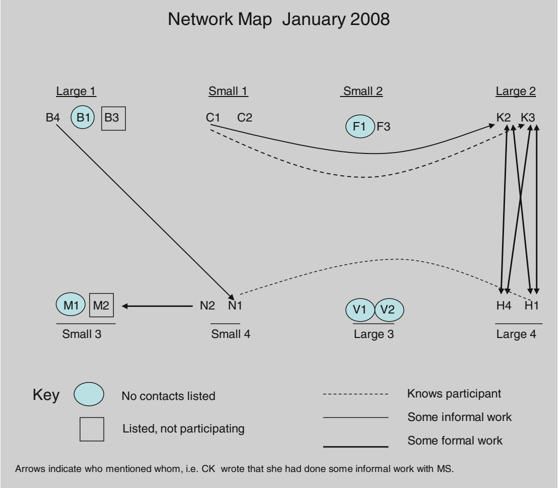
Exploratory Study Results

STEPS Social Network Analysis

An examination of educator interactions throughout the project proved to be especially revealing in terms of how well the collaborative model worked to combine CoP with TLT. We used social network analysis (Hanneman & Riddle, 2005; McCulloh et al., 2013) to look at the interactions and social bonds of the informal educators from the eight partner museums and science centers as they developed over time. Figures 7.3, 7.4 and 7.5 present three snapshots from the project depicting three different patterns. Importantly, these connections focused on how the participants, from both large and small institutions, perceived their relationships with others (strong, weak, or mixed). Figure 7.3 shows how the group perceived each other at first—relatively few established relationships across the group. Figure 7.4 shows the network map near the end of the first year of work. It is what we might expect from a healthy community of practice, highly engaged across multiple dependent and independent lines, and in several cases strong mutual ties. Finally, Fig. 7.5 shows a situation that arose several times within the structure of Team Leadership Theory—the emergence of a leader who, for a brief period of time, is a focal point for the group. In more traditional top-down leadership models, the person at the top of the leadership hierarchy would normally occupy such a central position at all times during a project. However, in the distributed leadership model of TLT, each participant was both required, and at other times individually opted, to occupy central leadership roles on a rotating basis in the interest of professional development.

It is also interesting to note the lack of cross relations between the other reporting participants. This is a marked difference from Fig. 7.4, but here again represents a

Fig. 7.3 STEPS initial social network map



Network Map January 2008

Arrows indicate who mentioned whom, i.e. CK wrote that she had done some informal work with MS.

Fig. 7.4 STEPS interim social network map

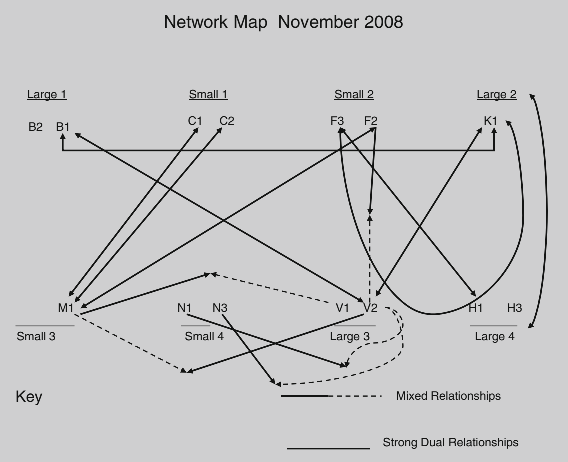
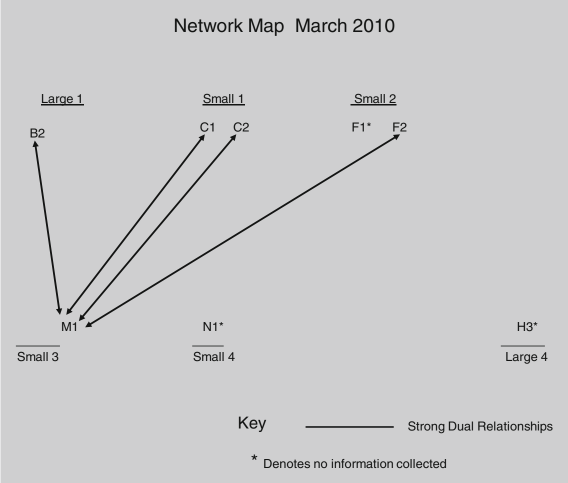


Fig. 7.5 STEPS focal point network map



feature of the project leadership design—an oscillating pattern between extensive cross communication within the community of practice at times of collective creative work (divergence) and temporary participant leaders emerging as rallying points in association with approaching project milestones.

In the case of Fig. 7.5, the project team was unveiling the STEPS software and conducting live audience testing and evaluation of the astrobiology shows in preparation for a conference debut. M1 was in a designated leadership position at that time.

Online Collaboration

In concert with the social network analysis, we also looked at communication patterns among participants online through the Basecamp Contribution Analysis. Basecamp was an online project management tool utilized during STEPS to facilitate meetings, schedules, share documents, conduct creative work, send messages and make postings. An analysis of these communications through the first three years of the project (the time of most active participation by educators) provided valuable information regarding professional development outcomes.

Using NVivo software and an open coding process, all such Basecamp contributions gave rise to an interesting set of categories: (1) scheduling; (2) technology; (3) meeting agendas; (4) network paths (referring to collaboration between individuals and institutions, whether STEPS-related or not), and; (5) edification (items promoting general professional development, including articles, reports, newsletters, etc.). Categories 4 and 5 in particular suggested the growth of relationships beyond the parameters of the STEPS project.

By reducing the data on the number and type of contributions by year and by project totals, we could track the frequency in each category by each individual and even determine how many "original" postings versus "response" postings were generated by each person. This analysis revealed several interesting patterns about how individuals moved in and out of the center of the community-of-practice and leadership roles.

First, the majority of participants demonstrated highly active involvement in the project. Secondly, as the project progressed the number of highly active communicating participants decreased, while at the same time the median number of message postings per year increased. This indicates that an increasingly smaller community-of-practice was handling increasingly more work. There seem to be at least three possible reasons for this.

1. Year 1 includes several more of the administrative staffers from each institution who were more engaged during that time in helping to create the infrastructure for the project. Once that work was accomplished, there was a diminished project presence on the part of administrative staff.
2. Staff attrition accounted for loss and replacement of project personnel throughout the project. This fact combined with the national economic downturn hitting museums at the time of the project work meant that multiple roles were often collapsed onto one person, leading to a situation in different museums of fewer people doing more work.
3. Finally, two museum partners were unable to fulfill their project obligations (in part due to the same economic situation) and ended up leaving the project by year 3, resulting in a smaller STEPS CoP.

A third observation is that there was an extremely wide range in the data in terms of who is posting and with what frequency over the three years. When one considers that a community-of-practice is a dynamic organization of people, this kind of range for evidence of communication is not unexpected. This may be especially true when CoP is combined with TLT, which, in the case of STEPS, required different individuals to move into the center of the CoP to assume leadership roles at different times and in different capacities. Therefore, we see leaders emerging in year-one while others had yet to assume such leadership roles at that time. In years two and three we see different leaders emerging and in some cases from joining the project midstream as new participants. This kind of movement to and from the center and periphery of the CoP indicates the successful implementation of Team Leadership Theory at least in terms of function. That is, we were successful in moving different individuals into and out of positions of leadership throughout the project. Unsurprisingly, we observed a correlation between the level of communication and engagement with the CoP and the degree to which an individual was impacted by their participation in STEPS.

Based on the analysis we describe above, we believe that the life events of some participants (such as maternity leave and health issues, as well as job changes which necessitated leaving or coming into the project midstream) had a tremendous impact on participation and communication levels. A perspective on professional development that is identity-based acknowledges that the professional identity of "informal science educator" must exist in harmony with other identities (such as mother, father, patient, new-guy, etc.). Professional development that does not take identity into consideration is more likely to place these identities in conflict and create staff isolation or attrition.

Basecamp contribution comparisons to the mean communication levels for each year revealed four patterns or characteristics of individual position and movement within the CoP:

Pattern 1: High Stasis. Consistently the most active members. To remain at this level, participants had to be active in the work of several subteams, as well as a frequent leader within one or more of them.

Pattern 2: Low Stasis. Consistently the least active members. Isolated, least communicative in terms of number and frequency of interactions.

Pattern 3: Toward the Center. We noted this pattern several times and most likely was underemphasized due to the change in participants and time spans used (with no finer granularity than yearly totals, for example).

Pattern 4: Toward The Periphery. This pattern was noted for several participants at different times—often the same participants who had movement towards the center at other times. This is also as an expected feature of the successful implementation of TLT. Certainly, not everyone can remain at the center of the CoP all the time, even for projects requiring full time commitments from it members (as STEPS did not). As with movement toward the center, this pattern was likely underemphasized or underreported given this method.

Another interesting approach to this data involved comparing average yearly Basecamp contributions from small versus large museum partners. We had originally hypothesized that due to greater access to resources and staff members, larger museums would demonstrate a greater rate of contributions than the smaller

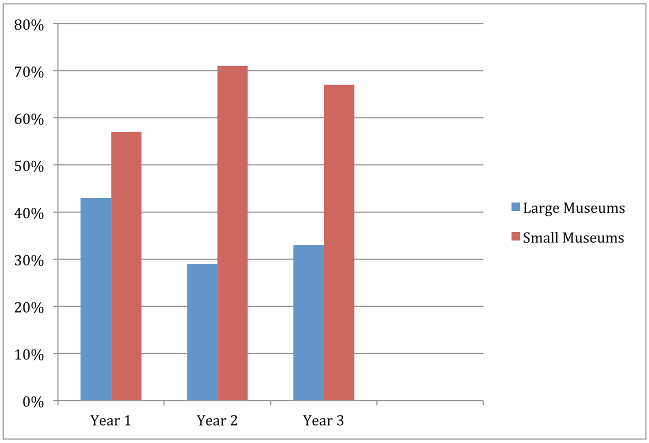


Fig. 7.6 STEPS small versus large basecamp contributions

museums. Interestingly, this was not the case. Figure 7.6 shows the average contributions separated by small and large museum staff. The results are intriguing.

The contributions from smaller museums consistently outpaced those from larger museums in each year of the project. The percentage of contributions from small museum staff doubled that of large museum staff in the second and third years. What factors could be responsible for such a dramatic difference? From interview data, it can be reliably concluded that small museum staff generally perform a wider variety of tasks within their jobs overall, are more accustomed to doing so, and have greater flexibility in scheduling those tasks themselves. By contrast, large museum staff are often more formally engaged in narrowly prescribed roles, too busy with designated tasks and do not have discretion over their schedules to spend as much time on "extra" work beyond the normal range of their daily activities. An additional indication is that participants from small museums were more ready or motivated to expand their skill sets and involved themselves in more aspects of the project in the interest of professional development, hence reflected in more Basecamp contributions. Certainly, these are significant differences in the range of professional identity for informal science educators.

STEPS Interview Analysis

While the social networking and Basecamp contribution analyses provided evidence of successful implementation of the STEPS collaborative model (Community-of-Practice and Team Leadership Theory) as well as insights into the project experiences at individual and institutional levels, interviews provided more direct assessments of personal impacts and professional identity impacts in particular. Between the exploratory study and the evaluation efforts, we conducted interviews quarterly for three years. These interviews focused on Professional Development Opportunities, Institutional Impacts, Network Impacts, and Outside Network Impacts. Of particular importance for professional identity construction, three themes emerged from the interviews as types of outcomes that operated on an individual level, but often extended to institutional and network levels as well. We dubbed them the STEPS Professional Development Outcome Categories:

1. Awareness, knowledge, and understanding
2. Engagement, interest, and attitude
3. Skills development and transfer

Within these categories, we sought to examine and interpret participant project experiences for their possible impact on professional identity—acknowledging that not all professional development experiences would have such impacts. For example, these categories seemed to suggest a continuum of deepening impact, progressing from one to three; introductory knowledge, to active engagement and personal relevance, to expertise development and expanded engagement in or transfer to other areas of work. The deeper the impact of professional development experiences along this continuum, the more likely it had impacts on participants' self-perceptions (identity). In fact, this is what was observed among participants who experienced the deeper impacts, presented in the specifics examples below.

Example 1 Sam was the senior astronomy educator at a small museum. He was chiefly responsible for the operation and maintenance of the museum's planetarium. Although technically proficient, he had little content knowledge of astrobiology or the power of theatrical productions for learning. He maintained a very high level of participation throughout the entire project. He eventually became the leader of the story and script development subteams. As a result of his work, his museum eventually hired a local theater director to train actor volunteers for the performance of STEPS shows (and other shows later on). Sam himself performed a STEPS show at the 2012 Middle Atlantic Planetarium Society conference. In his final interview, he stated that through his STEPS experience he developed a greater appreciation and skill for theatrical productions and their use in science learning and that this has changed how he develops and produces his regular planetarium programs.

Example 2 Ginny was a children's museum educator from a small museum. She became a participant toward the end of year one due to staff attrition and reassignments at the museum. While on the project she participated at high levels in all of the threads. Toward the end of the project, she became interested in furthering her education (partly based on her interactions with other STEPS participants). At first she began looking at online graduate programs, so she could remain at her institution for the sole purpose of staying on the STEPS project. She ultimately chose to leave the museum only after completion of the STEPS project and training of other staff to ensure the project's continued usage. As she stated, "the [STEPS] project has continued to impact my professional experiences and provides inspiration for future endeavors."

Example 3 Kath was a senior science educator with a large museum. She entered the project near the end of the first year due to a significant lay-off at the museum and reassignment of duties, including STEPS work. She became an active participant in all threads of the project, even becoming one of the performers of the first story for live audiences at conferences. After quickly familiarizing herself with the project, she maintained high levels of involvement to end culmination. She also saw immediate applications of the STEPS model and required skills and hardware to the museum's in-house and outreach programs. She was the first to recognize and promote the concept of a portable STEPS kit that could easily be transported to outreach sites. This led to an entire redesign of the STEPS hardware for all participants. Partly as a result of her leadership in STEPS, she was promoted to her current position as senior science educator, representing a formal professional identity enhancement.

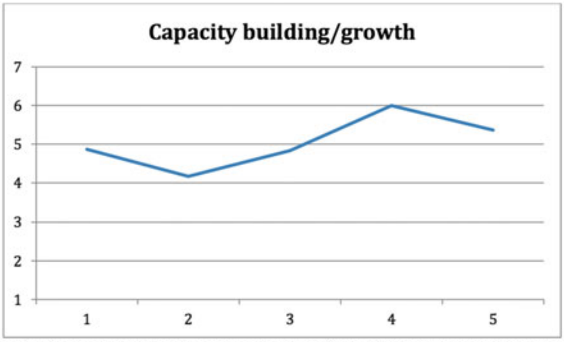
Each of these participants demonstrated significant development in all three professional identity development outcomes to the point of professional identity enhancement—positive development of their self-perceptions as informal science educators. This suggests that the three professional development outcome categories, considered as a continuum of deepening impacts, may constitute operational pathways for designing and perhaps evaluating educator training that is specifically aimed at enhancing professional identity.

While the overwhelming majority of results indicated positive gains in the professional development outcome categories, contra-indications should also be noted as this may help with the design and implementation of future programs or even the recruitment of participants into such programs.

Example 4 Vance was the director of a theater program at a large museum. He was initially a very active participant on the project, due in large part to his long-standing expertise in theatrical production and performance. He enthusiastically shared his knowledge of the foundations of theatrical performance and production. After the initial scripts were developed, he became increasingly overwhelmed by and resentful of the project's research and evaluation requirements, as well as the technical knowledge required to successfully complete all facets of the project. Eventually, these elements of the project led him too far outside of his comfort zone and ultimately outweighed the benefits of the project to him. Despite showing several positive gains in the professional development outcome categories to a point, the educator ultimately perceived a detriment to and/or an invalidation of his professional identity through project participation. In this case, out-of-comfort zone tolerance was lower and indicated an important issue for future project leaders to consider when generating challenges or risk opportunities for educators with the intent of personal or professional growth.

However, for the rest of the participants, there were significant positive gains, which fall under the three professional development outcome categories. In this way, these categories may comprise a practical underpinning for enhancing informal science educator professional identity. In the STEPS project specifically, these

Fig. 7.7 Capacity building/growth



Note: The x-axis represents each pulse check (PC1-PC5). The y-axis represents the mean score from 1 to 7.

categories were operationalized within the primary project design threads, which formed the core components of the project deliverables.

Additional evidence for professional development and professional identity impacts was gathered in the external project evaluation, conducted by UXR Consulting. Specifically, the evaluation scrutinized the use of Team Leadership Theory and its impact on participants. The consultant evaluation found that the use of TLT in combination with the CoP was particularly effective in developing and maintaining a bottom-up distributed leadership structure and achieving the professional development and self-efficacy goals of the project.

> STEPS provided opportunities for every individual to learn a new skill, try something outside of his/her comfort zone, and take leadership roles based on individual self-interests. These benefits were exchanged for challenges with decision-making throughout the project. (STEPS Summative Evaluation, p. 2)

Subsequently, the evaluation compiled periodic self-assessments from the participants (Likert-like surveys on a 7-point scale) known as “Pulse Checks,” including categories for Capacity Building and Growth, and Decision Making and Leadership, (among others) as shown in Fig. 7.7.

Qualitative participant comments suggested that capacity-building and growth was a success of the project. Participants cited growth at the professional development level and institutional level. Due to the unique leadership structure, each participant’s growth context was individualized. For some, the key learning experiences were content based and for others they were related more towards transferable skills, as revealed in the following interview responses.

> The opportunity to just stretch in a different way, and knowing that there was no one else that was doing it [in our area] and struggling deeply to differentiate the museum from the competition in the area.

> It helped me be able to showcase what I know, like stuff people [at my institution] didn’t really know everything that I could already do and that helped bring it out and people say ‘Oh, wow! She’s good at that’ Now I’ve gotten more projects to do and things like that.

> I think dealing with these different teams and having to run team meetings helped me in a way, for a while I was leading [a subteam] and I felt like I developed professionally from that. I learned about running a team, and trying to be efficient about it, and being able to report back to a larger group.
>
> I've done some things on the project that I wouldn't have done otherwise… Like making that video in Camtasia. I wouldn't have done that before but I already have ideas for how I can use that in other parts of my work and just working with the STEPS system, that's a departure from my typical work.
>
> In the actual project, I was put in such a leadership position… I was given the opportunity to demonstrate my leadership – to manage stuff. That's something that I had [at my previous job] and you know I've never really been able to do [it at my current job]. This project gave me the opportunity to prove myself. I was really lucky. I was given a promotion when we were doing two layoffs. (STEPS Summative Evaluation, p. 17–18)

These benefits, made possible through the employment of Team Leadership Theory for the STEPS project came at some costs in terms of efficiency for decision-making. This area of the evaluation demonstrated mixed results of importance to consider for balancing professional development gains with project deliverable achievement. While Pulse Check data showed moderate gains in this area throughout the life of the project (Fig. 7.8), qualitative results from interviews revealed some challenges here in addition to benefits.

> The decision-making and leadership structure were two intertwined components of the collaborative process. The use of TLT required a bottom-up, distributed leadership framework, which led to the creation of subteams to accomplish specific milestones and the introduction of parallel timelines for specific deliverables. … [some] participants identified that at times the process for making final decisions was ambiguous and slowed because of this approach. … Several participants commented on the need for more structure and more top-down leadership than the TLT framework calls for, particularly at critical milestones along the process.
>
> As a whole the ownership shift from being [the PI's] baby out to it being shared among all of us really worked quite well actually, unlike a lot of projects I've done like this. It was fostered well, you could take an area and go with it and you weren't second-guessed along the way. You were really given complete ownership. That I thought worked really well.
>
> I definitely liked the idea of giving everyone the opportunity to be a leader. You know, I never expected to be the leader of the [sub]team, but it was a great experience… (STEPS Summative Evaluation, p. 34)

Fig. 7.8 STEP pulse check decisions/leadership

Finally, the summative evaluation used a set of four scales (three from the existing literature) to compile a participant survey on professional identity constructs, including perceived cohesion, professional development, clarity of professional identity, and overall professional identity. These included:

- The Perceived Cohesion Scale (PCS), modified from Bollen and Hoyle (1990) and defining perceived cohesion as, "an individual's sense of belonging to a particular group and his or her feelings of morale associated with members in the group" (p. 482). For STEPS the scale was used to focus on a project member's perceived cohesion toward the informal science educator community.
- A professional development scale developed specifically for STEPS where professional development was broadly conceptualized as how informal science educators grew in their careers through involvement in the STEPS project.
- The Clarity of Professional Identity Scale modified from Dobrow and Higgins (2005) and using Ibarra's (1999) definition: "the relatively stable and enduring constellation of attributes, beliefs, values, motives, and experiences in terms of which people define themselves in a professional role." (p. 3).
- A general identity perceptions measure using a modified version of Brewer, Van Raalte, & Linder's (1993) professional identity measure, which conceptualized professional identity as the degree to which people identify with their professional role.

Notably, the summative evaluation also considered the impacts on the project partners from professional organization (not informal science educators) for comparison.

Both science museum educators [Group 1] and professional organization employees [Group 2] reported high levels of perceived cohesion, indicating that in general the team felt that they were part of a larger network of informal science museum educators (see Table 7.2). However, the two groups differed regarding professional development. Informal science educators reported higher levels of professional development from participating in the STEPS project than professional organization employees. This is perhaps not surprising since STEPS was designed

Table 7.2 STEPS identity scales summary

	Group	N	Min	Max	Mean	SD
Perceived cohesion scale	1	7	4.5	6.83	6.12	0.79
	2	4	4.33	6.50	5.63	1.07
Professional development	1	7	5.25	7	6.07	0.69
	2	4	3	5.50	4.69	1.14
Clarity of professional Identity	1	7	4.25	5.25	4.82	0.35
	2	4	3	4.00	3.56	0.43
Overall professional identity	1	7	5.67	6.17	5.91	0.16
	2	4	3.00	5.33	4.42	1.00

Note Mean values range from 1 to 7. Group 1 = Science Museum Educators, Group 2 = Professional Organization Employees, *SD* Standard Deviation to the benefit of museum and science center educators specifically. As one science museum educator reported: "It's been a huge benefit for me as far as the professional development. I've been exposed to things that I probably wouldn't have been able to do without STEPS." Scores on overall professional identity indicated that informal science educators identified with and valued their professional roles. Scores for clarity of professional identity were slightly lower. Future studies would benefit from monitoring changes in these scores over the course of such projects—which was not possible during STEPS.

Discussion

Based on these results, covering a variety of approaches to examine professional identity construction, the finding on the question, "Did the project enhance the professional identities of the participants?" is generally affirmative, it did. Further, it seems to have done so through the combination of using Team Leadership Theory in concert with the high demands of the project in terms of professional development within three broad categories (the STEPS Professional Development Outcome Categories) and including risks that took participants out of individual comfort zones.

The participant project experiences were often difficult and represented challenges, risks, and rewards which were individualized for different participants in different ways, each according to his/her own dispositions, capacities, and efforts. Consequently, as revealed in the wide range of interview responses, they led to differential identity impacts in terms of personal agency, attitudes, self-efficacy, and capacity as informal science educators.

This then also represents an avenue for future research in terms of unpacking the construct of professional identity into more specific constituent elements, which were beyond the reach of this study. Additional tools designed for related concepts, such as for personal agency or self-efficacy could be employed for such future inquires, along with more refined tools for directly assessing self-concept and identity impacts in the future.

Conclusion

With STEPS we set out to examine whether and how an innovative, difficult, highly collaborative, and distributed leadership project across a multi-institutional network could enhance the professional identities of informal science educators. The findings of this exploratory study indicate that the professional identity of "informal science educator" is highly individualized and hence so are the impacts of participation in something like STEPS. The results confirm that the STEPS Collaborative

Model succeeded in enhancing the professional self-concepts of participants, although not in all cases.

The emergent professional development outcome categories [(1) Awareness, knowledge, and understanding; (2) Engagement, interest, and attitude; (3) Skills development and transfer] suggest a structure for both designing informal science educator professional development programs and for evaluating the results. Considered as a continuum of deepening impacts (from 1 to 3), these outcome categories could be used as pathways for intentionally enhancing educator professional identity.

Additionally, although not covered in detail here, our exploratory findings support the notion that institutional capacity is inexorably linked to individual capacity and indicate reciprocal development of each, in most cases. Therefore, investment in staff professional development is essentially an investment in institutional capacity. Inversely, staff attrition is a divestment in institutional capacity (but not necessarily in individual capacity). Further, multi-institutional networks provide educators with a highly personal community that may extend in time and content well beyond project work. For STEPS, Team Leadership Theory operationalized within a distributed community-of-practice model proved to be effective for both individual professional development and institutional capacity building, but at some detriment to work efficiency and timely decision-making. Clearly, this is an area for improvement.

By placing educators at the center of concern for the project, STEPS prioritized the elements of leadership, collaboration, responsibility, and creative freedom, which in "normal" projects would typically be considered side effect benefits in service to the production of deliverables, if they occur at all. In this case, the "normal" formula was turned upside down, with lasting and transferrable gains for most of the participants. Importantly, these elements were intended to pull participants out of their comfort zones and present them opportunities to take risks and develop new skills. In the most successful examples, this brand of professional development impacted their sense of professional identity.

Therefore, our findings suggest that informal science educator professional development strategies may be well served by the following recommendations:

- Utilize project work explicitly as extended professional development opportunities for staff by providing supports and structures to facilitate gains and growth for individuals (not just production of deliverables).
- Design professional development beyond content knowledge and skills acquisition towards individual professional identity construction, including strategies for challenging intellectual, social, and emotional components.
- Create professional learning environments that encourage and support participant risk-taking in intended growth areas (out of comfort zones to a degree).
- Design and evaluate professional development efforts in terms of the three learner-centered professional development outcome categories: 1. Awareness, knowledge, and understanding; 2. Engagement, interest, and attitude; 3. Skills development and transfer.

- Consider treating these outcome categories as a continuum of deepening impacts, potentially leading to professional identity enhancement, and evaluate for such impacts.
- Explicitly link individual professional development efforts and outcomes to institutional capacity by incorporating a degree of team leadership, community building (within a single institution and/or a multi-institutional network), and actively seeking opportunities for transfer of gains to other areas of activity.
- Create protocols for online archival communication (e.g. Basecamp) and peer-to- peer mentoring (in person and online) to support collaboration, mitigate the consequences of staff attrition, and bring new educators up to speed quickly and effectively.

As an exploratory study, this work presents innovative methods for investigating professional identity impacts. However, future studies would do well to develop more direct methods for looking specifically into informal educator professional identity construction specifically. For example, the constructs of professional identity salience, commitment, and importance to an individual are all significant identity characteristics that can be more deeply explored with established methodologies from the field of identity research (Burke & Stets, 2009), but modified for informal science educators specifically.

Further, our work on this study has contributed to subsequent identity-based research by our group, XSci, at the University of Colorado Boulder. Notably, this has included important components of science educator identity construction such as the development of agency, emotional connection, personal relevance, content confidence, and behavior/choice effects within formal and informal learning environments. However, much more can done in this area. In fact, the current literature looking into the professional identity of educators predominantly deals with formal classroom teachers and has struggled with agreed upon definitions and models for understanding identity (Beauchamp & Thomas, 2009).

Defining identity in this or any context is a key step in generating research methods for examining it. Although this study was reinforced with a robust definition from the sociological area of identity theory, the methods used for examining identity impact were indirect (excepting the interviews). Other studies have utilized methods such as participant drawings, narratives, shared reflections, and even video creation as innovative approaches (Katz et al., 2011; McLain, 2012; Beauchamp & Thomas, 2009). Far less investigation into identity has been conducted for informal educators in informal learning environments, leaving the field wide open for new methods and inquiries into this difficult but important area.

As STEPS set out to enhance the professional identities of informal science educators through a novel project structure and strategy that placed a high stake on individual educators and collaboration between them, and was in large part successful in that endeavor, the findings challenge traditional thinking about the purpose of professional development. While the field of informal science education matures and becomes increasingly professionalized, STEPS and other projects are examining such front-line jobs (as opposed to administrative) in museums and science centers as “destination careers” rather than more transitory “career moves” one might make on journeys elsewhere. Identity is central to the distinction between the two ends of the spectrum in this regard.

STEPS suggests that professional development in terms of content and skills is not enough and may actually set institutions up for a lower or even negative return on their investment in staff development (through attrition) if they fail to also attend to the continual enhancement of staff professional identity. Certainly the results of this study are beginning to articulate ways of doing this along with the importance of doing so. Identity represents a personal connection; an ownership or self-integration of the role at hand, and when reinforced and afforded growth, it becomes a powerful influence on behavior, choices and effectiveness.

NOTE: For a full discussion of the other findings regarding linkages of identity to institutional and network capacity, see the STEPS Project Final Report, NSF ##1043060, Program Officer A. DeSena or contact the Project P.I. and chapter author B. McLain at XSci.org

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Part III
Designing Programs

Chapter 8
There Is no "Off Button" to Explaining: Theorizing Identity Development in Youth Who Work as Floor Facilitators

Preeti Gupta and Jennifer Negron

Being scientifically literate is not a choice anymore; it is a necessity in order to exist in today's world. Alarmingly, there is a general sense that levels of scientific literacy in the United States are low, with only 28% of American adults able to understand basic scientific ideas presented in the Science section in the New York Times (Miller, 2006). Being scientifically literate is more than being able to understand the natural world, but to also make critical decisions related to life. Adults need to be able to read or view a news piece and understand whether there is evidence backing the claims and if that evidence is valid and reliable. Feinstein (2010) argues that there is great disconnect between what we profess as important work necessary to produce a scientifically literate citizenry, namely schooling, and actual evidence that active participation in school leads to such a citizenry. He urges us to think about what it means that one is scientifically literate. Is it a degree, is it conceptual understanding grounded in a set of facts, is it a combination of conceptual understanding with skills or it is something else, the ability to draw on key ideas of science on an as-need basis when enacting life? He proposes that science literate citizens are "competent outsiders with respect to science: people who have learned to recognize the moments when science has some bearing on their needs and interests and to interact with sources of scientific expertise in ways that help them achieve their own goals (Feinstein, 2010, p. 13). He emphasizes the need for engagement, a construct that requires participation, attention and motivation (Hidi & Reninger, 2006). He uses the word "competent outsider" to account for those that are not necessarily working in a science or in science related fields, but still comprise society.

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In this chapter, we describe how youth become insiders, how that mediates their identity as science people and ultimately contributes to them becoming “competent outsiders.” For youth, opportunities to engage with science means the opportunity to imagine themselves as people who can participate in the practice of science, speak about science and acknowledge that science is prevalent in all aspect of their lives. We describe how informal science institutions (ISIs) are critical players in engaging youth and converting them into lifelong learners of science. We do not claim that these teenagers are by definition, scientifically literate citizens because for one, there is no agreed upon definition or vision of what that person is like, but also because there is not a longitudinal study, as Feinstein pointed out, that has been able to make that link.

We embrace the phenomenological approach (Van Manen, 1990), which means that lived experiences are valued and count as data. We bring in autobiographical accounts and couple them with lived experiences of many others from various ISIs and make claims using a hermeneutic approach (Alvesson & Skolberg, 2000) where we interpret those lived experiences and look for patterns and contradictions by examining all of the accounts as a whole. Sources of data are evaluation reports, and research studies that document experiences of youth working in such settings. We describe our own experiences as teens that began our passion for science by working in one particular ISI and theorize how experiences like ours are good examples of how working in ISI settings in meaningful contributory ways mediates identity development as a science person. We are both former employees of a site used in this study and as such, our data is representative of that museum in a particular time and space. We recognize that cultural sites are dynamic, and transforming at all times. We also use excerpts of various evaluations of youth employment programs to back our claims and conclude with specific programmatic recommendations for program designers, which we consider critical in supporting teens in these endeavors.

The Context

Engaging teens in floor facilitator roles is common in informal science institutions. While each institution is unique, what is common is that high school teenagers are invited to work in these settings and get trained on not just the science of the exhibits or community projects, but on science communication techniques. For many of these places, having a youth staff is a critical component of operations and the teens in these programs are fully aware of it. Both of us began our engagement with science by securing a job in one such institution, the New York Hall of Science (NYSCI). Since 1986, NYSCI has had the Science Career Ladder program, and through it, hundreds of teens are trained to serve as floor facilitators, called Explainers. The job is advertised through schools and online websites where urban youth generally look for part-time jobs in order to attract a diverse group of people who need jobs at that point in their life in order to support themselves or contribute to their families. As such, many teens that end up with the jobs are not necessarily science-lovers, but have a commitment to work hard. Both of us began our journey of transformation by getting a job as an Explainer.

Preeti's Trajectory

I (Preeti) am a first generation Indian American. I worked at NYSCI for 22 years beginning my tenure as an Explainer at age fifteen and slowly developed my identity as a science educator. I experienced an awakening in understanding the social and cultural nature of science. I recognized that learning science was a very personal construction, but one that needed to be embedded socio-culturally. I was also exposed to the teaching profession in a much different light than I experienced growing up. For me, the Explainer experience created opportunities for successful interactions in science teaching. I was intrinsically motivated to create positive learning experiences for visitors and perfect my craft whenever possible.

As a teenage Explainer, this semi-social workplace was something I began looking forward to every Sunday. My job was to approach people and engage them in science conversations at hundreds of science exhibits. I also had to conduct the different daily demonstrations which are 20-min scripted experiences performed on the museum floor for approximately 15–20 people. I was trained to use the exhibits, and I was given time to learn one of the demonstrations. It was scary to approach visitors and I lagged behind the others in learning a demonstration. Being naturally shy, feelings of insecurity fueled my discomfort, but I still liked being in the museum setting.

One day, my supervisor, Carlos Lopez, someone who became a great mentor and friend to me, approached me and said that I needed to pick a demonstration and learn it or I would not be allowed to keep my job. In order to get certified in the demonstration, I had to perform it in front of a live audience. The demonstration assessment rubric measured science content proficiency, presentation skills, and flow of concepts. I panicked about losing my job and picked the laser demonstration, a 20-min experience that taught people about properties of light and applications of a laser. Carlos supported me by setting up peer-training sessions and helped me by reviewing difficult science concepts in accessible ways to me. Three workdays later, I was up for certification and I performed the demonstration in front of a live audience. After the demonstration, Carlos approached me and said that I did it really well and he was really impressed. That comment from Carlos, who three weeks before had warned me that I might lose my job, affected me in a powerful way.

Shortly after that, I became certified in all six of the demonstrations one after the other (at a much faster rate than my fellow Explainers!). The truth was that I was excited to receive praise from Carlos, someone that I viewed as a smart, eloquent mentor who was great at engaging visitors. I also really enjoyed conducting the demonstrations and teaching visitors. I soon realized that in many cases, I knew more science than the families watching my demonstration and became excited to dialogue with them about science. As I continued to perform demonstrations, I became better at gauging my audience and their prior knowledge about topics. I also inspired other Explainers to get certified and provided peer training when necessary.

Having conversations with visitors was fun. Sometimes I approached them and sometimes they approached me. We mostly talked about science, but occasionally they asked about where I went to school and how did I get to know all of “this stuff.” I felt that I was making a difference to the visitor experience and that these folks talking with me might actually remember the concept we talked about or the demonstration they saw.

This created a sense of purpose in me. I felt important and that I was contributing to a higher cause. My world expanded beyond my problems and my issues. Working at the museum was something I looked forward to each week because I was part of a larger mission and my actions would affect not just me, but the museum as well. This experience played a role in the development of my self-confidence, and it transcended the museum. It became visible in my high school life and my family life. My teachers noticed my confidence in class and my friends noticed that I was happier than before. In school, I spoke about topics beyond just the high school. I talked about people I met at the museum and occurrences with visitors that I found interesting. This job allowed me to develop my sense of self and also acknowledge the role others played in this process. My experience as an Explainer reverberates for many people who have been Explainers. The Explainer experience transformed my life, and I believe it has done so for many people. There are Explainers who chose careers in teaching and credit their Explainer experience at NYSCI in supporting their decision.

Jenny’s Trajectory

Born in Queens by a Puerto Rican mother and a Colombian father, I (Jenny) was raised in an environment where family time was primarily spent in outdoor settings like beaches and parks. While I do remember visiting museums, zoos and botanical gardens on occasion, it was not a regular family pastime. I remember thinking museums were boring places where one had to be quiet and learn. No fun allowed.

On the day of my interview for the Explainer position at NYSCI, I was surprised to find this huge building right in the perimeter of Flushing Meadows Corona Park, a place where I spent most of my time growing up. It was a building I never knew existed. When I first heard about the opportunity to work there, I assumed it would be a long hall with pictures of scientists and science facts along the walls. I did not think that there would be much of a future for me there except for possibly collecting tickets at the admissions office. I mean, what else could someone like me do at a science museum? I barely made it through my science classes in high school. But it was a paid internship, and I needed a job.

Walking into the museum for my interview was a really exciting experience. I was wowed by the spinning lights, the colors, the bubbles, all the stuff that you could do. It looked fun, and overwhelming, and scary. But I got through the interview and was ready to start the following week. My summer job would be learning about the exhibits and explaining it to visitors. Little did I know at the time that this 2-month internship would turn into a 13-year career.

As an Explainer I remembered feeling scared to talk to visitors. I did not think that I had the capability of ability to teach other people about science when I felt I could not understand it myself. I spent my first few weeks on the exhibit floor reading the exhibits over and over again and feeling insecure because I did not understand the content but I had to present it in front of a group of my peers at a weekly training session. But that soon changed. The team at NYSCI was encouraging and supportive. Luckily, I had an amazing peer mentor, who never put me down but instead encouraged me to try. He challenged me by asking me to present the exhibits the way I would to a visitor, giving me constructive feedback on my presentation skills and adding tips for other science concepts I could talk about. I learned quickly that I loved to explain how the exhibits worked, even though I did not fully understand the science concepts. While I did not feel comfortable with going deep into the science concepts, I really thrived at making my explanations engaging and fun for the visitors. One day I was doing a cow's eye dissection demonstration for a group of upper elementary school kids, of Hispanic descent. They were completely engaged and after my demonstration was over, the group stayed and continued to ask me questions. Didn't I think it was gross to touch a cow's eye? How did I learn how to do this? Is this my career? Was I teacher? Was I a scientist? That experience, and many more similar interactions with visitors of all ages and cultures, made me realize that science was part of who I was.

Being an Explainer came at an opportune time for me. While I myself was just a teenager, I was also a mom. My son was just 2 months old when I first started at NYSCI. Being an Explainer taught me how to see the world in a new way. I learned how to feel comfortable with asking questions and exploring new things without the feeling of failure. How to deal with failure was a skill I learned. And any time I did not do something right, or did not know the answer to something a visitor would ask, I was not afraid to admit it and took the opportunity to learn something new. I took all these skills with me when I went home. And as my son got older, we would explore the world together.

My comfort, confidence and science identity continued to grow and develop as time passed. But this would not have been the case without the help and guidance of the supportive mentors that took me under their wings. After a few months of explaining on the exhibit floor, I was asked to assist in a weekend science camp. The science instructor gave me the ownership to help her create lessons and co-teach with her and a group of other Explainers. Each week, when the kids left excited about the day's lesson, I felt proud. Throughout my time at the museum, my supervisors looked to me when a new opportunity was available. They were supportive and encouraging at every new challenge that I faced. It is because of these mentors and the supportive environment at NYSCI that I realized I had a future there.

Theorizing Our Experiences

Consider an ISI as a field, which has porous boundaries where culture is produced, reproduced, and transformed (Sewell, 1999). Fields have structures, both visible and invisible and those structures include people, objects, ideas, rules and tools. When teens work in an ISI, a field, they engage in meaningful activities that are authentic, collaborative, and create a sense of awareness and ownership. In the process, they are producing/reproducing and transforming the culture in that field. The activities the youth engage in are mediated by those invisible and visible structures and equally important, the actions of the youth are also mediating change in those structures. This is known as a dialectical relationship. It means that one cannot exist without the other and is constantly mediating change in the other (Sewell, 1992). An Explainer's activity is dialectically related to structures of that field in which that Explainer is working. As the teen sees herself engaging successfully in activity (interacting with the public, conducting demonstrations, etc.), not only utilizing the visible and invisible structures (the exhibits, scripts, training sessions and her peers), but also creating change within those structures, she sees the value in her work and considers it meaningful. As people view her work as important, necessary and high quality, they ascribe an identity to her. Being ascribed a certain kind of identity by others begins to shape her own perception of herself (Gee, 2001). She then invests more in herself for the sake of the other. The self and other now enter a dialectical relationship, each contributing to shaping/reshaping the activity, her identity and the field as a whole. In Preeti's case, when Carlos Lopez praised her, he ascribed to her an identity of one who is competent with conducting a demonstration. Over time, she viewed herself as not only competent, but also comfortable and confident at conducting demonstrations. She also states that she saw her work as an Explainer as part of a "larger mission". She, as an individual, was mediating positive change for the public, the collective. She knew that if she did her part well, the visitors would get more from the visit to the museum and the more the visitors responded well to her actions, the more she was motivated to do a better job of facilitating experiences. Jenny describes a similar experience when she notes how she conducted a cow's eye dissection demonstration for a group of children of Hispanic descent. Being able to convey concepts to a group (the collective) was part of her job, her mission. The feedback she received in the form of questions and comments made her want to present more often and become better at it and as she describes, ultimately made her see herself as a "science person". If we theorize facilitator-visitor experiencesin a science institution as an endeavor and the larger goal of the institution to be that of contributing to the development of a scientific literate society, then we have set up opportunities for teens to contribute to meaningful authentic activity. Each Explainer individually is contributing to that collective's goal and the collective is mediating change in the individual. Each individual carries her own structures within her - her experiences, beliefs, knowledge, abilities and skills. She carries these structures into the endeavor. The individual also becomes aware with the structures of the collective, the visitors to the museum. The visitors' needs and motivations for visiting the museum, their prior knowledge and beliefs about particular concepts, their experiences with visiting science museums all comprise the structures of the collective. There is a dialectical relationship that exists between the structures of the individual and the structures of the collective. For example, one college Explainer who worked at NYSCI, Rhonda, describes an incident when revealing how she fell into a trap of making assumptions about her learners. She was doing the cow’s eye dissection demonstration and used the word “inversion” to talk about how images look through a lens. She continued on with her demonstration until one 11th grade visitor in the audience commented, “Ms., you think we know what you mean, but we don’t. What is inversion?” Rhonda was taken aback at this comment. She realized she was making assumptions about her visitors. This interaction mediated a change in Rhonda. She became fully aware of how teachers can make assumptions about their learners. She reworded what she wanted to convey in the demonstration for those visitors but also became fully aware of her approach with future interactions. She continued for months to provide examples of where she was about to make an assumption, but then didn’t and tried alternate ways of communicating science. In this vignette, the 11th grader’s comment mediated a change in Rhonda’s way of thinking about learners. Rhonda’s actions did not just impact that one student, but all of the visitors that Rhonda encountered thereafter creating a change in experience for all of the visitors, the collective. This vignette demonstrates how Explainers and visitors mediate changes in the structures within the other. A way to visualize this is by using the Scheffer mark,|, which denotes dialectical relationships (Roth & Lee, 2007). Then, we represent the relationship like this:

Individual | collective

Individual’s structure | collective’s structure

11th grader’s comment | Rhonda’s beliefs and approaches | Visitors’ experiences

The structures of the ISI also contribute to the larger mission of the ISI. The specific exhibits, the layout, the welcome desk, the signage are examples of the physical, visible structures. In particular to the youth program, visible and invisible structures include the rules of the Explainer program, the leaders and mentors of the program, the nature and content of the training, the nature of promotions, the recruiting and hiring practices and other such schema. These structures now also mediate the structures for the collective (the visitors) and the individuals (the Explainers). The dialectical relationship then becomes where the three, the individuals, the collective and the ISI all mediate changes in each other:

Individual’s structure | collective’s structure | ISI’s structure.

Continuing with the vignette described above, Rhonda shared her experiences with a group of Explainers in a reflective practice session. This experience became a “thought object” and everyone in the group including us began to note examples of where we were making assumptions in our learners. Both of us (Preeti and Jenny) were in positions of leadership and were responsible for mediating change through training and professional development for larger groups of Explainers, pre-service teachers and museum educators. This thought object, making assumptions, became a topic of conversation across all these audiences ultimately impacting teaching and learning across the museum, albeit in small ways. Rhonda's growth as an educator (a change in an individual's structure) mediated change not just for the visitors but also for the ISI's structure (what teaching and learning was like across museum programs).

Structures and Identity

As teens enact culture and do the work of a floor facilitator in an ISI, they leverage the structures of the visitors and the institution. Over time, those structures become linked to the developing identity of teens as science people: Structures | identity.

A vignette from an Explainer who worked at the Exploratorium in San Francisco demonstrates this point well. This young woman describes a time when she was in a different country, in a non-science situation, and how she began explaining a science concept just like she would at her museum.

"In Italy [for a choral trip]… everyone's bought like the laser pointers… and then I did a little mini-laser demonstration and I played with my class ring… I did like the whole entire demo that you could do without the supplementary things, and a bunch of kids were like, 'Whoa, that's cool, are you in physics?' I'm like, 'No.' They're like, 'Oh, are you going to take it next year?' I'm like, 'Oh, I can't, I didn't meet their math requirements'… but like everyone thought I was so incredibly smart just for knowing that. It kind of like showed me that people think that to know a lot of cool stuff, that you have to be quote unquote a smart kid, be in like the hard classes, and working at the Exploratorium has showed me that you don't have to have a hard class… learning is so cool and like science is accessible and it's not just like formulas and books, and that has like opened me up, to like go out and find out what I'm actually interested in… that if there's stuff that you want to understand, like you can understand it."

The laser pointer and the ring on her finger are physical structures to invoke her "inner Explainer" as she begins to describe the properties of light to her friends. She says that she did a mini-demonstration, which means that she has internalized the script that accompanied that demonstration and is now performing it for these people. Demonstration scripts are not traditionally like acting scripts; they are guidelines of key ideas to address and each Explainer creates her own version of the script that is in the form of a dialogue with the visitors. There are some key rehearsed points but it is more akin to good teaching than acting.

Alumni Explainers from NYSCI exhibited the same behavior after an alumni event. Although the festivities had come to a close, a group of five people decided to make one round through the exhibits before they leave. They encountered the *Steam Engine Demonstration*[1] on the lower level of the museum. One hopped

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[1] Exhibits at NYSCI described in this chapter may not be on public display anymore.

inside the wooden fence and began to conduct the demonstration mimicking the blowing of the whistle to attract visitors and using hand motions to describe the function of the piston. The other people mimicked being visitors. I, Preeti, had been walking around to make sure everyone had gone when I encountered this. When I inquired into their intentions, they claimed that they remembered this demonstration fondly and it helped them appreciate the connection of science and history so much. Re-enacting the demonstration was simply a nostalgic act. The steam engine is simply an object, not one found in everyday life. This object, as a structure, was sufficient enough to remind them that it is where they learned to appreciate science and history.

Another vignette demonstrates how science identity that is shaped in one field carries into another field. One high school Explainer, Victor, at NYSCI once described how he considers himself a shy person, who goes to school because it is

Table 8.1 Porous boundaries

Speaker	Discourse	Actions
Alison	Science like, after working here, is like pretty cool. Cuz, like, then I’d be like, I already know that I know that from the Main Level	Snapping her fingers with a gesture of having command of a skill
Preeti	What’s on the main level?	
Alison	Oh, like in chemistry, I was like, that’s easy, I know that. The energy levels in the exhibit	
Paul	Yeah, like when it jumps to different energy levels	
Preeti	Where does that show up in your course?	
Paul	That was chemistry last year, because of *Realm of the Atom*, you can visualize it. Oh, you can come to the science center and oh, that’s what he [Referring to the hypothetical science teacher] means	
Victor	That reminds me. Cuz, we was doing Earth Science. And, um, I was telling them about um, ultraviolet light, and you know the upstairs, in *Seeing the Light*, I was like going into my gear now, I was like explaining like I do at the science center, talking about ultraviolet, infrared	
Preeti	But, you were in class?	
Victor	Yeah, I was in class! The teacher was like, “Ok” But honestly, I learn more here than I do in school. Honestly, I wouldn’t lie about that	Group laughter
Preeti	But, it looks like, what you learned here, you took to school?	
Victor	Yeah. But there are more topics to learn in school. But if I had school like this, I would probably do a lot better	

the right thing to do, but doesn't participate, doesn't really speak up in class, and gets average to low grades. In Table 8.1, we witness a conversation between Alison, Victor, Paul and Preeti. Alison, Victor and Paul are all high school students who work as Explainers and in particular, Victor has been working at NYSCI for just under 2 years. In the vignette below, we see how Victor brings what he has learned from being at the ISI into a different field, his school.

Alison and Paul are describing how they think science is cool after working at the science center, but Victor claims that he contributes to the conversation in his Earth Science class when the topic is about the electromagnetic spectrum. Victor points to a specific exhibit area, *Seeing the Light,* and describes how he "goes into his gear". Victor starts teaching the concept to the people in his class just like he does the visitors in the science center. This idea of "going into gear" is symbolic of how youth carry the academic capital they develop in one field into another field. Over time, this buildup of capital leads to one's own transformation of identity as a person who can know science and can teach others about science.

Cascading Influences

While there are numerous programs internationally that engage youth in these meaningful, contributory experiences, there is lack of research on this topic and very few organizations have been able to understand the long-term impact of such programs on youth. Some places as described below have evaluations that collectively provide evidence of impact youth employment programs have when positioned within ISI settings. NYSCI commissioned a retrospective alumni evaluation (Sickler & Johnson, 2009) and found that being an Explainer significantly changed the way Explainers thought about science in their everyday life and the role they played in it. Eighty two percent (n = 164) reported being extremely aware of science around them in their lives and 70% claimed an increase in having conversations about science on a regular basis.

In contrast to this program, where Explainers work for at least a year, but often more, the AMNH conducted an online alumni survey (Gupta, 2014) to understand the impact of participation in the Museum Education Employment Program (MEEP). In this program, college students are hired for the summer to develop their own learner-centered tours based on a theme of their choice and then lead summer camp groups through the tour. Seventy-six percent of the alumni who completed the survey (n = 69) feel that after participating in MEEP, they notice science more in their everyday life and they have increased numbers of conversations about science and science related topics with people in their lives. Seventy nine percent of them feel that after MEEP, they were more likely to think about science topics and issues, 85% feel that they learned how to teach others, and 84% have interest in sharing what they know about science with others.

However, these evaluations are limited in that the methods used are self-reported surveys and they are unable to capture whether these people are engaging with science in more immersive ways than simply talking about it or watching documentaries during their leisure time. There is some evidence that teens enact culture differently during and immediately after participation in teen programs. They become conduits into their communities, where science is not a discrete subject, but ever-present as they go about their daily lives. The title of this chapter comes from one such young man, a former Explainer from NYSCI. During one of the weekly training sessions with Explainers he talked about a situation where he experienced a science interaction outside of the New York Hall of Science. He described that he was at a party with friends and one guest pulled out a board game and it had glowing dice. Everyone was amazed and excited by them. This young man was also excited to see them but went into a question and answer style dialogue about the science behind the glowing dice. He described how he started asking them questions, making it relevant to their daily lives until they figured out the reason. He concluded his story to us by saying, “there is no off-button to explaining” and continued to say that he uses his skills as a science facilitator in all different situations. For him, he didn’t stop what he was doing to engage in science conversations, it just happened, it was natural and it was part of his identity. Another young woman in the AMNH program who became expert at conservation science stated similar sentiments. She was enrolled in a program where she spent a year working along a museum scientist conducting authentic science research. When asked to describe how the museum experience impacts her everyday life, she stated,

> One of the things I love to do in my free time is actually create my own vegetable garden. So every spring I start planning all of my seeds and I see them sprouting…. So I’ve been learning about different species in con bio[logy]. So now I have avocado plants that are taller than me!

In an internship program at East New York Farms (ENFY) in Brooklyn, NY, teens run a half acre organic farm and provide support to other gardens throughout East New York. They learn about the environment, health and nutrition, entrepreneurship, and leadership. They also use food as a lens to examine issues of social justice and ultimately make change in the community. As described earlier, the teens are engaged in meaningful authentic activity, with a mission, and they individually are contributing to the mission of the collective. During the winter of 2012–2013, ENYF administered an alumni survey to evaluate the long-term effects of the program on its participants. The survey was sent to 97 former interns for whom ENYF staff had valid contact information and who were at least 18 years old, had participated in the program for at least 3 months, and who had been out of the program for at least 1 year. ENYF had a response rate of 52% (N = 50). The survey included questions about alumni’s current and previous school and work experience, their leisure activities and civic engagement during the past year, and open-ended questions about their experiences at ENYF. In the report, one person described,

> Working with ENY Farms prepares you to be mature and to make decisions for yourself at an early age. No one in JHS [junior high school] had the responsibilities I had at such a young age. It was fun and encouraging to have that trust and sense of independency.

Programs such as these have the opportunity to directly impact behavior and ways of interacting in the natural world. In the alumni report, 74% said that they care about nature and the environment very often, 54% said they try to find ways to reduce waste (compost, reduce, reuse) very often, 94% said they enjoy learning new information very often. 58% said they are comfortable with applying math and science concepts when they need them very often, and 36% said they do so sometimes. One alumni wrote,

> I learned a lot about pesticides and how eating organic foods are really healthy for you. It opened my eyes to vegetables I have never heard of, and to this day I continue to shop at Farmer's Markets and buy organic foods.

While we present only a few vignettes from a few programs, it is clear that collectively, informal science institutions that invest in youth programs are making big contributions to developing a future citizenry that identifies with science.

Program Design Implications

Programs that espouse positive youth development principles, that move beyond the negative view of teenagers, build upon the strengths of teens and prepare them to become productive members of society (Lerner, 2004). The programs described in this chapter reflect this positive view of teens as key players and contributors to informal science institutions. According to Lerner, there are three features that when combined lead to a positive and effective youth development program. These features include (1) positive and sustained relationships between teens and adults; (2) activities that build important life skills and (3) opportunities for teens to use these life skills as both participants in and as leaders of valued community activities. The Youth Development Institute, a non-profit organization in New York City that supports the growth and development of young people by strengthening the quality and increasing the availability of experiences offered by the organizations that serve them, includes two additional factors that foster resiliency in young people. These include (4) having high expectations of teens and (5) sustaining relationships with teens beyond the time they leave the program.

It is evident in both of our autobiographical accounts that there was someone present in our experiences at NYSCI to mentor and guide us along our way in the program. In program design, the structural contribution of caring and trusting relationships between program leaders and teens is critical. All the programs mentioned in this chapter provide opportunities for teens to have one-on-one relationships with adult staff and with their peers. The adult staff serves as mentors, guiding teens as they learn and develop the skills they need to interact with the public. They help teens identify and develop their strengths and work through their challenges so that teens see failure as an opportunity to grow, not to give up. For Preeti, Carlos served as that caring adult. He encouraged her and motivated her. The young people in these programs often start at the same time, learn together, teach

each other and grow together, essentially creating a community of practice (Lave & Wenger, 1991). More experienced teens serve as peer mentors. Over time and through structured activities teens develop a connection to one another and to the institution. It is through this connection with their peers and institution that they develop a shared identity with each other, focused on the science work that they are learning and doing. As teens start to develop their confidence and competence in science, and as their peers, and the public acknowledges this ability, their science identity strengthens. In an online forum, the Explainers shared their thoughts by starting a discussion called “You know you work at the NY Hall of Science when….” Through this forum, Explainers commented on examples of their shared identity. Symbols such as the red apron (the uniform that they wear), a laser pointer and what they think of when they see a school bus, reflect that shared identity.[2] One response that stood out was, You start explaining things to your friends and family in “real world” scenarios… and ending your thoughts in “…does anybody have any questions?” This response, while written in a humorous tone, indicates that for this teenager the identity of speaking like an Explainer permeates the other aspects of his life, his interactions with friends and family. He cannot divorce himself from “explaining” science and relating it to everyday life and then follows up with an invitation for more questions. The experience of being an Explainer has empowered him to see himself as a science person, and see opportunities to share that science identity in environments outside the institution. This person is given a platform, the online forum, in which to reveal this about himself with just peers and immediate supervisors. This online forum is a safe environment for the Explainers to share their experiences. The forum becomes a platform for developing sustainable relationships with each other by talking about a shared area of interest ultimately contributing to their developing science identities, but also revealing how the work of being an Explainer is mediating change for them. This forum is also used to inform the program staff that uses this information to make improvements and changes to the program. The online forum becomes a venue for identity development. The individual Explainers comment and the more they comment, the more it mediates change in the collective’s understanding of the impact of this program on themselves and they want to contribute their own examples to the forum. As leaders of the program read this forum, they use it to design changes to the overall program structure. There exists a dialectical relationship between individual Explainer’s posts and the collective’s posts and the program leader’s actions.

Another key element in any program design, as evident in the examples provided in this chapter, is that teens are engaged in meaningful authentic activities that build important life skills and are contributing to society. When teens serve as floor staff at an informal science institution, they build a network of peers who share the same values and experiences, they learn science content and how to communicate with

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[2] This data was collected from an internal social networking site, clumpology.ning.com at the New York Hall of Science.

the public, and they learn vocational skills such as problem solving and about the importance of time and money management.

Helping teens see the long-term value of participating in the program, and scaffolding activities where teens build their confidence and competence is important in program design. Both Preeti and Jenny were able to see the long-term opportunities available to them through the Science Career Ladder program. For Jenny, having supervisors that provided her with new opportunities when she was ready for the next challenge helped her realize that she had a future at the institution. However, not all ISIs have the capacity to build in robust career ladders. Making sure that challenging activities are available, whether or not a program has the ability to create a ladder of experiences is important. In the Exploratorium report it was noted that, "in order to combat the possibility of burnout, Explainers were given increased opportunities to participate in additional activities such as producing webcasts and working with other museum staff" (p. 4).

The increased opportunity comes with more responsibility and higher expectations. The mentors described in this chapter are not just teaching and training teens, but also having high expectations of them, another key element in program design. Both of us were held accountable for creating positive experiences for visitors. While the trainers were supportive, they also pushed us to do things that we didn't think we were capable of. They provided us with the support we needed and through their encouragement they instilled in us the competence and confidence we needed to communicate science with others. Teens also develop high expectations of their mentors. The mentors are seen as leaders, as people with more experience and more authority. Both of us could envision that we, one day, could be in those roles and could beat those greater responsibilities. And when it came time to serve in those leadership roles, we were able to reflect back on the experiences and feedback from the Explainers to make improvements on the program over time. At the Exploratorium, 82% of the alumni reported getting feelings of pride, accomplishment, appreciation and respect as positive impacts of the program. Having these high expectations of teens while they are in a supportive environment encourages them to have high expectations of themselves. In the ENYF report, one alumna stated, "I see that I tend to be more goal oriented than others my age. When I start something I always finish it" (p. 11, 2013).

In these programs, teens learn the rules and structures of the workplace. They learn about the importance of being on time and being held accountable for the decisions they make and their interactions with visitors and the community. Without floor staff at the science institutions or teens to run the farmers markets, the organizations would not be able to function completely. The teens in these programs see how important their role is in the institution.

Giving participants ownership of the program empowers them and builds leadership, interpersonal and organizational skills, and a positive work ethic. As evident in the examples described in this chapter, teens and alumni are given the opportunity to share their ideas and thoughts about the program and are asked to reflect on their experiences—through reports, assessments, feedback sessions, observations, and by providing spaces for participants to feel comfortable with sharing their experiences.

In the vignette highlighted above, Preeti created a safe space for Explainers to reflect on their daily experiences. Through online forums, social networking sites and alumni events, teens and alumni can continue to reflect on their experiences and provide feedback on the program. Giving teens opportunities to create learning experiences is another great program element. In the MEEP program, the teens are the developers of the tours. At ENYF, the teens develop plans for how to reach out to the community and share the work they are doing at the Farmers Markets. For Jenny, one moment that stood out was when she was asked to not only assist in the weekend Kids Club program, but also help in the planning of the activities. This gave Jenny the confidence that she had something to contribute to the program.

Further Research

In the introduction to this chapter, we talked about the importance of having science literate citizens, who according to Feinstein (2010) are “people who have learned to recognize the moments when science has some bearing on their needs and interests and to interact with sources of scientific expertise in ways that help them achieve their own goals (p. 180)”. Through the youth development principles that we have described above, the programs described in this chapter have engaged youth in meaningful activities where they participated in science and were motivated to share that knowledge and experience with others. While a number of them may not necessarily be working in a science or science related field, the competence, confidence and comfort in talking science is something they take with them long after they leave the program. One alumna from the Exploratorium explains this perfectly when she said,

> The Explainer program was really my first introduction to the world of science as a possible career. It was the first time I felt that being interested in science was considered “cool” and that’s a pretty huge thing for a self-conscious high school student. I learned how to interact with the general public, speak in front of groups, break down scientific ideas into manageable and understandable chunks, and gauge the teachability and interests of my audience. All of these skills I use on a daily basis in my career. (p. 19).

Being able to contribute to a larger endeavor with opportunities for growth, responsibilities and high expectations position youth to mediate changes to their institutions, but also their own communities. The impact sustains beyond the experience. As seen above, it transforms the way youth think about science and their role in science. The statement from this alumna from the East New York Farms program exemplifies this.

> I would really have to say what I learned from East New York Farms can’t be written in words to be explained…It has fostered my interest in agronomy and how I go about perceiving life. (p. 10).

This alumna says that what she has learned cannot be written in words to be explained. This poses for us challenges in understanding the long-term impact of such youth programs. We are also presented with opportunities to think creatively about the nature of social research and how one goes about understanding the nuances of impact. There are several strands of knowledge production that can be explored. Some questions ripe for investigation are, what are the biggest motivators for teens to first engage in such out of school time experiences and are certain teens more attracted to these experiences than others? While we recommend program design elements that foster positive experiences for youth, there is an opportunity to further dissect the various program models, and look for patterns. Longitudinal studies are difficult and costly. How can the ecological approach that documents the near-term decisions that youth take be useful in understanding the trajectory towards becoming scientifically literate? Youth engagement programs continue to proliferate in informal science institution settings. The claims we make in this chapter based in the empirical data from various youth programs set the stage for further research.

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Chapter 9
Integrating Mobile Computers into Informal Science Education

Heather Toomey Zimmerman and Susan M. Land

Over the past decade, mobile computers have infiltrated people's everyday interactions across the globe (Gulati, 2008; Kukulska-Hulme, Sharples, Milrad, Arnedillo-Sanchez, & Vavoula, 2011; McCay, Thurlow, & Zimmerman, 2005; Pachler, Bachmair, & Cook, 2010). Mobile computers, as defined here, include a range of devices (and their applications) such as cellular or smart phones, Internet-enabled mp3-players such as iPod Touch™, computer tablets, netbooks or small notebook computers, and portable gaming systems. Most research and education efforts focus on hand-held mobile computers that have capabilities to access the Internet via wireless or cellular signals, enabling communication and collaboration as users share files, data, or information with other users. While not adopted equally across socioeconomic groups, emerging research shows that mobile computing is more currently being adopted by low-income families and families of color in the United States than other forms of computing (Warschauer & Matuchniak, 2010; Yardi & Bruckman, 2012). Consequently, we write this chapter from the perspective that mobile computing is increasingly an effective way to reach a wide-range of learners in informal environments.

In relation to informal science education (ISE) practice, informal learning environments have been early adopters of mobile technologies. The integration of mobile computersin museums is a productive line of research and practice (e.g., Frohberg, Göth, & Schwabe, 2009; Hsi, 2003; Kukulska-Hulme et al., 2011; Phipps, Rowe, & Cone, 2008; Sung, Hou, Liu, & Chang, 2010; Wishart, & Triggs, 2010). Many ISE sites—including gardens, parks, aquaria, zoos, science centers, and museums—are integrating mobile computers into their exhibits through the use of self-guided tours, into camps and programs that use mobile devices, and within exhibitions using image-based tags (i.e., barcodes, Quick Response (QR) codes) or

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electronic (i.e., Radio-frequency identification (RFID) to supplement on-site signage with targeted information for visitors.

In this chapter, we address the need for emerging ISE professionals to understand how to effectively integrate mobile computers into informal learning environments through four design recommendations derived from the informal education and education technology research literatures. By combining informal learning perspectives with affordances of mobile computers from educational technology, we can codify strategies that focus on supporting informal learners to reflect and externalize developing understandings (Jonassen, 2000; Kafai, 2006; Linn, 2006) that are situated within ISE settings. To achieve our goal of offering design perspectives to support innovative ISE practice, the initial part of the paper will orient readers to key concepts related to the role of mobile computers in informal education. Next, we advance a set of empirically-derived design recommendations by reviewing studies.

Fostering Learning with Mobile Computing in Informal Environments: Key Concepts

Prior to offering design recommendations, we start with five concepts related to research in ISE settings and educational technologies, that can be used to orient the design of ISE learning environments that utilize mobile computers: open learning environments, context sensitivity, personalization, place-based education, and informal learning as lifelong, life-wide, and life-deep learning.

Learner-centered perspectives, also called *open learning environments* (Hannafin, Land, & Oliver, 1999; Hannafin, Hill, Land, & Lee, 2013; Land, 2000; Land, Hannafin, & Oliver, 2012), offer to ISE the concept that the learning environment is not only defined by what occurs within that particular setting, but it is also influenced by the prior ideas and purposes of learners. In the open learning environment perspective, a designer considers that the learners' interpretations originate from their personal experiences, emphasizing the mediating role of the individual in defining meaning and establishing learning needs and goals (Hannafin et al., 1999). Open learning environments are typically technology-enhanced and require the coordination of tools, resources, and activities that augment or extend thinking (Land et al., 2012). Identifying learning as a process of constructing knowledge, rather than of passive acquisition of knowledge, requires the designer to be aware of the learner's responsibility to his or her learning process, which, in the end, can create a deeper learning experience (Hannafin & Land, 1997).

Another key concept related to the integration of mobile computers into ISE settings is that of *context sensitivity*. Context sensitivity (Squire & Klopfer, 2007; Squire & Jan, 2007) is one primary affordance of mobile computing, where mobile computers are connected to a specific place through the computer's camera, GPS, or other location-awareness attribute. Sharples (2010) enhances the concept of context sensitivity to encompass more than just being attuned or connected to a location. Sharples argues for a sociocultural view of context sensitivity, where context includes the setting *plus* all the negotiated interactions with other computer users, the computer, the physical location, and others in the physical location. We adopt this broader conception of context sensitivity, where the context relevant to learning with mobile computing blends the leaners' intentions and knowledge, location, time, physical ISE setting, social interactions, and mobile device.

Recently *personalization* has been offered as a perspective underpinning learning with mobile computers (Gamrat, Zimmerman, Dudek, & Peck, 2014; Kearney, Schuck, Burden, & Aubusson, 2012). Two elements of personalization include empowering learners to make their own decisions and customizing their technological experience (Kearney et al., 2012; Pachler et al., 2010; Phipps et al., 2008). Relevant to ISE practice, Kearney and colleagues refer to personalization as the ability for learners to have "just enough, just-in-time, just-for-me" experiences on a "tailored learning journey" (2012, p. 9). Given visitors to informal settings have varying interests, agendas, and expertise (Falk, Moussouri, & Coulson, 1998; Zimmerman, Reeve & Bell, 2008, 2010), personalization, conceived of this way, suggests a role for mobile computers in informal learning environments to help visitors customize disciplinary information provided in ISE settings.

Our conception of informal learning reflects learning as a *lifelong, life-wide, and life-deep* process (Banks et al., 2007) where a trajectory of activities leads to learning across the lifespan—in ways that cross disciplines, institutions, and activities in personally—and culturally-relevant ways (Bell, Lewenstein, Shouse, & Feder, 2009). Learning is a blend of experiences from informal, formal, and informal-formal hybrid activities—often grounded in learners' everyday experiences, interests, and expertise. Informal learning that is lifelong, life-wide, and life-deep includes the learning of content knowledge but it also includes the development of identity, values, beliefs, practices, and expertise.

While our chapter's focus is on supporting informal learning with mobile computers, educational standards still influence learning in informal institutions and in families' homes. In fact, due to educational standardization, one unintended outcome is that people are learning less about their own communities (Gruenewald, 2003). The particulars of local anthropology, ecology, geography, history, and geology are replaced with global issues or generalized concerns. Recent perspectives in science education (Eijck & Roth, 2010; Lim & Calabrese Barton, 2006; Tzou, Scalone, & Bell, 2010) have called for more attention to be placed on science-related *place-based education*. We too take the perspective that mobile computers in ISE settings can support place-based education goals to enhance community-based perspectives in programming and exhibits because, as Smith (2002) argues, "an investigation of local natural phenomena can have comparable benefits and serve as the foundation on which investigations of more distant or abstract phenomena can be constructed" (p. 588). Relevant to ISE practice, place-based education activities keep learners' efforts grounded in their everyday, informal experiences, as a means for learners think through concepts of global and local importance. Relatedly, a thorough review of educational fieldtrips using mobile devices (Meek, Fitzgerald, Priestnall, & Sharples, 2013) found that place-based perspectives were often part of a successful learning experience for learners.

In summary, mobile devices, with their context-sensitive affordances are ideal tools for use within open learning environments that are personalized to support place-based, lifelong, life-wide, and life-deep learning in ISE settings. For example, mobile devices may be effective in applying informal education perspectives given the research that shows digital photography can be a tool to support reflection about activities within a place (Ching, Wang, Shih, & Kedem, 2006) and is an important home-to-school place-based tool (Tzou & Bell, 2010). Additionally, when blending open learning environments with place-based education pedagogy on mobile computers, ISE practitioners can reinforce the role of educational field trips to local areas, finding connections of the local setting to global issues of the broader curriculum (Bouillion & Gomez, 2001; Zimmerman & Weible, 2016).

Recommendations for Integrating Mobile Computers into ISE Learning Environments

From bringing together theoretical perspectives at the intersection of educational technology and informal science education from the prior section of this chapter (i.e., open learning environments, context sensitivity, personalization, place-based education, and informal learning as lifelong, life-wide, and life-deep), we derived the following four design recommendations for integrating mobile computers into informal learning environments.

1. Facilitate "heads-up" technology use that supports social interactions within informal spaces;
2. Augment the visitors' experiences with games, scientific narratives, and disciplinary-relevant aspects;
3. Incorporate activities that move the visit away from a passive consumption of facts towards the active generation and use of new knowledge; and
4. Revisit the learning experiences afterwards with the inclusion of bridges to home or community, use of social media, and connections to the same or other ISE sites.

Facilitate "Heads-up" Technology Use that Supports Social Interactions Within Informal Spaces

Work in ISE settings suggest that design for technologically-enhanced learning should support visitors to use mobile computers to supplement—not replace—the ISE experience in order to avoid what has been called "heads-down" interactions (Hsi, 2003; Lyons, 2009), which is the "one-way transmission of information via a tiny display" (Hsi, 2003, p. 317). Our perspective on successful integration of mobile computers into ISE learning environments advocates for designing engaging *heads-up interactions* with the scientific phenomena, ISE setting, and social partners for visitors in ISE settings (see Fig. 9.1).

Heads-up learning includes opportunities to communicate in informal environments. Communication is important for visitors in ISE settings because talk in museums is a needed part of the process of learning (Allen, 2002; Leinhardt, Crowley, & Knutson, 2002). Conversations are used to understand new ideas, to integrate new ideas with existing knowledge, to support collaborative sense making, and to engage in science practices like explanation building.

One strategy to foster learning conversations is to use mobile computers to support the learners' observations within the ISE setting with additional images or digital resources. These digital supports can provide museum visitors with perspectives not typically visible or accessible to them without significant prior knowledge or other externalized support (Land, Smith, & Zimmerman, 2013).

Fig. 9.1 Two learners using a mobile computer environment designed by Zimmerman and Land's team to support learning about trees (Zimmerman et al., 2014). This photograph shows heads-up engagement, where learners engage with the nature phenomenon and each other as they use mobile computers on an outdoor ISE natural trail

Tan, Liu and Chang (2007) provided such support via photographs presented on a mobile device depicting an actual scene of a pond. Learners were cued to recognize where to locate a given plant, in order to access corresponding scientific information about the plant species. Mobile computers provided close up images of plants that would otherwise be difficult for learners to recognize without support. Similarly, Reiger and Gay (1997) designed a mobile fieldwork environment for use by undergraduate genetics students for an exercise at a corn test plot on the Cornell campus. Using computers in the field, learners reviewed databases of digital images, genetic models, and cross-sections. Learners entered data such as plant height and soil pH, in addition to pooling the data across groups, supporting more complex knowledge sharing and analyses onsite.

In another example of mobile computers fostering conversations between peers, Rogers and colleagues (2004) found that learners who engaged with the mobile learning tool *Ambient Wood* developed explanations of their own data collected about moisture and light in an ISE forested environment. This research found conversation also occurred as learners compared their data to their peers' data to make sense of patterns about which species lived in specific parts of a habitat.

Augment the Visitors' Experiences with Games, Scientific Narratives, and Disciplinary-Relevant Aspects

Our second recommendation for integrating mobile computers into learning environments is to use the mobile computer as a tool to augment the visitor's experience through bringing in digital content in a context sensitive way. Technologies can support learners to "engage with virtual information superimposed on physical landscapes (such as a tree describing its botanical characteristics or a historic photograph offering a contrast with the present scene)" (Dunleavy, Dede, & Mitchell, 2009, p. 8). For example, practitioners can use mobile computers to support ISE learners to access disciplinary-relevant information, collaborate with peers or experts not present in the setting, and create novel content in social media, web-based products (see Fig. 9.2).

A strategy relevant to ISE practice related to integrating mobile technologies into programming and exhibits is to use the mobile devices to highlight important scientific information that experts would attend to (Linn & Slotta, 2000) if visiting that place. For example, mobile devices can display graphical information that can direct learners to notice key characteristics of an ISE exhibit. Research in a botanical garden with families (Zimmerman et al., 2015), presented photographic images of pinecones similar to, or different from, those trees available on-site in the Arboretum at Penn State; this use of photographic images as data promoted observational inquiry (Smith & Reiser, 2005) and explanation building around the concept of biological form and function as evidenced by the describing talk (called perceptual talk by Allen, 2002) uttered by visitors. Supporting contextualized

Fig. 9.2 Three learners and a naturalist are using a mobile computer environment designed by Zimmerman and Land's team (Zimmerman et al., 2014). This photograph shows the use of an augmentation on the mobile computer through a conceptual display of the life cycle of trees, to show learners information related to their ISE experience

information on mobile computers allowed learners to notice relevant distinctions and formulate disciplinary-specific explanations about them. Phipps et al. (2008) used video, rather than photographs, to augment the narratives in a space. Phipps and colleagues found that providing videos to visitors at an aquarium, including information of behind-the-scenes footage, was well received by the 68 groups of visitors who participated in their study. In their discussion, however, they noted that there might be a limit to how much augmentation that visitors would appreciate, noting that too much inclusion of new materials may not be aligned with visitors' expectations of visiting an ISE facility.

Many mobile learning projects use argumentation as part of a gamification pedagogy of "participatory simulations" where a game-based narrative is added as a virtual layer on top of the actual setting. Environmental Detectives is a participatory simulation where the physical setting is connected to the gaming narrative deployed by a mobile computer where the learners engage in an environmental engineering game (Squire & Klopfer, 2007). Likewise, Outbreak @ the Institute is a participatory simulation where players encounter virtual avian and seasonal influenza as they play a game interacting with others across a physical space (Rosenbaum, Klopfer, & Perry, 2006). Similarly, some scholars have integrated gamification elements into mobile storytelling in historic sites (Dunleavy, 2014; Oppegaard & Grigar, 2014). Such projects create a blending of the physical and digital environment using mobile computers, connected via historical storytelling of "what is implicitly built into the local landscape" (Oppegaard & Grigar, 2014, p. 21), but may no longer be recognizable in the physical space itself. Mobile computers offer technological affordances that can be deployed to layer various interleaving narratives, biographies, and artifacts that ISE sites inherently contain but are not generally accessible without some level of disciplinary expertise.

Incorporate Activities that Move the Visit Away from a Passive Consumption of Facts Towards the Active Generation and Use of New Knowledge

Given the portability of mobile computing devices, informal learning environments have utilized mobile computers to provide users the ability to access information, record field observations, or search databases onsite to identify plant, insect, or animal species present in natural settings (Chen, Kao, & Sheu, 2003, 2005; Rogers et al., 2004). Many ISE settings rely on docents or volunteer enthusiasts to provide tours or instruction. Others have set-up citizen science programs that use technology to engage learners in self-directed exploration that capture, collect, and categorize digital information about plant and animal species or environmental conditions more generally (e.g., Newman et al., 2012). To address learners on-site or in citizen science programs, mobile devices have been used to augment the expertise or information that is available to transform the ISE space into a just-in-time, personalized learning space. Our third design recommendation incorporates the successes of these programs so that technologically enhanced learning activities move visitors away from passively consuming facts towards actively generating and using new knowledge. Such personalized, just-in-time computing strategies can potentially transform an outdoor ISE from a place of casual activity into an interactive field laboratory. For instance, the Sundial project (Halpern et al., 2011) developed an iPhone app for use at a science museum. Families used the iPhone app to systematically engage in and record field observations using photos, videos, field notes, and through responding to questions generated by the application. In one activity, users were guided to take photographs of shadows from a large sundial and asked questions about the role of seasons on the shadows. The users' photographs and field notes could be shared with a facilitator at the end of the experience to be used as artifacts for further discussion (see Fig. 9.3).

Informal learning environments have also utilized mobile technologies to store rich information, images, or resource repositories that can be searched and accessed on demand while exploring at an ISE setting. For instance, Chen et al. (2003, 2005)

Fig. 9.3 Two learners are engaged in a knowledge generative task by Zimmerman and Land's team (Zimmerman et al., 2014). This image shows a photo collage that the girls created on an iPad mini during their summer ISE camp experience

developed a mobile image-retrieval system to support bird watching and butterfly watching, with the goal of simulating the kind of support provided by a naturalist. The retrieval system provided additional detail and ecological data about the species being observed. Likewise, Liu, Peng, Wu, and Lin (2009) used Tablet-PC devices for learners in Taiwan to learn more about local ponds and aquatic plants. The mobile learning environment was developed to guide natural-science learning of plants using illustrations and photos depicting the characteristics of the actual species in the pond. Learners saw close-up views and detailed information in order to easily locate the corresponding plant. The activities encouraged visitors to engage in comparisons between plants to foster stronger understandings. Research findings suggested that use of the mobile learning environment resulted in increased knowledge and understanding of the aquatic plants as well as enhanced learners' observational practices.

An important design element of augmenting ISE learning is to provoke reflection and discussion by users about their surroundings (Rogers et al., 2004). This can include content information (e.g., what kind of object or species users are viewing), but also other information that may not be directly perceived by most users in a space, either due to seasonal regularities, changing climates, or the absence of specific wildlife at the time of the visit. The Ambient Wood Project (Rogers et al., 2004), for instance, involved a variety of augmentations that could be accessed via PDA at an ISE's woodland to "reveal abstract processes taking place in the habitat (e.g., photosynthesis), enabling the learners to discover things they might not notice otherwise" (p. 3). This was accomplished via probe tools for discovering data about the habitat such as moisture readings or pre-recorded sounds of bird sounds or insect scuttling.

Revisit the Learning Experiences Afterwards with the Inclusion of Bridges to Home or Community, Use of Social Media, and Connections to the Same or Other ISE Sites

While the focus of the three prior recommendations was on integrating mobile computers within informal settings to enhance the experiences of people during their ISE visit, our final recommendation focuses on how mobile technology can also extend the learning experience and conversations *after* the visit. Early work (Hsi & Fait, 2005) examined the use of RFID tags within a science center to personalize the visitors' experiences through displaying interesting content on learners' personalized Web pages. Zimmerman, Gamrat and Hooper (2014) conducted design-based research to integrate postcards to home from youth attending a summer camp. They found that after receiving an email with a digital picture that their child took during summer camp, parents reported that the digital postcards served the purpose of alerting them to their child's interests related to camp (see Fig. 9.4). Parents indicated an intention to follow-up on their children's interest in future summertime activities.

Scholars have also used mobile technologies to enable users to capture and share information from an ISE visit to coordinate with later classroom activities (Huang, Lin, & Cheng, 2010; Hwang & Tsai, 2011). Sometimes referred to as "nomadic inquiry" (Cahill et al., 2011; Hsi, 2003; Kuhn, Cahill, Quintana, & Schmoll, 2011;

Fig. 9.4 This is a digital picture of a frog in a pond taken by a child and used in a digital postcard that was sent to parents during the Zimmerman et al. (2014) partnership with a nature summer camp

Rieger & Gay, 1997), these mobile learning activities span across at least two settings to help bridge school and ISE settings, such as museums, zoos, parks, and aquaria. Quintana and colleagues (see Cahill et al., 2011; Kuhn et al., 2011), for instance, developed *Zydeco*, which is a mobile-app system to support students to plan investigations, capture, and annotate evidence from an ISE site, in order to link evidence with future explanations that are further explored back in classrooms. Similarly, Tan et al. (2007) developed a mobile learning infrastructure to enable educators to manage pupils' learning at the Guandu Nature Park in Taiwan. Learners scanned RFID tags at the park to receive context-aware content to their PDAs. Learners used the system to receive messages from teachers, record videos from the park for later classroom annotation, and create and share notes that could be compiled into a team report. Children using this system outperformed peers who did not use the system across six different assessments of learning, suggesting that designs that extend how learners engage with disciplinary-relevant information in ISE environments show promise as an informal learning strategy.

The photographic capabilities of the mobile computer can also be used to aid learners in capturing photographs from an informal learning environment that can later be analyzed to make meaning about the observations they see. So and colleagues (2009) built on this idea when they found that social tagging supported collaborative knowledge building among the class on a fieldtrip. Through the use of Google Maps, a learner could see the notes and tags that classmates added about the same location. Learners could ask questions, answer someone's questions, or provide additional information about the places that the class visited. In addition to digital photography, learners can capture other forms of data; for example, people can take environmental quality data as in the FreshAiR project that combined augmented reality with electronic probes (Kamarainen et al., 2013). In the case of FreshAiR, sixth graders from five classrooms measured the quality of water at a pond while on a fieldtrip. These learners were able to share their data both on-site as well as back in the classroom, extending the fieldtrip experience beyond the actual visit.

Conclusion

Within this chapter, we presented a four-prong design framework to integrating mobile computers into ISE. By building on the concepts of learner-centered, context sensitivity, personalization, place-based education, and informal learning as lifelong, life-wide, and life-deep, we developed four recommendations that that focused on supporting informal learners to develop robust understandings and meanings within ISE settings. The four empirically-derived design recommendations with implications for mobile computing in ISE settings are: (1) Facilitate 'heads-up' technology use that supports social interactions within informal spaces, (2) Augment the visitors' experiences with games, scientific narratives and disciplinary-relevant aspects, (3) Incorporate activities that move the visit away from just a passive consumption of facts towards the active generation and use of new knowledge, and (4) Revisit the learning experiences afterwards with the inclusion of bridges to home or community, use of social media, and connections to the same or other ISE sites. These recommendations represent a starting point for ISE practice on integrating mobile computers into museums and other informal settings.

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Chapter 10
Designing Informal Astronomy Education Toward Participatory Learning Environments

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Researchers have characterized informal science learning as self-motivated, voluntary, and guided by learners' needs and interests (Dierking, Falk, Rennie, Anderson, & Ellenbogen, 2003). Further, it is strongly observational and participatory, fusing both emotional and intellectual domains, and occurring where meaning is intrinsic to context (Scribner & Cole, 1973). This finding is important and should be taken into consideration in the design and implementation of effective learning environments for learners. With the increased emphasis on informal learning, this article places particular emphasis on informal science learning and describes the stories of how to design informal astronomy workshops for Singaporean youth.

Astronomy is not provided for in formal school education for youths in Singapore, but students usually have high interests in learning astronomy concepts in many informal learning settings including families, the Science Center, museums, and communities. To provide astronomy education opportunities, our research team designed outreach programs by collaborating with a school physics teacher. In particular, we focused on designing hands-on modeling activities so-called "Multimodal Mediated Modeling Activities" (EMMA) (Kim & Lee, 2013). A growing body of literature has also demonstrated the beneficial effects of hands-on activities in science teaching and learning across formal and informal learning contexts (Schwarz & White, 2005). It is commonly recognized that teachers play a vital role in the development of hands-on model-based activities. Yet, novice teachers and even experienced teachers often face many challenges in adapting the modeling-based approach to the experience, knowledge and needs of learners (Kim & Ye, 2013). Therefore, this chapter aims to describe the stories of how to design informal EMMA workshops so as to support prospective teachers to engage in modeling-based activities.

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Literature Review

Given the implicit importance of the model-based instruction literature to the development of EMMA, this section will provide Vygotskian theoretical perspectives while considering conceptual change theory that has been advocated by science educators in order to develop new learning environments. This literature review is important because these perspectives implicate radically different pathways for designing learning environments as compared to traditional science teaching and learning.

Model-based instruction in science education has focused on a radical and major reorganization of learners' prior knowledge for the acquisition of scientific concepts drawing on cognitive perspectives. From this perspective, it is argued that learning is not a way of adding new knowledge into learners' existing knowledge but a process of conceptual change. Hence, learners' conceptual change is viewed as theory change in science, which is characterized by the knowledge acquisition. Conceptual change, as researchers argued, is the use of an additive mechanism that causes a learner to add the new information into the incompatible knowledge base, leading to producing *synthetic models*, *misconception* or *alternative frameworks* (Posner, Strike, Hewson, & Gertzog, 1982), rather than the development of currently accepted, correct scientific views. As such, conceptual change researchers have made much contribution toward understanding and explaining learners' difficulties in learning astronomy behind the formation of misconceptions.

In that sense, Vosniadou's, (1994) theoretical framework, so-called 'knowledge-as-theory' with a top-down approach, becomes one of the most prominent approaches that guide research and instructional practices in astronomy education. However, her framework was also subjected to several criticisms (e.g., Caravita & Halden, 1994; Smith, diSessa, & Roschelle, 1993). It was pointed out that *alternative conceptions*, *preconceptions,* or *misconceptions* may be not as robust as it is in theory, and conceptual change is a slow and gradual process rather than a dramatic, gestalt shift happening over a short period of time. It was also argued that misconceptions are not always well-formed and/or resistant to change. By considering these critics, Vosniadou (2007) also modifies interpretation of conceptual change into *the framework theory* from *theory-like*. From this framework theory approach, the naïve, intuitive, and domain-specific theories become more focused. Naïve ideas are interpreted as resulting from the learners' everyday experiences under the influence of lay culture and needed to be changed. It is stated that "science learning does not require the replacement of 'incorrect' with 'correct' conceptions, but the ability on the part of the learner to take different points of view and understand when different conceptions are appropriate depending on the context of use" (Vosniadou, 2007, p. 10). This seems to be better congruent with constructivist emphasis on learners' prior knowledge and experience.

However, this is quite different from the sociocultural views of knowing and learning first outlined by Lev Vygotsky's theory on concept formation in two aspects: (1) *dialectical aspect of concept formation*; and (2) *activity-based concept* *formation*. First, compared to the above stated conceptual change theory influenced by constructivist perspectives, Vygotskian (1986, 1987, 1997a) perspectives draw attention to a dialectical approach to higher mental functions. For him, it is taken as important that concepts are not merely mental representation such as entities or images of some kind existing inside the head. Instead, he gave real insight into the learner's knowledge or capacity within a particular socio-cultural context rather than differentiating a world of mental objects and a world of material objects in terms of Cartesian dualism. Vygotsky argued that mental processes are not independent processes but are dependent on, subordinated to and defined in the course of changes originating in human social environments. Hence, his approach to concept formation is quite different from simply categorizing objects under certain concepts or defining a verbal definition of the concept outside the context of everyday life.

For instance, Vygotsky (1986) pointed out the genetic and dynamic relationships between spontaneous or everyday concepts and nonspontaneous or scientific concepts. He suggested that children's scientific concepts are viewed top down and their everyday concepts are viewed bottom-up (p. 102). Thus starting from opposite positions they move towards each other. For example, learners become conscious of their everyday concepts once they have acquired scientific concepts. Through integration with everyday concepts, scientific concepts as taught in formal learning contexts descend to become concrete, and unconsciously defined, performed and embedded in everyday practices. However, although Vygotsky classified scientific concepts learned in formal education system in order to compare them with spontaneous everyday concepts acquired in everyday life, he viewed the two types of concepts as parts of an essentially unitary process. He therefore stressed the important role of teachers who need to explicitly integrate a student's subjective experience and personal knowledge of everyday concrete events with conceptual knowledge in communities of domain-related practices (van der Veer and Valsiner, 1991).

Secondly, unlike traditional experimental psychology, Vygotsky suggested that lower natural mental processes could be transformed into higher or cultural psychological functions through the mediation of words and other semiotic tools. As such, he characterized the process of concept formation as mediated activities by semiotic tools, rather than by the immediacy of intellectual processes. In particular, Vygotsky addressed a dialectical process of interconnecting the senses and perception with knowledge and truth, which tend to be viewed as independent entities. Although he focused on the role of semiotic tools, in particular the function of language, Vygotsky (1978) also regarded make-believe play, drawings, movements, mathematics, and arts as important tools for supporting learners' unique and idiosyncratic sense making towards the development of concept formation (Kim, 2011).

Compared to Vygotsky's well-known meaning making processes, his notion of sense making receives less attention. Meaning is the most stable and precise zone of several dynamic, fluid, and complex zones of sense (Vygotsky, 1986, 1997a). *Sense* refers to the whole set of psychological events elicited by a word in terms of activities, impressions, and personal meanings. His notion of inner speech indicates also the importance of sense-making for constructing concept formation. Inner speech is more mediated by the personal emotionally charged sense of *words* or *concepts* rather than by the common understandings of the sociocultural meanings of words or concepts. Since words acquire sense from the contexts in which they occur, inner speech is not intelligible without context. Vygotsky (1987) used this concept of sense to explain the internalization process through which sense develops in the individual's system of meaning and is developed by sociocultural meanings.

These interrelated aspects of meaning suggest the need for a reconsideration of socioculturally mediated concept formation. Vygotsky addressed the important role of social interactions in sociocultural contexts in developing higher mental functions through the appropriation of semiotic tools or what Vygotsky (1978, 1997a) called 'psychological tools' including extra-linguistic tools (e.g., drawing, movement, works of art, music, numeracy). Consequently, these Vygotskian perspectives on concept formation allow a better understanding of the participatory learning environments whereby learners are considered as active knowledge constructors through participating in authentic activities. Drawing on these Vygotskian perspectives on concept formation, this chapter will examine the design principles of the EMMA workshops working with diverse populations in informal multiple settings so as to promote their deeper conceptual development of astronomical phenomena in a participatory learning environment.

The Study

Over the course of two years, our research team has developed the EMMA workshops across different contexts working with diverse population who have interests in astronomy with an aim to create opportunities for them not only to learn astronomy phenomena but also to teach the astronomy related topics to others, especially within informal educational settings (Kim, Lee, & Ye, 2012a). This EMMA workshop views the workshop participants as both teachers and students of astronomy.

Setting and Participants

Starting from 2009, the research team conducted four workshops in the pilot study phase with the focus to explore the relationship between the interconnected elements among modeling, observation, and concepts as shown in Fig. 10.1. These four workshops were designed not only to promote workshop participants' interests

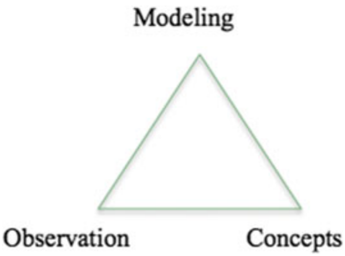


Fig. 10.1 Interrelationship among observation-modeling-concept formation

in astronomy but also to explore design features that could guide subsequent EMMA workshops toward developing a participatory learning environment.

Table 10.1 describes each of the EMMA workshops including participants, sites, and duration as well as the main theme.

Four workshops were conducted such as EMMA I with the school astronomy club students (15–17 years old) at a local junior college, EMMA II with 4 primary school teachers and the school astronomy club students at a local junior college (15–17 years old), EMMA III with 15 children with special needs (aged 7–14 years old) at the primary school, and EMMA IV with 22 secondary school students (13–15 years old).

Table 10.1 Settings and participants in the EMMA workshops

Workshops	Site	Number of participants	Duration	The main theme	Models
EMMA workshop I	Malaysia	10 local junior college students (15–17 years old)	Two nights, 3 days astronomy camp in 2009	Solar System	2D drawings, 3D physical models
EMMA workshop II	Malaysia	2 student facilitators, 11 local junior college students (15–17 years old) of astronomy club, 4 primary school teachers	Two nights, 3 days astronomy camp in 2010	Solar System	2D drawings, 3D physical models
EMMA workshop III	Singapore	15 children with special needs (aged 7–14 years old) at the primary school	1 day in 2010	Day and Night	2D drawings, 3D physical models, Role-playing
EMMA workshop IV	Singapore	22 secondary school students (13–15 years old)	2 days and half day in 2010	Moon Phases	2D drawings, 3D physical models, 3D computer models

Data Collection & Analysis

The overall research project adopts a design-based research (DBR) approach to create the EMMA workshops through cycles of co-designing, implementing, analyzing, and refining the EMMA workshops with the participants (Barab & Squire, 2004; Brown, 1992). The main purpose of this chapter is to explore design principles that enhance the effectiveness of the EMMA workshops toward a participatory learning environment. Through four separate EMMA workshops taking place across multiple sites with diverse population (see Table 10.1), this chapter will examine the main design progression across the EMMA workshops that characterize the overall nature of the design principles toward participatory learning environments. For the in-depth understanding of the learning process among the participants, multiple interconnected data sources were collected such as the participants' paper-and-pencil pre- and post-survey regarding the workshop theme, video- and audio-taping of the workshop, artifacts, interviews, Facebook posts, and the researchers' reflective journal. Detailed information about each workshop can be found in other articles (Kim, Lee, & Kim, 2011; Kim, Lee, & Ye, 2012b). Specifically, this article employs a narrative research (Clandinin & Connelly, 2000). Hence, after collecting detailed stories of each workshop, I reorganized and rewrote the stories within a chronological sequence (Ollerenshaw & Creswell, 2002) for "organizing episodes, actions and accounts of actions" (Sarbin, 1986, p. 9). Using the constant comparative method (Strauss & Corbin, 1990), empirical findings of each workshop were also compared with the overall EMMA workshop goals and outcomes.

Once audio- and video-recordings of each workshop were transcribed, three researchers independently went through these transcripts while connecting with other relevant data sources. Drawing upon such individual interpretations and emerging evidences, in order to reach a consensus about identifying and defining the main design procession of the EMMA workshops, all three researchers engaged in communication, argumentation, negotiation, clarification and identification of the design progresses in terms of dynamic interrelationships among the workshop design objectives, the workshop results, and the workshop reflection for improvements. This data analysis also focused on making sense of how to make a connection among the successes and challenges across the EMMA workshops.

Findings

As described in Fig. 10.1, the interrelationship among observation-modeling-concept formation was addressed so as to explore how authentic observation experiences could be integrated in multimodal modeling activities for promoting the participants' concept formation. Table 10.2 summarizes these workshop objectives, outcomes and reflections.

Table 10.2 The Summary of the EMMA workshops

Workshop	Objectives	Results	Reflection for improvements
EMMAI	• Integrating observation-based modeling for concept formation • Exploring affordances of modeling	• The workshop participants represented their prior knowledge (e.g., size and order of planets in the solar system) when they constructed a model • Sky observation stimulated the participants to integrate new celestial objects into their initial model (e.g., male group: Inserting a star chart in their model; female group: revisiting their observation experience to identify the position of their constellation) • Some participants made cultural association and aesthetic representation in their models (e.g., angel for representing virgo constellation) • Multiple models provide collaborative learning within and between groups • Model modification required scaffolding from facilitators. • Most participants needed inquiry learning skill to explore and improve models • Weak connections between observation and modeling • Insufficient guidance for facilitating observation, modeling and concept formation	• To explore facilitator scaffolding strategies • To conduct a literature review about affordances of models • To improve the connection between sky observation and modeling
EMMAII	• Integrating observation with modeling • Incorporating modeling evaluation and revision • Investigating the roles of student facilitators and main facilitators • Investigate how teachers learn through modeling	• The workshop participants talked about their prior knowledge about stars, planets, and tilted plane of the Earth while constructing the model • The workshop participants had difficulty to build explanatory models of the solar system initially • Student facilitators played the roles to facilitate the workshop participants to build a model to connect their solar system knowledge and night-sky observation • A main facilitator (HJ) developed an argumentative approach by posing a scenario-based question to bridge the gap between modeling and observation • Teacher participants constructed their model by	• To improve instructional design for allowing the workshop participants to engage in observation-based inquiry and to develop an explanatory model beyond an illustrative model • To establish an astronomy community to support modeling experience in learning and teaching astronomy-related topics

(continued)

Table 10.2 (continued)

Workshop	Objectives	Results	Reflection for improvements
		relying on authoritative sources (e.g., their knowledgeable colleagues, reference books or the owner of the material shop) under lack of inquiry skills to explore their own models • Teachers did not incorporate their night-sky observation experiences in modeling. • The workshop participants recognized the limitation of their model	
EMMAIII	• Integrating observation with modeling • Developing multimodal modeling including ICT-integrated storytelling • Allowing young children with special needs to understand better concepts of day and night • Providing them with their first multimodal modeling experience	• Developing multimodal modeling teaching and learning: Multimodal modeling activities (audio, visual and kinesthetic modality) such as 2D drawing, ICT-integrated storytelling and role-playing were employed to anchor their interests and experiences to explore concepts of day and night • Understanding young children's prior experiences and perceptions about day and night: They enjoyed multimodal modeling activities including moon and saturn observation and role-playing • 50% of students explained occurrence of day and night drawing upon motion of celestial objects • Connection between activities was still weak • Observation makes learners engaged and facilitates their interests	• To improve the connection between sky observation and modeling • To improve the connection among activities • To co-design lesson with school teachers to better understand their students' experiences, knowledge and interests
EMMAIV	• Integrating observation with modeling • Developing interdisciplinary activities • Exploring a guidance for modeling from illustrative to explanatory models • Exploring students' understanding of the moon phases	• Developing interdisciplinary modeling lessons for "moon phases and moons of jupiter" • Constructing, evaluating, and modifying models are key learning activities • The modeling process allows the participants to engage in discussion to clarify their models. This allows them to change their perspectives • Participants were able to understand and explain the position of new moon and full moon through modeling	• To improve the connection between sky observation and modeling: The topic of moon phases need long term observation • To improve the connection among activities • To co-design lesson with school teachers to better understand their students' experiences, knowledge and interests

(continued)

Table 10.2 (continued)

Workshop	Objectives	Results	Reflection for improvements
		• Multimodal models afforded the workshop participants to explore different concepts of the moon phases (e.g., 2D drawing to discuss about the sequence of moon phases; 3D concrete model with a light bulb to indentify the positions of the new and full moons; 3D software to demonstrate the tilted plane of the Moon's orbit) • Facilitation is important to highlight participants' contradictory ideas, which in turn motivate them to prove their argumentations	

EMMA Workshop I

A two-night three-day astronomy camp in 2009 was designed to support the participants' solar system concept formation through night sky observation and their collaborative construction of models (Kim et al., 2011). In the workshop, there were ten Singapore junior college students belonging to the school astronomy club with high interests in learning astronomy. Night sky observation in Malaysia was arranged for them to observe stars and planets and become motivated to model them using 2D drawing and 3D physical models. Their school teacher named HJ (pseudonym) guided and facilitated the workshop activities as a result of the collaboration with the research team. As an expert physics teacher, HJ had won teaching awards locally and he himself enjoyed and recommended strongly sky observation in understanding and exploring astronomical phenomena. As such, the research team with HJ explored and predicted upcoming sky conditions during the workshop using computer-based models (e.g., Saturn at about 8 pm; Milky Way from 8 pm onwards; Mars, Jupiter and Neptune at about 5 am) so as to encourage the participants to make a connection between sky observations of certain astronomical phenomena and modeling activities. For instance, multiple materials such as polystyrene balls, sticks, wires, papers, star chart, cotton wool, cardboards etc. were prepared for the participants to make their own decisions on which materials were appropriate for modeling night-sky observations.

There were two groups because the participants preferred splitting into groups with their respective genders. Interestingly, the ways of modeling of the night-sky observation were different between groups. A group of males did not spend sufficient time discussing what they observed. Instead, they put more efforts to display mainly their prior knowledge of the solar system to come up with their model. Below is the excerpt that showed their main focus and emphasis on factual knowledge about the planets in the solar system rather than incorporating their sky observation experiences. Figure 10.2 also shows that although they observed the

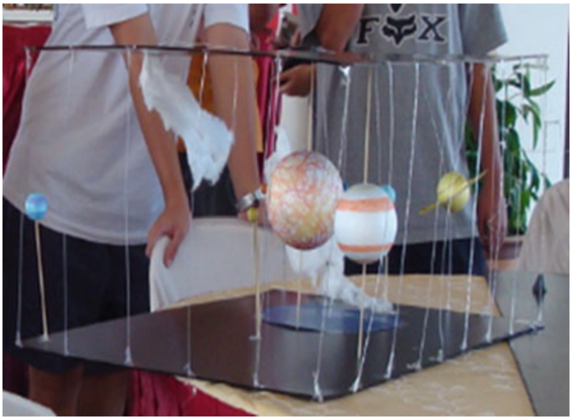


Fig. 10.2 The male group's night sky model

sky from the Earth, by drawing on their factual knowledge, they constructed their model from a top view perspective of the solar system representing the entire solar system with an emphasis on the accuracy of representing interesting properties, colors, shapes, sizes and distances of each planet (e.g., the red dot of Jupiter, the ring of Saturn, the tilted Earth).

M4: Mars a bit too small
(*M3 compared the size of Mars with other planets*.)
M2: No, Mars is nice.
M2: It's just bigger than Mercury and smaller than earth.
M2: Wait, that's not Venus, that's smaller…
M2: Shouldn't it be smaller than this?
M3: That's Venus.
(*Students agreed with the size of Mars after comparison*.)
M1: (Do) you want to do Jupiter or not?
M3: I will be doing it.
M1: You want to do Jupiter. Let's color brown stripes.

On the other hand, compared to the male group, the female group was very much based on their own experiences with the night-sky observation. They discussed among group members about where the stars were around a certain time and wanted to build their model to show their knowledge and experiences about the night-sky observations. In this process, the female participants tried to reflect on their prior knowledge, daily experiences, night-sky observation experiences on a previous night, and interpretation. As shown in Fig. 10.3, they constructed the night sky model as seen from the Earth perspective, including only what they observed. However, they were more artistically inclined so that they spent much time on discussing artistic aspects (see Fig. 10.3).

This result shows that it is not easy for the participants to integrate their concrete observation experiences with their modeling activities towards understanding and

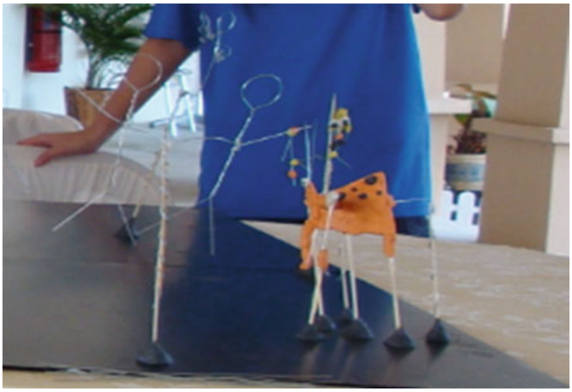


Fig. 10.3 Modeling the night sky in the female group

exploring why celestial objects appeared the way they saw on the sky. They just attempted to "arrange [the model] such as more like what we saw last night" (Interview with one student, March 2009). With respect to such a modeling approach, the research team including HJ tried to carefully observe and listen to what they did, expressed, told, constructed, and questioned. This careful listening allowed HJ to highlight and consolidate similarities and differences between two groups rather than simply pointing out the correct model. Eventually, the female group came up with the idea of merging those two very different modeling approaches. The male group also agreed with the idea of merging two models and started to discuss how to merge them. This emergent idea indicates that two groups became more open-minded and were willing to revise their models by communicating and integrating new ideas.

EMMA Workshop II

The integration of concrete observation experiences into modeling activities also became the most important part of the EMMA Workshop II. Similar to the EMMA Workshop I, there were also junior college astronomy club members who were all new members except two senior members. They worked as facilitators in the EMMA Workshop II to guide their junior students based on their previous experience in the EMMA Workshop I. Additionally, there were four primary science teachers who were supposed to explore how to involve their students in learning activities using a telescope recently purchased at their school. Despite having their science background, teacher participants tended to endeavor to look for one correct idea or answer when they constructed their model in relation to their night-sky observations. For instance, before arriving at the workshop without having observation experiences, they had already decided on a full set of modeling materials, astronomy reference books, and a star chart. Further, during the modeling activity, they mainly followed the direction of one male teacher with more of a physics

Fig. 10.4 Modeling the night sky in the teachers' group

background, rather than attempting to arrive at their own understanding and explaining of target astronomical phenomena. Hence, while constructing their model, teacher participants did not pay more attention to exploring how a phenomenon occurred at the night-sky. Figure 10.4 shows their model of the solar system, which mainly exhibited information that was recognized as a scientifically accepting fact by authoritative sources such as their knowledgeable colleague(s), reference books, or the owner of the material shop.

Hence, compared to student participants, teacher participants did not incorporate their own interpretations, experiences, and impressions related to night-sky observations and the modeling activities. For example, HJ pointed out that their initial model did not explain why they could observe the rings of Saturn and Milky Way from a particular direction in the sky at a particular location and time though they could not see the Moon. However, although the other group of students tended to communicate their understanding of the target phenomenon through reflecting upon their night-sky observation experiences or evidences, it was not obvious that they used their model to explain how observed phenomena occurred.

In order to cater to such learning needs of the participants, HJ played an important role of not criticizing but valuing, accepting and challenging their models. Specifically, there were two important instructional strategies HJ implemented based on close collaboration with the research team and his own learning and teaching experiences involving modeling activities. First of all, HJ explicitly addressed the importance of remodeling processes whereby the participants had an opportunity to make connections between their own sky observation experiences and the model construction. Similar to the previous workshop, he encouraged the participants to revise their models based on information from their night-sky observation experiences. Secondly, in relation to the EMMA processes, HJ started to emphasize and develop an argumentative approach by posing a scenario-based question, asking the participants to imagine themselves in a situation in which they were supposed to prove and explain their ideas or argumentations using models they constructed to persuade others (e.g., young children) who were assumed to be with little knowledge of science.

EMMA Workshop III

The subsequent two workshops also continuously attempted to develop the use of modeling so as to encourage the participants' engagement towards promoting concept formation in astronomy. In particular, with an aim to better support the participants' modeling experiences, *interdisciplinary approaches* and *multimodal modeling* were incorporated so as to emphasize the active participation of the workshop participants in authentic practices by integrating across domains using various forms of representations. Compared to the previous two EMMA workshops occurring in Malaysia, two workshops with the Scout Camp and the Science Club took place within Singapore because the participants were relatively young with special needs. By taking the interdisciplinary multimodality modeling approach, the research team came up with an authentic theme for the workshop with respect to the participants' expectations, experiences, challenges, and abilities. For the Scout Camp workshop, the theme of "Day and Night" was selected, because these were not only the daily astronomical phenomena for them, but were also recognized as one of the fundamental astronomical concepts (Lelliott & Rollnick, 2009). Further, the astronomy simulation software (e.g., Stellarium) predicted that the participants could observe the moon during the workshop so that it was possible for them to get an embodied, authentic, and concrete experience.

With an emphasis on contextualization and visualization of astronomical phenomena so as to connect with the children's prior knowledge and experiences, the ICT-integrated storytelling activities were designed and implemented. Rather than telling simply a scientific explanation about the cause of day and night, the research team helped the children with special needs experience a variety of stories with respect to the cause of day and night across different cultures. Following the storytelling activity, the children with special needs were grouped for communicating and sharing their ideas, thoughts and questions about day and night using a 2D drawing, 3D researcher-created physical scale models, human modeling as well as observing the Moon and the Moons of Jupiter through their naked eyes and a telescope offered by volunteers from amateur astronomy clubs. The children were encouraged to think about the cause of day and night by considering such guided questions as 'Why do we have day and night?', 'How do day and night occur?', 'What causes day and night?', 'What do you see at the day time or night time?', 'Does your moon/sun/earth move?', 'How does the moon/sun/earth move?', 'Where is the sun at night?', or 'Where is the moon at day?'. This indicated the affordance of involving the children with special needs in such multimodal modeling activities for activating their prior knowledge and daily experiences, encouraging them to describe, explain and make sense of their observation experiences and promoting their abilities to contextualize and visualize conceptions about day and night as well as to reason day and night formation.

EMMA Workshop IV

Further, for the Science Club workshop working with 22 secondary school students (aged 12–15), the theme of the "moon phases" was chosen because it was expected to observe the crescent Moon and Jupiter as well as four largest and brightest moons of Jupiter at the workshop (Kim et al., 2012b). Table 10.3 shows various activities designed in the EMMA Workshop IV.

The workshop activities were aimed to develop and implement multimodal modeling and interdisciplinary approaches towards promoting the participants' concept formation and deeper learning about the Moon Phases. According to Lelliott and Rollnick (2009), most of students are unable to explain why the phases occur or to develop a coherent understanding of the phenomenon. Hence, the

Table 10.3 The activities in the EMMA workshop IV

Activities	The EMMA process
Day 1	
2D drawing about the moon phases	Activating the participants' prior knowledge and experiences and simulating observation-based questions regarding the moon phases
Questions about the astronomy and physical astronomy concept mapping	Engaging the participants in observation-based inquiry; Constructing a physical astronomy concept mapping
Making a telescope	Hands-on activity: building a model of a telescope to experience, experiment, use and understand the concepts of telescope design and lenses
Sky observation using an astronomical observation software (e.g., Stellarium): moon and jupiter	Sky observation & exploration
Making a poster about "Tour to jupiter moons" and poster presentation	Engaging the participants in observation-based inquiry about the expedition to the space; exploration to new information about the moons of jupiter
Sky observation using a telescope: moon and jupiter	Sky observation and exploration
Day 2	
Playing a word game	Playing a word game to use key vocabularies in relation to the moon phases
Modeling of the moon-earth-sun system	Modeling and generating argumentations about the moon phases
Making a crater	Hands-on activity: Observing and exploring the formation of different types of craters on the sand surface using different sizes, shapes and materials of objects
Sky observation: moon	Observation and exploration

modeling activity was designed to develop inquiry skills among the participants who were supposed to explain how the Moon moves and why the moon phases occur by their 2D drawings and 3D physical models of the moon phases.

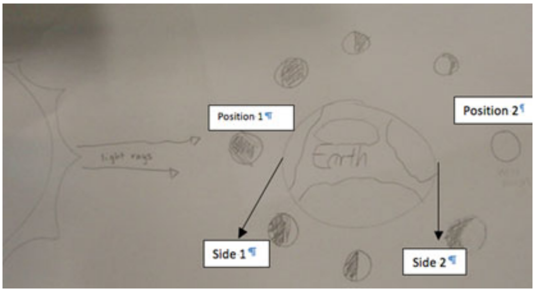
Similar to the teacher participants in the previous workshop, the students tended to rely on authoritative resources such as more knowledgeable peers or information using their mobile phones. While constructing models, each group encountered contradictions to explain the cause of the moon phases. Initially contradictions among group members were less obvious because they were more apt to ignore their contradictions engendered by different ideas or explanations. However, through being engaged in careful listening, as noted earlier, HJ respected and accentuated different ideas and explanations among the participants' ideas about the moon phases within a group.

For example, in the following excerpt, 14 year-old Jane mentioned that at the position of Moon-Earth-Sun (see Position 2 in Fig. 10.5), the Moon is a new moon because "the Earth blocks the light" whereas 14 year-old Alice addressed that at the position of Earth-Moon-Sun (see Position 1 in Fig. 10.5), the Moon is a new moon because the surface of the Moon that faces the Earth "does not get any light".

Interestingly, despite being apparently different argumentations about the new moon phase in relation to the Sun and Earth, both Jane's idea (Position 2 is the new moon which she cannot see at night, see turn 3, turn 5) and Alice's idea (at Position 2, she can see the Moon at night, see turn 7) were accepted by HJ as correct: "I'm saying that what you [Alice] are saying is correct and what you [Jane] are saying is correct" (see turn 14). Hence, HJ intentionally repeated and clarified the participants' descriptions, explanations and reasoning so as to reach a consensus between two contradictory argumentations.

HJ attempted to encourage the participants not only to express and share their own different, even contradictory ideas but also to listen to and respect other participants' ideas, which led him and the participants to understand and integrate such contradictory ideas as important and interesting argumentations. This ability to develop and create argumentations based on the participants' contradictory ideas, therefore, allowed HJ to guide them to discuss and argue on critically the concept of the causes of the moon phases to defend their own argumentations (see turn 19). HJ also provided emotional support to avoid the participants' frustration and encourage them to continue their discussion and exploration.

Drawing upon his own learning experiences with the research team, HJ further leveraged affordances of multimodal modeling such as contextualizing astronomical phenomena by utilizing 3D astronomy software, requesting the participants to verbally describe their visual representation to make sense of their 2D drawing (see turn 1, turn 4, turn 6, turn 8, turn 10, turn 12 and turn 14), and encouraging them to construct 3D physical models to find out evidences to support and explain their own argumentations (see turn 19). With respect to the moon phase modeling activities, HJ noticed the limitation of 2D drawing in terms of representing the concept of the inclination of the Moon's orbit. Therefore, he encouraged the students to build 3D physical models to find evidences to support their argumentations. As shown in the photographs in Fig. 10.6a 3D model provided the participants with better visual



01 HJ See ah. Here (position 2) you (Jane) say no moon right. Cannot see the moon right? So here (position 1) you say can see the moon?

02 Alice Here can see the moon?

03 Jane Here (position 2) is the moon what. This is the new moon. New moon means no moon.

04 HJ So how? So you see.

05 Jane There no moon what. It is written down there for you.

06 HJ So can see the moon here or here?

07 Alice There (position 2).

08 HJ Now at night where are you?

09 Alice Centre

10 HJ Huh? We stay at the centre of Earth ah? On the surface of Earth, right?

11 Jane At night there [point to the side 2] la. Morning here [point to the side 1] la. Morning got light.

12 HJ So at night you [Jane] are here (side 2). Can I see the moon?

13 Alice Can.

14 HJ You [Alice] say 'Can' just now. Just now you [Jane] say 'Cannot'? So you see the contradiction. Ah! I want you to see the contradiction. Okay I am going to tell you a scary answer. I just told them and they got stressed out. I'm saying that what you [Alice] are saying is correct and what you [Jane] are saying is correct.

15 Alice huh?

16 HJ Correct! The Earth blocked the light from the Sun then cannot see the moon (at position 2). But I'm telling you that, at night you are here [pointing to the side 2] right, so you can see the moon (pointing at position 2). Right? You are also correct.

17 Jane So there is still moon, you just cannot see only.

18 Alice How come?

19 HJ Ah! you want to see all these points, (so) you build first and then see for yourself. Ah okay. Start doing the building one. And then you must start looking at it and why what you say is correct, and what you said is also correct. Wah so confusing, Right? Funny right? I purposely want you to challenge each other. But actually both are correct. But later on I show you, you say ah… both are correct. Okay.

Fig. 10.5 The moon phases

affordances, where they created actual light rays by using a light bulb and manipulated their model by changing a position to simulate the dynamic system.

The following excerpt indicates that Jane productively engaged in constructing a 3D model and used her group's model to explain the moon phases. Initially using her group's 2D drawing model, Jane put more emphasis on illustrating the moon phases by simply naming each moon phase. This was challenged by HJ who attempted to motive her to use the model not only to illustrate but also to *explain*, *show*, *or demonstrate* her idea in relation to the moon phases, in particular the new moon phase (see turn 20, turn 28). Jane took an action to life up the bulb to demonstrate how the Sun is big enough to shed to the surface of the Moon at the Position 2, which she initially named as the new moon (see turn 3).

20	HJ	Okay don't worry. Just say. The basic questions. When is the first day, when is the fifteen day? How come you can see the moon, how come you cannot see the moon? Ah explain.
21	Jane	You don't know what we are laughing about. Never mind. This is the first day [point to position 1]; this is the fifteen day [point to position 2].
22	HJ	Okay. When can you see the moon? Full moon?
23	Jane	Here. [Point to position 2]
24	HJ	Why?
25	Jane	Because the sun is big.
26	HJ	Ah. Because the sun is big. Therefore what? What happened?
27	Jane	Therefore can see the moon.
28	HJ	How to see? You show me how to see?
29	Jane	There. [Jane lifted up the bulb so that the light can shed to the surface of the moon at position 2]
30	HJ	Oh. So you see the moon is now bright is it?
31	Jane	Yes. Here cannot see because it is blocked. [Point at position 1]
32	HJ	Here cannot see because it is blocked?
33	Jane	The Sun only shines here. The light is only here, this part, at the back only.
34	HJ	Ah one side only. Then we cannot see. Okay.

Hence, Jane's modeling activity indicates how she productively changed from an illustrative model to an explanatory model, and developed increasingly sophisticated views of the explanatory nature of models. She started to make connections between the moon phases as seen from the Earth and the relative position of the Sun, Earth and Moon. As such, this modeling practice shows that HJ and the research team used constructing a model as a way to generate contradictions from the workshop participants' multiple ideas, experiences, or beliefs in relation to a target phenomenon (e.g., the moon phases). The modeling practice motivated them to engage in modeling practice to look for more concrete evidence from the model to explain and prove their argumentations for both themselves and others.

As an important part of consolidation to resolve contradictions and reframe solutions into a more in-depth question, the participants were also supposed to

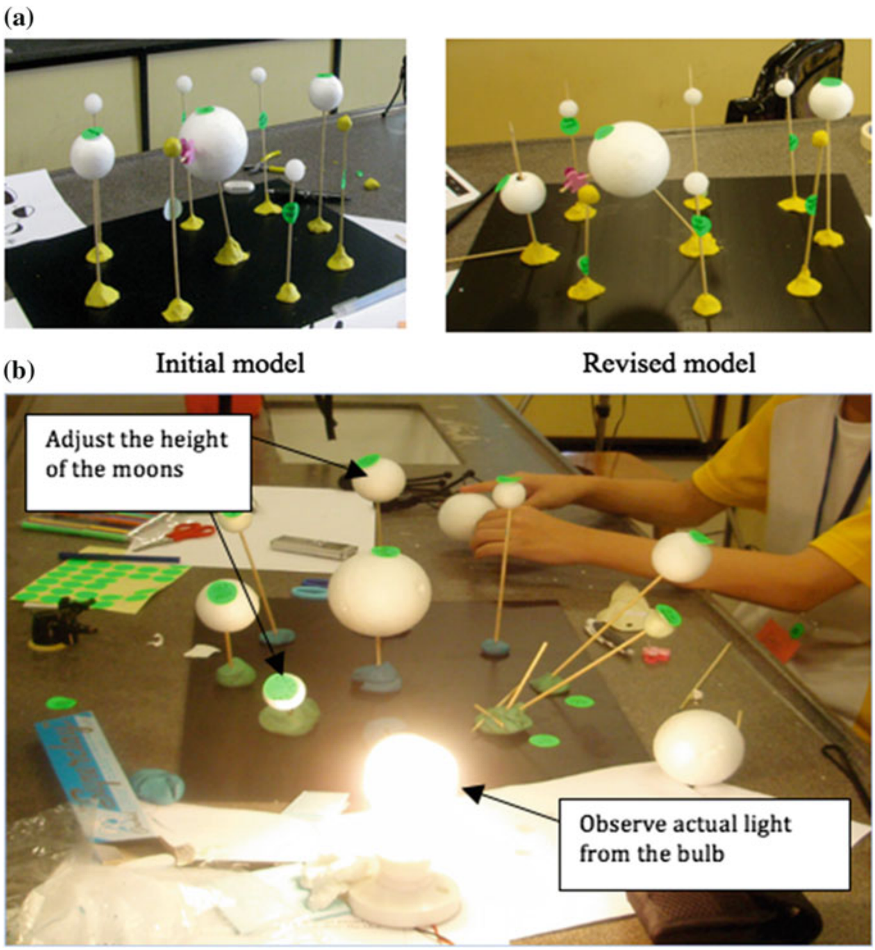


Fig. 10.6 **a, b** 3D model modified by students

engage in remodeling activities. As shown in Fig. 10.6a, initially all moon phases were arranged in a flat horizontal plane, but during the remodeling process (see Fig. 10.6b), the participants started to rearrange the moon phases in order to form the tilted plane of the Moon's orbit so as to prove that the Moon can receive sunlight at the Moon-Earth-Sun arrangement.

Furthermore, HJ used a computer simulation model to show the tilted plane of the Moon's orbit. He mentioned:

> You can see if the moon comes between the Sun and the Earth, you have what we called solar eclipse. That means if you are on the earth, you cannot see the sun because it is blocked by the moon. But before the moon blocks the sun, you can still see a little bit of the moon. So (we) can see the moon. You see? So in that particular sense, Jane's comment was correct. (We) Can see the moon. …. During the lunar eclipse? Look at this diagram. Now

> the earth is blocking the moon. So cannot see the moon what. Okay. So all these your good friend says about your model is correct. So two of you ah, are correct during the lunar eclipse and solar eclipse.

Hence, by using the model of the Moon's tilted orbit, he showed how to use the model to predict important relevant phenomena such as the solar eclipse and lunar eclipse. HJ also explained why he argued that Jane's argumentation could be reasonable during the solar eclipse at the position of Sun-Moon-Earth whereas Alice's argumentation could be also correct during the lunar eclipse at the position of Sun-Earth-Moon.

Discussion

Based on results from the aforementioned four EMMA workshops in informal learning settings, the following section will consider four emerging design principles, which can guide subsequent EMMA workshops toward developing a participatory learning environment: Developing observation-based inquiry, Constructing multimodal modeling, Generating argumentations using models, and Remodeling through evaluation and reflection.

- **Developing observation-based inquiry**: Observation-based inquiry encourages participants to reflect on their everyday experiences and to explore inquiry. This inquiry can be collaboratively generated by participants, experts, or researchers based on their sky observations with naked eyes or/and telescopes including pictures and videos taken by others. Specifically, in astronomy education, observation, whether it was made in the authentic environment (Sherrod & Wilhelm, 2009; Trundle, Atwood, Christopher, & Sackes, 2010) or designed virtual environment (Bakas & Mikropoulos, 2003), provides learners with embodied experiences in an authentic learning environment. This does not only facilitate learners' conceptual learning, but also enhances their motivation and interests. In EMMA workshops, the research team provided participants observation experiences both in field trips and through observation photos. In the EMMA Workshop IV, students were even encouraged to observe the night sky using their own telescopes. In some workshops where real observation was hard to achieve, we used observation photos or simulation software to engage the participants. Learners usually got excited about authentic observation and became more engaged. However, observation should serve the purpose of more than just triggering students' interests, and it should also meaningfully relate to the content they are going to learn.
- **Constructing multimodal modeling:** Astronomy is by nature a very interdisciplinary science. By stressing the sociocultural context of science literacy, this practice-inspired design also takes an interdisciplinary approach to experience, understand and explore diverse interpretations of astronomical phenomena from different perspectives across subject areas. This interdisciplinary approach aims

to have participants apply new knowledge across a variety of contexts for deep understanding. For instance, our EMMA workshops show that there are five main modes of meaning-making: (1) Sky observations, (2) 2D drawing, (3) 3D physical modeling with clay/Styrofoam, (4) 3D computer modeling, and (5) ICT-integrated storytelling. Physical models have a true 3D perspective at a system level (e.g., solar system, Sun-Earth-Moon system) so that they may be viewed from or moved to different spatial locations. Participants used their 2D drawing and hands to demonstrate the planets' movements or illuminations. This mode of meaning-making gave participants an opportunity to further explore their ideas about planetary light and motion in addition to working with 3D computer models. Computer modeling includes creating and manipulating 3D objects, running and observing the model from multiple levels and perspectives within the 3D space, and visualizing and collecting data of the system's process with provided symbolic representations. EMMA Workshop III showed that ICT-integrated storytelling offered participants opportunities to make an aesthetic response to astronomical phenomena. Specifically, ICT-integrated storytelling aimed to support emotional and cognitive challenges; thereby, motivating participants to reflect on their experiences of astronomical phenomena and communicate what they experienced with others.

- **Generating argumentations using models**: Our participants throughout the EMMA workshops were encouraged to make argumentations and to use their models in order to communicate with others. This involved communicating and socially negotiating with others through on-line and off-line. In particular, as described in the finding, the real sky observation triggered them to ask all kinds of questions. Most of the questions could not be answered on the spot, but the research team encouraged them to record the questions and argumentations for later exploration through multimodal modeling tools. In the process, participants applied their knowledge and learned skills and theories through problem solving. This accords with the notion of situated cognition put forward by Brown, Collins, and Duguid (1989) where knowledge is viewed as "situated, being in part a product of the activity, context and culture in which it is developed and used" (p. 32). Throughout the EMMA workshops, the main facilitator HJ gradually developed the strategy of argumentation. For instance, as indicated in EMMA IV, rather than telling the fact, HJ attempted to challenge his students with alternative ideas while encouraging them to construct models to find out evidences to support and explain their own argumentations.
- **Remodeling through evaluation and reflection**: Generating such argumentations is also an iterative practice because EMMA workshop participants constantly need to evaluate and modify their models as they deeply explore the system's processes exploiting various affordances. Such reflective engagement helps them make connections among their own observations, observation-based inquiry, and conceptual understanding.

These emerging design principles imply the importance of teachers' informal learning opportunities that in turn will support their students' informal learning.

In particular, our research suggests the value of the partnership between researchers and teachers. For instance, our research team collaborated with the teacher for more than 5 years through co-designing workshops. We discovered that he had changed in his pedagogy, such as asking for argumentation more frequently in his questions. He has initiated an Astronomy Club in his school and highlighted the importance of modeling as a way of learning in his lesson designs. He also adopted the learning-through-teaching approach to train senior students to be prospective facilitators of the junior students. Teachers need to participate in such a community of learners that can facilitate their role change from delivering information to designers and meaning-makers by collaborating with their students, researchers and other stakeholders.

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Chapter 11

Developing Effective Pedagogical Approaches in Science Outreach Programs for Young Children

Christine Howitt, Elaine Blake and Léonie J. Rennie

Major factors found to encourage learning in the informal sector relate to the use of the affective domain to promote engagement, and activities that not only engage children to learn science and learn about science, but allow them to do science (Stocklmayer, Rennie, & Gilbert, 2010). Outreach programs offered by science centres or museums provide an alternative method of engaging the public in science, where interactive exhibits are presented in community settings. Outreach programs have been found to enhance students' attitudes towards science, awareness of science, interest and understanding in science, and science skills (Burns, O'Connor, & Stocklmayer, 2003; Garnett, 2003; Rennie, Evans, Mayne, & Rennie, 2010).

The first 5 years of life are crucial in shaping a child's ability to learn and to think creatively (Council of Australian Governments, 2008). From birth onwards, children explore their world in an attempt to make sense of the things around them. Due to its capacity to engage and stimulate children, science education in the early years has the potential to improve many aspects of cognitive and social development. Recognition of the importance of providing science-related experiences for young children has resulted in increased numbers of outreach programs aimed at a preschool audience. Such programs require exhibits that respect the intellect and curiosity of the children they are to inspire. These exhibits also require informal educators to utilise pedagogical practices that show respect for a young person's competence and have an understanding of how young children learn, think, and communicate.

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This chapter explores the pedagogical practices of informal science educators in relation to a play-based *Early Childhood Outreach Program* aimed at 3- and 4-year-old pre-school children. Our purpose is to identify and describe a range of effective pedagogical practices that ensure the effectiveness of science outreach programs for young children.

Background

As play is the fundamental method through which young children learn, we begin by describing its significance. An exploration of the role of adults with children's learning is then presented to establish the theoretical framework that underpins our research into young children's learning in informal contexts.

Learning Through Play

In early childhood, play is considered to be the deepest form of learning (Bruce, 2011) and has been described as the 'work' of children (Kearns & Austin, 2010). Play is an essential part of childhood, helping children to construct their identity (Ebbeck & Waniganayake, 2010) and make sense of the world (Canning, 2007). Through play children develop their social, emotional, cognitive, linguistic and physical skills (Bruce, 2011). Play provides a supportive social environment where children can ask questions, solve problems, engage in critical thinking, and build new understandings (Department of Education, Employment, and Workplace Relations, 2009). Playing, with its "unique characteristics of unpredictability, novelty, flexibility, personal control, imagination and 'as if' potential" encourages adaptability and resilience (Lester & Russell, 2008, p. 24). Also, during playful experiences, children integrate emotions, thinking, and motivation that establish the neural connections critical for effective brain functioning. It is through play that children extend their creative thinking and enhance their interest in knowing and learning (Lester & Russell, 2008). Play, therefore, promotes positive dispositions to learning.

Play as a learning strategy can be classified along a continuum of activities from free play, guided play, directed play, to work disguised as play, depending on the amount of adult guidance provided (Kearns & Austin, 2010). A combination of different types of play provides an ideal learning context. The *Early Childhood Outreach Program* utilised both free play and guided play. Free play refers to impulsive situations where children have independent access to a range of materials. They make decisions about how to use the materials and are in charge of the play. Guided play involves others who provide support to assist the direction of play. In guided play, adults can add new materials, ask questions, or provide additional information. Directed play occurs when specific resources are included in children's play to develop a teaching point. Guided and directed play reflect intentional teaching. The role of adults is central in supporting and extending children's learning through play. Adults who value play as an important learning experience and actively support play can make a difference to the type and level of play (Dockett & Fleer, 2002). Adults can take on many roles in play with children, including managing time, space, and resources; facilitating play, through mediation and interpreting play experiences; and direct involvement in play through co-playing or play tutoring (Dockett & Fleer, 2002).

Learning Science Through Play

Positive and developmentally appropriate science learning experiences in early childhood have been found to develop children's scientific concepts, awareness of scientific explanations through engagement with science phenomena, science process skills, use of scientifically informed language, scientific thinking skills and positive attitudes to science (Blake & Howitt, 2012a, b; Bulunuz, 2013; Eshach & Fried, 2005; Patrick, Mantzicopoulos, Samarapungavan, & French, 2008; Peterson & French, 2008). Through play, young children are constantly exploring and experimenting as they try to understand the workings of their immediate environment. The processes children use in their play are analogous to those used in science learning: observing, communicating, predicting, planning, investigating, classifying, experimenting, changing variables, and reflecting. Bulunuz (2013) highlighted that while learning science through play young children are not only exploring and investigating but noting and differentiating various aspects of the objects and materials they are using. This allows children to participate in variations of the same activity to explore these different aspects. Early years science experiences can therefore lay the foundation for the subsequent development of scientific concepts and skills children will experience later in their schooling (Eshach & Fried, 2005), and emphasises the importance of these early exploratory experiences.

Adults' pedagogical practices play an important role in guiding and extending children's scientific thinking. Using guided play around a nature table with two 3-year-old children in an early learning centre, Blake and Howitt (2012b) highlighted various adult pedagogical practices that assisted the children to learn science as they engaged with materials. Pedagogy included actively listening to the children's ideas, developing conversations, providing guidance rather than answers, modelling actions and how to think, questioning to extend children's thinking, accepting competence, and providing enough time for children to explore their theories. In this case study, the use of guided play as a pedagogy led to the development of the children's scientific skills of observation, classification, problem solving, creativity, and critical choice (Blake & Howitt, 2012b). In another study, Blake and Howitt (2012a) provided an example of the scientific learning of sound with three, 3- and 4-year-old children through free play in an early learning centre. The adult pedagogical practices that supported this learning were the provision of resources and time; acknowledgement of the children's potential and prior experiences; the opportunity provided by the teacher at the end of the session for the children to report, discuss, and retest their ideas with their peers; and acknowledgement of the children's scientific inquiry process through collaborative learning. As a consequence of their free play the children developed the scientific skills of observation, comparison, explanation, test-retest, discussion and investigation. Peterson and French (2008) highlighted the pedagogical strategies preschool teachers used to support the development of 3- and 4-year-old children's explanatory language through science inquiry. In developing the children's explanatory discourse about colour mixing phenomena, three main types of teacher support were provided: modelling and eliciting appropriate language forms, encouraging explanation through observation and prediction, and engaging children in collaborative inquiry. These examples highlight the role of the adult in assisting young children develop their scientific thinking, skills and communication.

Fleer (2009) explored the relationship between teachers' beliefs about scientific learning and scientific teaching during free play activities relating to 'potions,' through a single case study of 24 preschool (4- and 5-year-old) children and their teacher and teaching assistant. The teacher believed that the best learning opportunities for the children would occur with the provision of materials and minimum teacher input; thus, the resources would themselves generate learning opportunities. In contrast, the teaching assistant believed that the best learning opportunities would occur through discourse between children and adults. These two differing philosophical views emphasised the use of either materials or adult intervention as the focus of attention for science learning. Observations of the classroom highlighted that if resources are not introduced to children within an appropriate scientific framework, or teacher-child interactions were not focused on scientific concepts, then limited science learning occurred. Teachers' philosophical views about how young children learn can thus influence the children's learning.

Young children bring a wide range of prior knowledge and past experiences to their science learning. As a consequence of their everyday interactions with the environment, young children develop a range of understandings of scientific concepts (Skamp, 2012). While many of these ideas may be at odds with the scientifically correct concept, they make perfect sense to children. Fleer (2007) suggested that adults should use these everyday experiences as the starting point to make connections with scientific concepts for young children. Harlen (2001) proposed that in the early childhood years adults should distinguish between what is the 'right' answer and what is the 'correct' answer. A right answer allows children to respond according to their everyday experiences and their current understanding. This provides an opportunity for them to make observations and gain confidence in their ability to describe what they think is happening, and why it is happening.

Adult-Child Interactions in Informal Learning Contexts

In recognition of the adaptive influences that cultural and social nuances can bring to new learning there is a growing focus on using a socio-cultural perspective to explore learning within informal learning contexts (Rennie, Feher, Dierking, & Falk, 2003). A socio-cultural perspective focuses on collaboration among people, including children and/or adults, with various artefacts and the influence of the environment where the learning is taking place. Research in informal contexts, such as museums, has shown that greater learning occurs when exhibits encourage social interaction and collaboration among family members (Meisner et al., 2007). Borun and Dritsas (1997) noted that families are more likely to collaborate and talk when exhibits include multiple access points, a multiuser capacity, multiple possible outcomes, and content that is directly relevant to the children and their families' prior knowledge and cultural experiences.

Children who participate with science exhibits with their parents have been found to have better engagement with the exhibit, increased discourse about the experience, and enhanced educational opportunities (Bell, Lewenstein, Shouse, & Feder, 2009). Crowley et al. (2001) conducted an observational study of 91 families with children aged between 4 to 8 years as they interacted with a zoetrope in a children's museum. They found that when children engaged with an exhibit with their parents, their "exploration of evidence was observed to be longer, broader, and more focused on relevant comparisons than children who engaged the exhibit without their parents" (p. 712). Parents supported their children's scientific thinking through helping children to select and encode relevant evidence, thus assisting them to generate evidence and provide explanations. Through assisting children to identify, generate and interpret evidence, these results highlight the important roles that an adult plays in supporting children's everyday scientific thinking.

Both parents and informal science educators can assist in children's learning; however, this is dependent on their perceptions of how children learn and their perceptions of their role in that learning. Schauble et al. (2002) interviewed 32 parents of children aged 6–10 years after they had been interacting at one of two science exhibits in a science gallery. They also interviewed 16 informal science educators stationed at the same exhibits. The purpose of the interviews was to discover each group's beliefs about learning and how adults could work with children to enhance learning at the exhibit. Results from the parents highlighted two different perspectives about the educational potential of the exhibits (doing or learning) and their role (leave children alone or assist children). One group of parents (44%) believed that activity, observing, and fun with hands-on materials would lead to learning through sensory experience and excitement. These parents believed that the best role for adults was to stay out of children's way, only assisting if help was required to interact effectively with the exhibit.

The second group of parents (28%) believed that play alone was not enough to support their children's learning, and wondered what else was required to make the learning experience valuable. This group expressed the view that parents should assist their children's learning, but were unsure about what that role should entail. Only 13% of adults commented that the role of the adult should be to ask 'how' or 'what if' questions, while only 9% mentioned modelling. The majority of informal science educators (75%) believed that being involved in the activities was the best way to assist children's learning. They considered experiential forms of learning were most valuable for children, with their role being to assist children to discover. These educators mentioned a variety of ways to assist, including discussing, asking questions, and posing challenges. They considered some parents to be disengaged and others too didactic, and were unsure how to encourage parents' active involvement. The informal science educators expressed uncertainty about whether or when learning was occurring at the exhibits. Like the parents, they perceived conflict between playing (the children's agenda) and learning (the science gallery's agenda).

The literature reviewed above highlights the importance of understanding young children's thinking and learning processes so adults (both parents and informal science educators) can better support children's learning in informal contexts. The place of play and learning should be acknowledged, and seen as complementary rather than incompatible. A socio-cultural perspective emphasises the importance of cooperation and collaboration between adults, children, and the available objects or exhibits to extend children's thinking during play and thus promote opportunities for learning. This perspective also emphasises that informal science educators require appropriate pedagogical strategies to assist them in effectively working with young children. In this chapter, we describe a range of pedagogical practices used by informal science educators in Australia in relation to a play-based *Early Childhood Outreach Program* aimed at 3- and 4-year-old pre-school children and draw some generalizations about the effectiveness of these practices.

The Early Childhood Outreach Program

The *Early Childhood Outreach Program* was developed by an Australian science discovery centre to engage children aged 0–4 years in age-appropriate science learning experiences. The program incorporates learning through play where both free play and guided play are encouraged by adults and open-ended activities are used. It is delivered as a 1-h outreach program into pre-kindergartens (3-year-old children) and kindergartens (4-year-old children) by two or three informal science educators, subsequently referred to as educators. The program aims to introduce and engage young children in everyday science, provide for them an avenue for scientific discovery through play, and offer ideas and resources for teachers and parents that encourage scientific discovery by young children.

At the time of the research, the program included five activity centres devoted to light energy, sound energy, movement energy, animals and plants, and mathematics. Each activity centre comprised different components, such as a box, an easel, and individual objects. The total of 13 components is summarised in

Table 11.1 Components of each of the five activity centers

Activity center	Components
Light energy	Light energy box, light maze, making shadows tent
Sound energy	Sound energy box, tubes of sound, easel
Movement energy	Push/pull energy box, car racing easel, frog walking table
Animals and plants	Animals box, make-a-face easel, bush animals easel
Mathematics	Hop scotch mat, balance

Table 11.1. Boxes that housed the components were painted a specific colour and contained a range of toys along with every day and not so common objects, based on the theme of the activity centre. Easels provided vertical magnetic puzzles or activities for children. Most components had a question associated with them to act as a catalyst for adults to encourage investigation or play.

The hour-long program was structured to provide a 10-min introduction period, 40 min where children and teaching staff/parents/educators interacted with the exhibits, and a 10-min conclusion. There was a set script for the introduction where a puppet story was used to review the five senses with the children. For the conclusion, children were gathered together and asked to describe their favourite activity and their engagement in that activity. Finally, a book was read or a familiar song was sung. Prior to the start of the program other adults present (teaching staff and parents) were informed that the program had an emphasis on learning through play and that their role in the program was to assist the children's engagement, particularly through questioning.

Research Design

This research was designed as a multiple case study. Venues were selected from bookings already made through the science centre. Permission was obtained from each site manager and individual teaching staff to carry out the research. Data were collected from nine classes at seven different metropolitan schools in Western Australia during 2009. Two classes were pre-kindergarten, catering for 3-year-old children, while the remaining seven classes were kindergarten, catering for 4-year-old children. A summary of the classes, class size, and number of adults present during data collection is presented in Table 11.2. Data were also collected from the informal science educators who presented the program.

The main form of data collection was observation of adults (with an emphasis on the informal science educators, but also including teaching staff and/or parents) and of children interacting with each other and the activities. Data were collected by one or two participant observers. If children approached the researchers with questions

Table 11.2 Summary of classes involved in data collection

Class	School	School type	Year level[a]	Class size	Number of adults present[b]
1	A	Private	K	22	3 ISE, 3 TS, 1 P, 2 R
2	B	Catholic	PK	19	3 ISE, 2 TS, 1 P, 2 R
3	C	Private	K	22	3 ISE, 2 TS, 2 P, 1 R
4	D	Government	K	20	2 ISE, 2 TS, 0 P, 1 R
5	D	Government	K	17	2 ISE, 2 TS, 0 P, 1 R
6	E	Government	K	20	3 ISE, 2 TS, 3 P, 1 R
7	F	Government	K	20	2 ISE, 2 TS, 0 P, 1 R
8	F	Government	K	18	2 ISE, 2 TS, 0 P, 1 R
9	G	Catholic	PK	20	2 ISE, 2 TS, 4 P, 1 R

[a] *PK* Pre-kindergarten, *K* Kindergarten
[b] *ISE* Informal Science Educators, *TS* Teaching Staff, *P* Parents, *R* Researchers

or observations, the researchers engaged in the same role as other adults: assisting engagement and questioning. Observations concentrated on any interaction with any component. These interactions could range from a few seconds, where a component was picked up and then placed down, through to 5 min where engagement with a component was more concentrated.

Data were also collected from six informal science educators through a focus group interview, in which the purpose was to obtain feedback about their perceptions of the program in terms of content, presentation, children's engagement, and adult participation. Following the process used by Blake and Howitt (2012b), individual case studies were written for each class and interpreted in terms of the factors that assisted or hindered adults interacting or supporting young children's engagement and learning in the program. A cross-case analysis then identified the major themes to emerge from the data (Merriam, 1998). These major themes are described in the findings.

Findings

Five major pedagogical practices were identified that supported young children's learning in the outreach programs. These practices are: (1) providing emotional support for young children to encourage exploration, (2) using modelling to demonstrate interactions for young children, (3) using open-ended questioning (where answers offered explanations or descriptions) to extend young children's thinking, (4) understanding the purpose of the active role of all adults, and (5) acknowledging young children's competence and capabilities.

Providing Emotional Support for Young Children to Encourage Exploration

In order for young children to explore freely and engage in play, they require a positive, nurturing environment that provides emotional support (Ebbeck & Waniganayake, 2010). These authors noted that through the establishment of such an environment an adult can motivate young children to participate. It was recognised that having a program with a range of new components set up in their classroom, accompanied by people they had never seen before, can be quite intimidating for young children. Their emotional requirements first had to be satisfied before they would willingly interact with any components. In such circumstances, the pedagogical role of the informal science educator is one of comfort to ensure young children know the environment and resources are safe. This is clearly demonstrated in the description below taken from Class 2 with 3-year-old children.

> Once the Introduction was over there was a real hesitancy in the children to interact with the activities. One of the educators moved inside the Making Shadows Tent and was promptly followed by a group of children. The educator then modelled and explained to the children how to make shadows using the light and the range of stick fish. The children then started exploring shadows. An educator moved to the Sound Box and demonstrated what was required to play each of the musical instruments. The children then became engaged with these musical instruments. An educator noticed there were no children at the Light Box so moved to it. She was immediately followed by a group of five children. The educator modelled and described what to do with the range of mirrors, spoons and binoculars. The children then copied her. Two children stood by the magnetic Frog Walking Table wondering what it did. An educator moved over to the table, pointed out the magnet beneath the table, and then started asking the children questions. These two children started using the magnet to make the frogs move.

This description clearly illustrates the children's initial hesitancy to interact with the program. At first they seemed to be overwhelmed with the program and people, and unsure of what was required of them, or what they were allowed to do. The action of the educators moving to the components and demonstrating what to do enabled the children to feel safe and begin their exploration. In particular, it was only when the educator moved into the shadow tent that the children followed. This initial hesitant response by the children was also seen in Classes 3, 5 and 9, again with a 'follow the educator' approach to exploring the components of the program.

During the interview, the educators in the focus group also commented on the children's hesitancy. However, they related this to shyness or needing time to internalise the information they had been presented with, rather than one of emotional security. One educator commented:

> But sometimes they are a little bit more shy and there's a lot going on in the [pre-kindergarten] … and you say "Alright, you can go now" and three go … then the others look around and wonder what they are doing.

A second educator acknowledged the need to allow children time to think:

> But then again I don't think there is anything wrong with a kid taking his time to get his bearings 'cause sometimes we dump all this information on them and their little brains don't know – they are still trying to figure out what you said. "Am I allowed to go now?" They sometimes miss that bit.

Rennie and McClafferty (2002) noted that new situations in informal learning centres can initially be dysfunctional for children, as the novelty can interfere with the learning process. They stated that children have to orientate themselves to an unfamiliar environment before they can concentrate on engaging with any exhibits. This orientation is a mechanism whereby children develop their emotional security. Informal science educators can assist in this role by moving to, introducing, inviting, and modelling use of the exhibit.

Using Modelling to Demonstrate Interactions for Young Children

Positive social interactions between adults and children occur when responsibility is shared to achieve a common goal. Both are 'active' participants, where the adult is considered the "cultural expert who guides the child towards achieving a goal in a play context" (Ebbeck & Waniganayake, 2010, p. 32). These interactions lead children in developing their cognitive, physical, social, and linguistic skills.

One of the most important roles that informal science educators play in the program is that of modeller. In this role adults demonstrate how to use the various components, in the intended manner, to engage the children with the science-based content. In contrast, when this role is missing children will tend to explore the components in their own manner, as demonstrated in the following description of Class 5.

> One girl took various 'treasures' into the Light Maze, including the egg beater and a plastic bottle from the Push/Pull Box. She used the egg beater for a while, pretending to beat the yellow flower picture that was on the side of the maze. She then squeezed the bottle onto the flower, and then cut the flower into pieces with her hands. Finally, she offered the adults a piece of her 'cake'.
>
> Three children were observed at different times trying to strike the Tubes of Sound, but missed. Their inability to strike the vertical tubes led them to immediately move on to another activity. A boy came to the feather and bottle (as part of the Push/Pull box), took out the feather and tried to open the bottle. Since the lid did not come off he placed the bottle down and moved on. These children did not know what to do with the objects.

Hutt (1981) presented a taxonomy of play where children approach objects and ask 'What is this object?' or 'What does this object do?' If not shown what to do, children may shift their thinking to ask 'What can I do with this object?' The girl in the Light Maze did not know what was required so she started her own imaginary play with the objects, pulling on her prior experiences of cooking, to bake a cake. As noted by Fleer (2009), when resources are not introduced to children within a particular scientific framework or through appropriate adult-child interactions that are focused on scientific concepts, children will draw on their prior experiences and create imaginary situations in which to frame their use of materials.

Lack of interaction between the informal science educators and the children led to limited engagement, little exploration, and ultimately the children became disinterested. These children started playing with the class toys rather than those brought in for the program. For example, the light maze was used as a game of ‘chase’, with children running around the classroom. At times all four adults present, including the two informal science educators, were standing to one side of the classroom, disengaged with the children and the program. This lack of modelling was also witnessed in Classes 3 and 9. In contrast, effective modelling was demonstrated in Classes 1, 2, 4, 6, 7 and 8 and here children engaged with and explored the components of the program, with interest.

In the focus group interview, when asked how they encouraged children to interact with the components, the informal science educators commented on how they invited children with, “Look at this. Do you want to come over here?” or “Look! What have we got here?” There was no mention of modelling, even though it was happening frequently, in the program. This may indicate that the informal science educators were not aware of the various roles they undertook in the program.

Using Open-Ended Questioning to Extend Young Children’s Thinking

Questioning provides an effective mechanism to support children in thinking for understanding (Campbell, 2012). Questioning was used throughout the program in different forms: asking direct questions of the children; developing ‘science conversations’ with the children based around questions that required explanations of their thinking; using the questions that were written on the components of the program; posing open-ended questions to arouse scientific curiosity and elicit descriptive responses of their exploration and investigation; and questions that encouraged children to stop and think about what they were doing. The use of questioning to encourage children to think about what they were doing is illustrated by observations from Class 4.

> A boy was playing with a push giraffe and took it to an educator to demonstrate how it worked.
> Educator: How does it go floppy?
> He showed the educator his thumb was pushed down under the toy to make the giraffe toy flop down.
> Educator: How did you do that?
> The boy kept showing the educator his thumb, and finally said, “You push it.”
> Educator: Does it still work upside down?

> The boy placed the giraffe upside down to see if the same thing happened, and found that it did.

Within this class, all adults were actively involved in the program through modelling, questioning, and extending children's thinking. Questioning had an emphasis on asking the children 'How does it work?' or 'How did you do that?' The active involvement of all adults in this program also reflected an active involvement of children who were prepared to explore, interact, and share their explanations. Questioning was present in all classes, but the quality of the questioning was dependent on the informal science educators interactions with the children and the other adults' understanding of their role in the program.

Notably, children asked very few questions during the program. Rather, they tended to follow an adult lead whenever a question was asked. As these children are still quite young, they may not know what questions to ask or how to ask them. Further, young children may think they are not allowed to ask questions if not invited to do so. Therefore, adults can model possible questions to develop inquiry. Providing leading questions for children, such as 'Is there something you would like to know about this?' affirms their right to ask questions.

In the focus group interview the informal science educators commented on how their questioning skills had improved through familiarity with the program, by developing a range of questions to ask, and understanding better how young children learn. Three main types of questions were used: 'How did you do that?', 'What happened when you did that?', and 'Why did that happen?' One educator commented on the appropriateness of such questions for young children: "They are open-ended questions and [children] can answer according to how they see it". Additionally, the educators also believed that using the 'How?', 'What?' and 'Why?' questions, posted on the component boxes, assisted the teaching staff and parents to know what types of questions to ask.

Understanding the Purpose of the Active Role of All Adults

The role of adults in this program was pivotal to its success. When adults had active involvement, through modelling and questioning, the children were more inclined to be actively engaged. In some classes only the informal science educators took an active role with the children. While teaching staff and parents were present in most classes, many did not appear to understand what their role was and did not fully contribute. The information provided to the teaching staff and the parents about their role, prior to the start of the program, was presented inconsistently by the educators, and sometimes not at all. This compounded the problem of lack of adult involvement.

During the focus group interview, the informal science educators commented that most parents appeared to lack confidence to be involved in the program and did not appear to understand the importance of play in learning, or the role of modelling and questioning in young children's learning. The following conversation expresses the concern the informal science educators had about parents wanting to provide the answer to the children, when the emphasis of the program is allowing children to provide their own answer:

> Educator 1: Do we actually say, "Look, this is meant to be play, let the children do it on their own. Please don't give your child the answer." Can we say that?
> Educator 2: Yeah. I think we do. I usually do. It's not about telling them what we see as being the right answer, it's about wondering why for the child.

Similar to the finding by Schauble et al. (2002), the informal science educators expressed uncertainty about how to encourage parents' active evolvement, how to stop parents giving children the answers and how best to present the initial information to them.

These comments highlight that information provided to the adults prior to the program should be framed in a consistent manner by all informal science educators. To make it more accessible a small handout, with a verbal description, could enable them to consolidate an understanding of their role. This information should not be considered as separate to the program, but as an initial and extremely important part of the program.

Acknowledging Young Children's Competence and Capabilities

Educators' beliefs about young children's ability to learn influences how they chose to support that learning (Fleer, 2009). Young children are highly capable and competent learners who display curiosity, creativity and imagination. Even at 3 years of age children possess a range of prior knowledge and understandings to help them form an opinion about how their world works. However, they may not have the 'correct' scientific understandings. Thus, allowing young children to provide a 'right' answer, as suggested by Harlen (2001), acknowledges their competence and developing ideas. This is demonstrated from Class 4.

The following conversation was developed around a feather placed in the lid of a bottle.

> Educator: How does it work?
> Girl: You squeeze it.
> Educator: What comes out of the bottle?
> Girl: Feather.
> The educator removes the feather and blows air from the bottle onto the girl's face.
> Educator: What comes out of the bottle?
> Girl: Cold things.

> The conversation did not continue as it was clear that this girl had not yet mastered the concept of air being in the bottle. The educator repeated this exchange with another girl, later in the program, and this time received the answer “Air!”

Additionally, young children may not possess the language to express their understandings. Thus, informal science educators should accept young children’s descriptions, or provide appropriate questioning to help them express their understanding. This is illustrated below from Class 8, where a 4-year-old child initially used the word ‘perfect’ to describe the smooth ramp. This provides an example of the use of ‘correct’ language with the ‘right’ understanding.

> Presenter: Why is this ramp the fastest?
> Child: It’s perfect.
> Presenter: Why is it perfect?
> Child: It’s smooth.
> Presenter: Absolutely. Why is this ramp slower?
> Child: It’s bumpy.

Discussion and Implications

Outreach programs for young children need to be developed around the principles upon which these children learn best: acknowledgement of the important place of play in learning and the significant role of adults in learning. Additionally, the pedagogical practices of the informal science educators who deliver the program are fundamental to young children’s learning.

The findings from our case studies highlight the importance of educators being sufficiently flexible to adjust their roles for the age and capability of children involved in the program. The pedagogical role of the informal science educators is one of active participation throughout the entire program. First, this role involves one of emotional support (it is safe to do this as I am here), followed by modelling (this is how you use the objects) and encouraging exploration by the children (allowing for manipulation, repetition and trial and error) and then questioning (to extend thinking). Through this process informal science educators can develop science conversations with children. Further, informal science educators should respect the prior knowledge and the competencies that all young children possess.

When children and adults are working in harmony with the objects being investigated, science-related understandings about how the objects work, and what can be done with them, can be developed. In outreach environments, such as those described in this chapter, where children are guided by an interested adult, be it educator or parent, more opportunities for their learning are presented. In contrast, when children are unsure of their capabilities or the expectations made of them, they may play with objects in a manner consistent with their current understanding and possibilities for advancing their knowledge will be missed.

Our research emphasised that informal science educators must first thoroughly understand the purpose and potential of their outreach program as a whole and that this means more than offering young children a variety of interesting activities. Rather, the educators' role is to ensure that children feel safe and confident to engage in those activities, and then to work with the children in ways that promote their learning. Further, and very importantly, this outreach program included fundamental information presented to teaching staff and parents, to make them aware that their active participation would make an essential contribution to the success of the program.

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Chapter 12
Gender Differences Reflected in Conversations at Exhibits

Sue Dale Tunnicliffe

Out of school work is increasingly recognised as an essential part of a child's education and thus pre-service educators need to understand the area and differing aspects of such work which may affect the responses of learners. Informal science learning environments such as science centers, museums, and zoos provide students with captivating science experiences that can be related closely to curricular objectives. Informal science education environments provide students with unique, engaging science learning opportunities and classroom educators with a wealth of science teaching resources.

A persons' learning, which includes not only the scientific aspects but also contributes to the forming of attitude towards and understandings of the environment, are profoundly shaped by their feelings, experiences and understandings of living organisms' (Tunnicliffe & Reiss, 1999). Animals are key members of the environment; this chapter considers children, formative learners, and their responses to animals as exhibits in venues frequently chosen by educators to visit with their charges during curriculum time. Although the occurrence may be rare, out of a belief that there is more than science to be learned at an informal science setting, formal school groups are sometimes taken to museums, zoos, and aquaria for educational objectives of a cross-curricular nature (Tunnicliffe, 1994). The gender of the viewer has an effect on the interest of a child and their learning opportunities and retention (Ramey-Gasseret, 1997).

What is out of school learning in terms of biology? Braund and Reiss (2004) provide an overview of different aspects and venues and maintain that informal, non-classroom based contexts can make an important contribution to the learner's study of science, particularly Biology Educators preparing for working in the classroom, or in v endures of informal learning, should also be aware of the other kind of informal leaning, that which occurs outside the auspices of school. Children

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being taken to a venue outside the school are still within the jurisdictions of the school whether it be a field trip to a nature centre, a cultural museum, a science centre, a zoo, or even a walk in the immediate locality. They are conscripts in such visits, (McLaughlin, Smith, & Tunnicliffe, 1998) there is no free choice about attending, because the visit is part of their formal curriculum. There may; however, be free choice in what take their attention and indeed what they may actively learn. That depends on what catches their interest (Schiefele, 1991). If we consider that there are 191 days in a year of which English learners attend state schools and school begins at 9 and finishes at 3:30 pm. (as do those for primary children), the children are in school 6 ½ h, during which time they have at least an hour and half of recreational breaks and lunch so they have 5 h of instructional time. Secondary pupils work later so have perhaps 6 h of instructional time. Thus, if they attend school, for 38 weeks and a day weeks, the rest on average being holiday; they receive, in a week, 30 h of schooling. However, in each school day they spend are 18 h elsewhere. Whilst children may indeed be involved in after school clubs, weekend activities, after school lessons, this provision is not statuary schooling under the auspice of a national curriculum. Thus, the role of both school and educator is not necessarily the most important influence one child's learning.

Furthermore, the hours of school-based work tend, particularly in English State primary schools (5–11 years of age), tend to be focused on English (literacy) and Maths (numeracy). These subjects are routinely tested and the results of pupils against prescribed standards results are published for public viewing. The English National curriculum for primary (Key Stage 1 and 2) and Secondary (Key Stages 3 and 4) can be found on the UK Government website https://www.gov.uk/.

Are Indeed Schools Places Where Children Really Learn?

The Council for Learning Outside The Classroom firmly believes that indeed learning outside the classroom changes lives, "that every young person (0–19 y) should experience the world beyond the classroom as an essential part of learning and personal development, whatever their age, ability or circumstances" (http://www.lotc.org.uk).

Here we are discussing visits out of the classroom. These may be to museums in the widest sense but also outside the school buildings in the yard or grounds, in the environment. Even in the playground during recreation. The response of one seven year English boy being interviewed for a research project about understanding of certain items such as an ant, a daisy, and a pond, for a funded project, (Tunnicliffe et al., 2011) illustrates this. He told me he lay on the ground during his recreation time at the edge of the school field and watched ants. He could tell me a lot about these animals based on his first-hand observations during this time 'at' school but not 'in' school.

I have always maintained that visits, which also contain a focus on activities designed to be performed during a visit at exhibits, as well as school based activities before and after a visit are an integral part of the learning. Indeed, I instituted such when working at zoos. Such an approach increases both student motivation and learning (Osborne & Dillon, 2007).Well-designed visits with activities that can be done during the visit itself as well as pre- and post-visit activities to be done in the classroom and which are linked to the curriculum can considerably increase student motivation (Osborne & Dillon, 2007). Tunnicliffe and Scheersoi (2010) suggest that,

> The skill of the museum as a communicating institution through its interpretative techniques, is to link what the visitor already knows and feels with the information which the institution possess about its exhibits. In this way a meaningful museum experience is created for the visitor in terms of both personal context, enjoyment and the acquisition of information (p. 191).

In most cases they maintain, at an exhibit about animals or a viewing of any kind of animal, a typical biological interaction sequence: identify—interest—interpret—investigate. However, the order of these interactions may vary.

Three factors interact in a person when at an exhibit, cognitive aspects, emotional characteristics, and value characteristics so that, depending on the visitor, when an individual encounters an object there may then be no further interest or there may be interest. Such immediate interest is referred to as situational interest (e.g. Shiefiele, 1991). This may or may not develop into individual interested and, if the information is accommodated into that person's construct, learning occurs. Facilitators at an exhibit, or an adult in the everyday interacting with a learner, can act as a significant other, a facilitator, and assist further leaning develop (Vygotsky, 1962). The gender of the educators and the learners can also affect the learning if it is something that which catches their attention about which they comment. However, pre-service educators may have their own prejudices about viewing animal exhibits, particularly in zoos, and such need to be discussed and worked though before visits, because attitudes may be uniformed and may change (Tunnicliffe, 2001).

Under whatever auspice children, and indeed the adults with them, are taken to look at animals they, as well as the person organising the visit, have an agenda which are known to affect their behaviour and learning (Anderson et al., 2008). These consist of content, time, objectives, and individual missions and rationale. Acknowledging such an understanding presents issues for the educators in their planning and delivery of educational aims and objectives for the visit. Thus educators in pre-service training should practice such an analysis and understand their own prejudices and preferences.

During a visit, learners, and indeed organisers, take on changing identities; several identities in one visit, depending on phase of visit (Falk, Heimlich, & Bronnenkant, 2008). Furthermore, visitors create conversations, which change in focus during and at the end of visits for which they have an entry narrative, which is likely to be self-reinforcing on learning and behaviour. Satisfaction relates to visitors matching their entry narrative (Doering & Pekarzik, 1996). The language used by adults focuses the attention of children on aspects of the immediate environment, and thus the presence of an adult with children, as McManus (1989) showed, affects the conversational behaviors. The adults accompanying the children are usually family members during leisure visits or school adults, educators, other school workers or a pupil's parent, during school visits. The adults with whom their children, or learners from their school, visit a zoo have a critical role in influencing what the children observe.

Learning the names of animals is a key part in acquiring knowledge about biodiversity. In helping children to learn names adults point out the object and name it, and, unless they indicate that it is not the case, adults name whole objects, not parts (Niño, & Bruner, 1978). Initially, the children and their adults identify the specimen and name it and often comment on a salient feature or structure. At dioramas featuring animal specimens, they also describe behaviours and make affective comments. If their interest is caught, they start interpreting the scenes presented, mostly in anthropomorphic terms, seeking to relate the subject to what they know and understand. Visitors rarely read the information provided by the museum (texts) and interpret at the level of their biological knowledge, which is generally basic. They may raise questions about the subject, ask why, how and what and construct hypotheses.

The educators and chaperones accompanying primary school groups are nearly all female (Tunnicliffe, 1996b). Boys and girls behave differently in science museums (Diamond, 1994). Moreover, the gender of staff is important in the museums. There is a close connection between science museums with a gender balance in staffing and what science educators see as important for encouraging young girls to learn science (Kremer & Mullins, 1992).

Listening and analysing the content of conversations generated at different types of animal exhibits by groups of boys only or only provide a foundation of information of what interest pupils of different genders. Such information is an important starting point in designing the curriculum for all pupils and providing equal but perhaps different access of opportunity for boys and girls. Furthermore, the data can assist museums and zoos in planning their interactions to take account of such gender differences.

Museum visits can be important in motivating people to learn more about science (Diamond, 1994). It is salutary to remember that, unlike the activities in the science centres where most visitor studies research has been carried out, 'animal looking' is not a hands-on experience of the same type. Attention and observation of exhibits may be cued by an inherent interest in animals, by prompts from guiding adults, from attention being captured by an action or unusual sight, from a task that has to be completed, or from the episodic memories and hence the stories engendered by the exhibit (Tunnicliffe, Lucas, & Osborne, 1997). Indeed, the reminisces of older people elicited by viewing natural history dioramas at the Powell Cotton Museum at Quex Park in England reveal they remember when they lived in parts of Africa, or Kashmir and the impact that wildlife had on them as well as other memories. Their memories recounted to others aloes have an impact on the listener (Tunnicliffe & Scheersoi, 2015, p. 191) Museum visits can be important in motivating people to learn more about science (Diamond, 1994). It is salutary to remember that unlike the activities in the science centres where most visitor studies research has been carried out, 'animal looking' is not a hands-on experience of the same type. Attention and observation of exhibits may be cued by an inherent interest in animals, by prompts from guiding adults, from attention being captured by an action or unusual sight, from a task that has to be completed, or from the episodic memories and hence the stories engendered by the exhibit (Tunnicliffe, Lucas, & Osborne, 1997).

In work I carried out, I collected the spontaneous conversations of primary school groups at live, taxidermic, and robotic animals in relevant locations in England. The conversations were identified as having mixed gender groups, group of boys only or girls only. To facilitate the analysis of the transcripts the data were considered in terms of units of conversations. A unit of conversation was defined as the 'group conversation in front of any one exhibit from the beginning of the conversation until it ceased. The units of conversation were identified during the typing of the transcripts from the voices of the different members of the group. The data are of conversational units generated by the group, which contained an adult as well as the children. The number of individual children involved in the conversations is not known.

An example of a unit of conversation and at a robotic animal exhibit is:

Location: Dinosaur gallery, Year 2 (6–7 Year old) pupils
Girl: Look/it‘s'/moving./That's/a *Tyrannosaurus*
Adult: No it‘s not/It's *Tectonosaurus.*
Girl: What is it/Camilla?
Girl 2: Look at/it's/neck
Adult: The big/one/moved its/leg then/I don't think it's/quite dead.
Girl: Look/at its/neck.
Adult: Ugh!

There are a great many ways of analyzing conversations (Tunnicliffe & Reiss, 1999). A systemic network was chosen. This is a means of grouping or categorising things, in this case conversations, to be a parsimonious representation of the data, while preserving the relationships between categories in such a way that comparisons can be made between groups. It is a type of analysis that changes qualitative into quantifiable data and each topic of conversation was coded according to the systemic network developed from the work of Bliss et al. (1983). After initial analysis it was apparent that the comments were grouped within four super ordinate categories, namely those concerned with the front end of the animal, those associated with the dimensions of the animals; those features which were unfamiliar to the viewers and included structures such as penises, nipples, horns and claws; and disrupters, the legs and tails of animals which disrupt the outline of the animals' shape (Tunnicliffe, 1996a).

The preliminary inspection and categorising of the pilot conversations showed that the visitors looked at specific attributes of the animals, identified according to their understanding, often naming an animal to the nearest fit. An Arabian Oryx for example was named as a goat, the nearest known specimen to which the visitors (a three generational group of females) could name. They ask questions and make statements about what they already know, and comment on their own experiences talked about their whereabouts and gave instructions to each other.

The four main super ordinate categories were 'social comments', 'exhibit focused comments', 'management and social comments' and 'exhibit access' or 'orientation comments' in which visitors searched for or located the animals. A 'dustbin category' for topics such as security announcements, which were uncategorised, was provided. The comments directly referring to the exhibits were divided into 'other exhibit' comments, those about other aspects of the exhibit (such as the rocks behind the dinosaur models) and those, which focused on animals. The animal-focused category was subcategorised into five subordinate groups: (1) Interpretative comments, which included knowledge source comments such as questions and references to a source of the information proffered, human resemblances; (2) Affective comments which included emotive responses such as 'Ah!' or 'Ugh' as well as comments about other attitudes, namely human-animal interactions (and vice versa) and welfare comments; (3) Environmental comments referring to the natural habitat or endangered status of the species; (4) Voiced comments about the animals' structure, behave your; and (5) Names for the animals, every day and occasionally scientific

If more than one comment of a particular category (e.g. a name) occurred within a single conversation, it was not scored again. Hence the analysis shows the number of conversations within which a topic is mentioned not the number of overall times that a topic is mentioned. Issues of the species. A fine-grained coding for 'body parts' or anatomical attributes commented upon by the groups was used, again allocating a number to the noun. There were 56 categories in the network

Each conversation unit was categorised with the appropriate number from the networks. Hence a section of a conversation at robotic dinosaurs was represented in the following way.

Location: Dinosaur Gallery
Year 2 Group (6 or 7 years old)
3/21/43
Girl 2: Look at/its/neck
3/21 43
Girl: Look/at its/neck.
28
Adult: Ugh!

Some comments were categorised more than once. For example 'Look!' was categorised as a management statement as well as one of exhibit access because it was an ostensive remark. The reliability of the network was checked.

Certain aspects of the exhibits are commented about more often in groups with only boys than are done so by girls. (Tunnicliffe, 1998). Table 12.1 shows the number of conversational units heard at animal exhibits from groups of boys with a formal educator and from groups of girls with a educator or other adult. The results

Table 12.1 Numbers of conversational exchanges collected from groups with boys only and girls-only at three types of animal exhibit

Type of animal exhibit	Total no of exchanges for all groups	Number of exchanges for groups with boys only	Number of exchanges for groups with girls only
Live animals at zoo	459	158	119
Preserved animals in natural history museum	407	184	104
Robotic animals in museum	422	144	89

are examined for the two categories, groups with only boy pupils and those with only girls.

There was a total of 182 conversational units collected at zoo animals from mixed groups with both genders of pupils. The number of conversations of only boy groups were 158 and those of only girls 119. The total number of conversational exchanges in the Natural History Museum was 407 of which 184 were from groups with only boy pupils and 104 from the groups with only girls. The groups at robotic animal exhibits generated a total of 422 conversational units of which 144 were from groups with only boys and 89 from those containing only girls.

The conversational content for the transcribed conversational exchanges at the exhibits were worked out for each type of animal exhibit. The data are presented in turn beginning with those from the zoo (Tables 12.2, 12.3, 12.4, 12.5 and 12.6).

The data generated at the live animals by school groups of boys-only or girls-only are remarkably similar. However, boys named animals in some way more often but girl-only groups expressed emotive attitudes in more conversational exchanges and commented significantly more about observed behaviours.

The following conversations occurred from girls of Year 6 in an Invertebrate House. The first at a display of ants which included food, teddy bears and a picnic hamper as part of the exhibit furniture, the second at an aquarium; the third at an exhibit set in a dirty kitchen thus proving identifiable contexts.

Conversation 1: Ant Display
Girl: Oh look! Teddy bears.
Girl: Giant ants.
Girl: Look they (the things) are smothered in ants
Girl: It makes me itch!
Conversation 2: Aquarium
Girl: Is there anything in here?
Adult: Let's look. Oh yes, there is a leech!
Girl: A leech! Oh! Yes.
Conversation 3: Kitchen Exhibit
Girl: Ugh! Uck!
Girl 2: Cockroaches.
Girl: I don't like any of them.

Table 12.2 Comparison of main comments in conversations in zoo of gender subordinate groups of school groups—main topics

Conversational category	School group n = 459 no %		Boys only n = 158 no %		Girls n = 119 no %		1 df (totals of sub-groups)	Probability	Phi^2
Man/social	354	77	113	72	82	69	0.22		
Exhibit access	289	63	94	60	68	57	0.15		
Other exhibit comments[a]	227	50	74	47	55	46	0.01		
All body parts	280	61	87	55	61	51	0.39		
Al behaviour	301	66	94	60	90	76	7.93	$p < 0.005$	0.03
All names	401	87	142	90	96	81	4.75	$p < 0.01$	0.02
Affective attitudes	193	42	66	42	42	35	1.20		
Emotive attitudes	143	31	27	17	37	31	7.49	$p < 0.01$	0.03
Interpretative comments	443	97	154	98	113	95	1.23		
Real/alive	41	9	8	5	3	3	0.11		
Knowledge source	254	55	82	52	58	49	0.27		
Environment	19	4	9	6	5	4	N/A[b]		

Phi is used as an measure of the strength of association between two samples. It ranges from 0 to 1 and if there is no association the value of Phi for the given data is 0. Phi is used to indicate the strength of association and the maximum value would be when there is a perfect association between the two variables. Whilst not strong enough for planning purposes the highest Phi values are the ones commented upon in the discussion

[a] Comments about smelling, hearing or touching the exhibits (including pushing buttons) or wanting to use another sense, particularly touch, and when child talked to the exhibit, other thing in the exhibit such as foliage and the mention of labels

[b] N/A = not applicable because of insufficient data. For 2 × 2 tables, the expected values in each cell should be 10 or more therefore it is inappropriate to use a chi square test on the data

Girl: Hum.
Girl 3: They have eaten all the inside of the apple.

Examples of conversation generated by groups of younger pupils are as follows. Note the affective response from the groups of girls.

Conversation 4
Penguins (4–5 year olds with a educator)
Girl: Ah!
Educator: What colour are they?
Girl: Black and white.
Educator: What are they covered by?
Girl: Feathers.
Girl 2: I can't see.

There is remarkable consistency in comments generated in the three main categories of animal observations, anatomy or body parts, behaviour, and naming. Whilst individual categories have yielded no significant difference within the naming super ordinate category the accumulative results shows that girl-only

Table 12.3 Comparison of content of conversations of the gender subgroups of the school parties at the traditional animal specimens in the natural history museum

Category of conversation	School groups n = 407		Boys n = 184 no %		Girls n = 104 no %		1 df	Probability	Phi^2
Management/social	270	66	123	67	54	52	6.25	$p < 0.025$	0.02
Exhibit access	219	54	102	55	40	39	7.66	$p < 0.01$	0.03
Other exhibit	220	54	91	50	45	43	1.02		
All body parts	243	60	117	64	53	51	4.38	$p < 0.05$	0.02
All behaviour	152	37	54	30	41	39	3.05		
All naming	344	85	154	84	84	81	0.40		
Affective attitudes	219	39	88	48	67	64	7.36	$p < 0.01$	0.03
Emotive comments	145	36	45	25	45	43	10.95	$p < 0.005$	0.03
Interpretative comments	395	97	117	96	101	97	N/A		
Knowledge source	296	73	124	67	72	69	0.130		
Real/alive	46	11	24	13	15	14	0.11		
Environment	45	11	12	15	13	13	2.93		

Table 12.4 The content of conversations of the gender subgroups of a school party visiting static (museum) animal specimens-animal focused categories—animal observations

Category of conversation	All school groups n = 407 no %		Boys n = 184 no %		Girls n = 104 no %		1 df (totals of subgroups)	Probability	Phi^2
All body parts	243	60	117	64	53	51	4.38	$p < 0.05$	0.02
Front end	67	17	29	16	16	15	0.007		
Dimensions	198	47	94	51	42	40	3.05		
Unfamiliar	67	17	23	12	4	4	5.86	$p < 0.25$	0.02
Disrupters	39	10	16	9	12	12	0.6		
All behaviour	152	37	54	30	41	39	3.05		
Position	69	17	21	11	19	18	2.61		
Movement	40	10	13	7	12	12	1.68		
Food related	18	4	5	3	6	6	N/A		
Attractors	63	16	19	10	16	15	1.59		
All naming	344	85	154	84	84	81	0.40		
Identity	297	73	134	73	71	68	0.67		
Category	232	57	103	56	56	54	0.12		
Compare	164	40	48	26	20	19	1.73		
Mistake	23	6	14	8	4	4	N/A		

Table 12.5 Content of conversations of gender subgroups within school groups at robotic animals-animal observations

Category of conversations	School groups n = 422 no %		Boys only n = 144 no %		Girls only n = 89 no %		1 df (totals of subgroups)	Probability	Phi^2
Management/social	304	72	94	65	59	66	0. 03		
Exhibit access	239	57	80	56	39	44	2.63		
Other exhibit	173	41	73	51	40	43	0.73		
Body parts	309	73	96	67	65	73	1.04		
Behaviour	363	86	126	88	70	79	3.22		
Naming	176	42	66	46	22	25	10.43	$p < 0.005$	0.05
Affective attitudes	229	63	82	57	55	62	0.53		
Emotive comments	199	47	58	40	44	49	1.88		
Interpretative comments	400	95	139	97	81	91	3.18		
Knowledge source	339	80	110	76	67	75	0.04		
Real/alive	170	40	54	38	31	34	0.16		
Environment	19	5	8	6	4	5	N/A		

Table 12.6 Content of conversation of the gender groups at robotic animals (animated models) —animal focused

Category	All conversations n = 422 no %		Boys n = 144 no %		Girls n = 89 no %		1 df	Probability	Phi^2
All body parts	309	73	96	67	65	73	1.04		
Front end	113	27	31	22	22	25	0.32		
Dimensions	173	41	59	41	36	41	0.01		
Unfamiliar	59	14	7	5	15	17	N/A		
Disrupters	162	38	48	33	29	33	0.0.1		
All behaviour	363	66	126	88	70	79	3.22		
Position	80	19	30	21	11	12	2.72		
Movement	249	59	82	57	41	46	2.61		
Food related	127	30	43	30	18	22	2.64		
Attractors	182	43	60	42	35	39	0.12		
All naming	176	42	66	46	22	25	10.40	$p < 0.0052$	0.05
Identity	147	35	54	38	19	21	6.67	$p < 0.01$	0.03
Category	85	20	30	21	12	14	2.01		
Compare	41	10	15	10	8	9	N/A		
Mistake	6	1	3	2	2	2	N/A		

groups refer to names less than do boy-only groups. Groups with girls only generated significantly more ‘emotive attitudes’- likes and dislikes, ‘Ahs’, ‘Ughs’, and ‘Ohs’ as in conversation 3, and comment significantly more about behaviour of the animals. In summary, at zoo animals, groups with only-boys name the animals, as in conversation 5, significantly more than groups with only-girls.

Museum animals are a different type of exhibit because the animals are static. These exhibits have been prepared from skins of animals and are different from live animals as exhibits in that:

- they can be seen;
- their presence is predictable;
- the behaviour they are portraying i.e. feeding, fighting, is predictable;
- visitors can look for as long as they choose;
- a strong and easily recognised story line or message can be given by the museum and received by the visitors;
- environmental features- habitat etc. can be shown clearly.

Furthermore, dioramas, which are effectively scenes at a moment in time, can show animal interactions—predator prey, male female, parental care etc. behaviours, which are not possible in zoos! Dioramas can clearly show the ecosystem and the food chain, concepts not usually shown with live animals unless it is accidental where a non-captive animal enters an enclosure and is devoured. I have witnessed tigers enter such pigeon entrants and an otter eating sparrows.

Some differences between the content of the conversations generated at live animals and at the museum animals is to be expected. However, this difference might be for both genders or it may be for only one. These data indicate some significant differences in conversational content. Boy-only groups had more conversations with at least one management or social comment, pointing out the animal or referring to it and mentioning significantly more anatomical aspects of the specimens. Groups with only girls generated significantly more conversations which contained affective attitudes including emotive comments such as ‘Oh!’ and expressions of like and dislike as in conversation 6.

The following exchange between Year 6 girls shows the more pronounced emotive emphasis characteristic of conversations of some groups of girls. They were looking at different species of dog.

Conversation 6
Girl: Oh, aren’t they cute?
Girl 2: Aren’t they gorgeous?
Girl: Oh my God!
Girl 2: Oh I love doggies.
Girl: Oh look at that one. Aren’t they cuddly? They’re lovely.
Girl 3: That is cruel. I don’t like that.
Girl: I like the big one.
Girl 2: It looks like it’s been stuffed.

The conversation is a commentary. The speakers respond with positive emotions to the images of the dogs but also recoil at the imagined treatment of the dogs in being preserved (an affective comment but not an emotive one).

The following conversations between a group of Year 6 boys illustrates the emphasis on body parts made by groups with only male pupils at the variety of animal exhibit at the entrance of a Gallery.

Conversation 7:
Boy: That doesn't have any legs.
Boy: That has 8 legs there 4 legs there and no legs there.
Boy: Stick the groups' name.
Boy 2: Oh yes.

Unlike the responses to the zoo animals, pupils at the museum animals held more conversations with at least one comment about body parts in general and unfamiliar parts in particular nor was there a significant difference in naming between the two groups of only boys and only girls.

At Museum animals, the groups with only boys 'found' the specimens. They generated more management commands, make more social responses to each other and found the cases or located the specimens and items of interest without the exhibit. The boys mentioned body parts significantly more as part of the 'Look-see that' sequence. Girls generated more affective and emotive comments.

Robotic animals are relatively frequent recent additions to the repertoire of animals as exhibits, which appeared in the last decade of the 20th. Of the two exhibits studied, one as located half way through a Dinosaur Gallery and one at the exit (In one exhibit the specimen was unnamed, hence the number of names that can be used is much reduced compared with the opportunities for naming a variety of species for museum and zoo animals. Moreover, the different nature of the robotic animals, whose movements are planned and sequenced, elicits a different emphasis in the responses. The predictability of the movement of the robotics is an important feature which differentiates such exhibits from the static museum animals and the potentially, but unprofitable, moving zoo animals. Predicting the next action is illustrated in as in the following dialogue (Conversation 8).

Conversation 8:
Boy: I have had enough.
Girl: I haven't done this yet.
Girl: That dinosaur that they are eating he looks really, really nice. The head will go up in a minute.

The data show that the only category mentioned in significantly more conversations was that of naming and it was, counter intuitively, done so by boys. The following typical boy only (Conversation 9) illustrates the use of names.

Conversation 9:
Boy: It move sometimes, look!
Boy: I know that's *Tyrannosaurus rex.*

Boy: Wow, wow!
Boy: They eat that one, that big dinosaurs that, … that dinosaur is moving.
Boy: Yes I know.

Girls are less concerned with naming and more with emotive comments.

Conversation 10:
Girls: Look! Ah! Look!
Girls: Its leg is moving, look down there the big one keeps moving.
Girl: But it's dead!
Girl: I want to hear the roar again I want to hear the roar again!

Boys made more emotive comments at these animal exhibits than they did at the zoo and the museum animals. They responded emotively to the story being told through the diorama exhibit of meat eaters eating the plant eater and name the species (Conversation 11).

Conversation 11:
Boy: Ugh! Look at that thing.
Boy: This is a *Terantosaurus.*

At the robotic animals the groups of boys name the dinosaurs significantly more and gave them an identity name, such as '*Tyrannosaurus*'.

Discussion and Implications

Nearly all groups had a female adult with them, or were alone with their own gender, so the adult-effect, noted by Diamond (1986) for family groups, was similar for chaperoned groups. We do not know if the comments of boy-only groups are different because of their response to female educators and chaperones or of their inherent interest. Moreover, we do not know the effect of male chaperones and educators on the content of conversations of all groups. It may be that the perceived role of gender influences preference by the pupils for participation in particular activities. From the content and form of the conversations reported it appears that little 'science' is discovered or 'science talk' (Lemke, 1990) constructed. Everyday comments and conversational form predominate even though these are school visits.

The novelty of exhibits attracts both boys and girls (Koran & Longino, 1986). This novelty factor is an influence in responses to the robotic animal exhibits. Differences between the gender responses similar to those elicited at other types of animal exhibit are not present except for the greater number of conversations generated by only-boy groups who name an animal. Overall, the response of boy-only groups to animal exhibits emerges as one that is more factual—categorising and looking. Girls, on the other hand, are overall more concerned with their feelings and concerns and their relationships with specimens. An illustration of this phenomenon was recorded at specimens of domestic dog in the museum, (Conversation 12).

Conversation 12:
Girl: Oh, aren't they cute?
Girl 2: Aren't they gorgeous?
Girl: Oh my God!
Girl 2: Oh I love doggies!
Girl: Oh look at that one. Aren't they cuddly? They're lovely.
Girl 3: That is cruel. I don't like that.
Girl: I like the big one.
Girl 2: It looks like it's been stuffed.

The emotional response to animals' colours most oaten in a context, which is familiar, or which the pupils can imagine such a stem pet dog or a kitchen setting with added cockroaches.

The greater emotive response by girls to the animals illustrates the point that girls and boys do develop different ways of responding to the world and bears out the folk lore. From a relatively early age boys want more facts and girls are more concerned about emotions, for example, eight year old boys ask for facts about babies and toddlers developing, whereas girls are exploring feelings and emotions (Tunnicliffe, 1997).

Overall, similar aspects of animals as exhibits catch the attention of school groups (Tunnicliffe, 1996a). Response varies with age of the children (Tunnicliffe, 1996b). Furthermore, there is a gender specific response in some areas. Girls comment on their likes and dislikes and mention feelings, both theirs and the animals'; whereas boy-only groups are more interested in establishing the data about the animals. The data presented in this paper indicate that boys respond differently to animal exhibits unless they are looking at a novel one. Robotic dinosaurs elicit similar comments from all groups except, even so, the need of boy-only groups to categorise and identify what is being looked at is still apparent. It is interesting that there are so few differences in the conversational content of boys and girls. This finding supports the practice of providing similar work about animals in school and in museums and zoos.

Implications

Pre-service Teachers

The implication of the data reported in this chapter about learners in informal settings as opposed to the classroom is for educators, and hence a crucial part of pre-service educator training. A formal educator organising such a learning opportunity, which usually has a relation to some topic at school, should identify which part of the 'learning trilogy' the anticipated visit belongs. Is it an introduction to subject, or designed to supplement the learning about a specific topic in the middle of the learning sequence or as a summative visit at the end? The relationship to the trilogy should be very clear as it relates to the aims and objectives of such a visit and their expected learning outcomes. The pre-service educator should develop his or her own assessment tool for use at whatever stage of the learning trilogy. The formal educator planning a visit to an informal location should be aware of the learning style and references of the students in their charge. Pre-service educators should seek the advice and knowledge of the formal and informal educator and consider the design of activities accordingly.

Learning for Boys and Girls

There are differences in the responses of boys and girls to the same exhibit, and indeed, in my experience to the cultural heritage of the learner. For example, informal educators might help boys reflect on more affective aspects of the animal exhibits and help girls to name the specimens to a greater extent. Data here also challenge informal educators to be aware of gender specific differences that are identifiable in the conversations of boys and girls as single sexed groups and even the comments which they make when part of mixed sex groups. The venues can assist in the interpretation provided, on briefing sheets for chaperones with questions being posed at exhibits by groups or through facilitators. Pre-visit discussion of the issues in both in-service education and in the educators' packs would be useful. Suggestions for cue questions to be posed to learners are an important part of preparation for an effective learning outcome. These are also invaluable in the briefing of chaperones in their task accompanying learning groups.

Final Thoughts

These studies of English primary pupils and their accompanying adults indicate that there is a similar basic interest held by English educated learners of primary age. Moreover, their pattern of responding to animals as exhibits has only a few significant variations. The insight gained into the preferences of the pupils of the two genders obtained from this study will be of use to both school educators and museum educators in England and serve as a baseline for further studies and as a guide to those in other countries. The knowledge could enable all educators involved in out of school visits to emphasize the relevant areas of the specimens which are given less focus by the groups and to build upon that to which the pupils do attend.

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Chapter 13
The Challenges of 'Measuring Long-Term Impacts of a Science Center on Its Community': A Methodological Review

Eric Jensen and Thomas Lister

In recent years, there have been increasing demands on informal science learning institutions to demonstrate their impacts beyond the immediate aftermath of a visit. Such research is rarely conducted because of its logistical and methodological complexity. A report commissioned by the UK government to assess whether science centres should continue to receive government support reached the following conclusion:

> We have not been able to assess whether science centres are good value for money relative to other comparator programmes. This is because there is insufficient evidence on the long term outcomes of science centres or comparator programmes (Frontier Economics, p. 2).[1]

This conclusion helped to increase the salience of long-term impact evaluation for science centers in particular, and informal science education in general.

The study by Falk and Needham (2011) entitled '*Measuring the Impact of a Science Center on its Community*' represents an ambitious effort to solve the considerable logistical, methodological and theoretical challenges inherent in long-term impact measurement of this kind. Since its publication, it has been held up as a model for informal science education impact evaluation, and widely cited for its conclusion that science centers are effective at achieving long-term impact.

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Jensen, E., & Lister, T. (2016). Evaluating indicator-based methods of 'measuring long-term impacts of a science center on its community (comment). *Journal of Research in Science Teaching,53*(1), 60–64.

A rejoinder for this chapter follows in Chap. 14.

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[1] http://sciencecentres.org.uk/govreport/docs/impact_of_science_centres.pdf.

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It has also been touted as a best practice model for measuring informal science learning institutions' long-term impact. Subsequent studies, including a recent international impact evaluation of science center impacts, have used a similar model. As informal science educators are increasingly called upon justify the long-term impacts of their practice, it is essential to understand the current evidence and methods of conducting such evaluation. This chapter critically reviews Falk and Needham's study in detail (cf. Jensen & Lister 2016; Falk & Needham 2016), using its methodological and theoretical limitations to illustrate the issues that continue to face those attempting the difficult yet important task of evaluating the informal science education impacts.

Falk and Needham draw upon St. John and Perry's (1993) notion of an educational infrastructure to highlight the complex and multi-dimensional nature of science learning. They highlight a wide array of institutions and services that contribute to public learning and understanding of science, including formal schooling, libraries, museums, nature and science centers, aquariums and zoos, botanical gardens and arboretums, television programs, film and video, newspapers, radio, books and magazines, the Internet, community and health organizations, environmental organizations and conversations with friends and family. These institutions, services and discussions are viewed as comprising a science-learning infrastructure.

Falk and Needham's study sets out to examine the impact of one component of this science-learning infrastructure: the California Science Center in Los Angeles. Previously known as the California Museum of Science and Industry, the center was redesigned in 1993 with the expectation of a marked increase in its impact on the local public's science-related understanding, interests and behavior. The revamped Center (re)opened in 1998.

Falk and Needham's long-term impact study orbits around a growing body of research on the educational value of informal science learning institutions. For decades, these institutions have made claims about their impacts on public learning and understanding of science. However, the availability of robust impact studies supporting these assertions is limited (e.g. Jensen, 2014a). '*Measuring the Impact of a Science Center on its Community*' aims to provide a great leap forward addressing this research gap.

Falk and Needham outline two methodological approaches that they contend can be used to monitor the influence a science center has on its public's understanding of science: "inside-out" and "outside-in". 'The *inside-out* approach was designed to identify visitors to the institution and assess the short- and long-term effects that various projects, activities and exhibitions had on these visitors' (Falk & Needham, 2011, p. 2). Essentially, the "inside-out" approach entails measuring the impact of an institution through visitors who have attended and participated in its activities. This is the standard approach used in educational impact evaluations (cf. Wagoner & Jensen, 2014). In contrast, an "outside-in" approach is defined as collecting data on a population scale to examine the prevalence, incidence and outcomes of visits to a particular institution amongst different demographic categories. 'The *outside-in* approach was designed to investigate through face-to-face interviews and large-scale random telephone surveys the science understanding, awareness, and attitudes of individuals within the broader community to determine any impact the Science Center was having on these individuals’ (Falk & Needham, 2011, p. 2). The outside-in approach uses correlation analysis to ascertain differences in outcomes between visitors and non-visitors, which are then attributed to the institution. Research supporting claims that science centers and other science-related institutions are significant contributors to public understanding of science have previously employed an “inside-out” approach (e.g. Falk & Storksdieck, 2005; Falk & Gillespie, 2009; Jensen, 2014b). The study by Falk and Needham that is the focus of the present article is unique in seeking to demonstrate the alternative “outside-in” approach, and in doing so, illustrate the newly developed Science Center was having a large-scale impact on the science literacy of Los Angeles residents. The present article is therefore designed to critically assess whether this is a good model for informal science learning researchers to adopt.

The two research questions posed by Falk and Needham (2011) were:

1. Who in L.A. has visited the California Science Center and what factors best describe those who have and those who have not visited?
2. Does visiting the California Science Center impact public science understanding, attitudes, and behaviors, and if so, in what ways?

Falk and Needham (2011, p. 2) identify two major challenges that limit the validity and reliability of any approach to measuring a science centers’ impact. The first challenge relates to the nature of learning per se. Science learning is cumulative, developing through a variety experiences (one of which is formal schooling) at different times during an individual’s life-course (Miller, 2001, 2004; National Science Board, 2006). Falk and Needham use an individual’s understanding of the physics of flight to illustrate this point. ‘[Ones understanding of flight] might represent the cumulative experiences of completing a classroom assignment on Bernouli’s principle, reading a book on the Wright brothers, visiting a Science Center exhibit on lift and drag, and watching a television program on birds’. They rightly point out that ‘no one source is sufficient to create understanding, nor one single institution solely responsible’ (Falk & Needham, 2011, p. 2) in such cases. The cumulative nature of learning makes assessing the impact of a single experience (such as attending a science center) on an individual’s overall understanding of science a major challenge that Falk and Needham claim to have to overcome with this study.

The second major challenge that faced Falk and Needham was to disentangle an individual institution’s impact, when a wide variety of institutions make up the education infrastructure (St. John & Perry, 1993). People encounter multiple components of this infrastructure throughout their life-course, from attending secondary school to engaging with a science organization, to watching a documentary on television or visiting a museum. This complex web of institutions and services is said to provide the conditions and capacities to support science learning. Falk and Needham (2011) suggest that the collection of cross-sectional data across multiple years would overcome this challenge, allowing researchers to ascribe change over time in the public’s science understanding and interest to this single institution.

Given the importance of these two longstanding research challenges that have frustrated past attempts to evaluate informal science learning impact, the present article focuses critically on examining Falk and Needham's (2011) proposed methodological solutions. This article proceeds by summarizing and critically assessing each step in the research process, from sampling to conclusions. We start by addressing the samples and their representativeness. We then evaluate the research design, including the innovations proposed as solutions to the challenges of long-term impact evaluation. We assess the details of the survey questions used to measure impact, and finally, discuss alternative approaches to evaluating long-term informal learning impacts of institutions such as science centers.

Evaluating Sampling and Representativeness

Falk and Needham's study includes survey data collected in 2000, relatively soon after the re-opening of the California Science Center, and again almost a decade later (2009). Taking these snapshots of the L.A. public's understanding and interest in science was intended to allow Falk and Needham to attribute observed changes at the population level 'to the presence of this new piece of infrastructure' (Falk & Needham, 2011, p. 3). A major strength of this study is the inclusion of non-visitors, who are so often missing from the landscape of research on informal learning institutions (Dawson & Jensen, 2011; Hood, 1995; Jensen, Dawson, & Falk, 2011). However, there are a number of major unacknowledged limitations that undermine the study's claim to have captured a representative sample of the L.A. public. Some of the study's limitations are actually revealed by Falk and Needham's (2013) paper '*Factors Contributing to Adult Knowledge of Science and Technology*', which focused on the 2009 survey data comprising the second data collection point for Falk and Needham (2011).

Sampling Description

The first sample included $n = 832$ individuals aged 18 and over. A slightly larger sample was contacted in 2009, with $n = 1{,}008$ respondents completing what was described as a comparable survey instrument. As the sample targeted the population as a whole, each sample was comprised of both visitors and non-visitors to the Science Center. Respondents were said to be drawn from five racially, ethnically, and socio-economically different communities within the Los Angeles metropolitan area: 'These communities were selected to be generally representative of the diversity of greater L.A. residents' (Falk & Needham, 2011, p. 4). The communities selected included Canoga Park, El Monte, Santa Monica, Torrance, and South Central.

Interviews were primarily conducted in English, with 14% carried out in Spanish in 2000, and 8% in 2009. Race and ethnicity were claimed to be relatively comparable across both samples. White/Caucasian residents represented 46% of respondents in both 2000 and 2009, whilst African-American respondents represented 13% of the 2000 sample and 16% of the 2009 sample. Respondents who indicated their ethnicity as Latino/Hispanic represented 29% and 25% respectively, with a further 7% and 8% claiming to be Asian-American. Those of 'other' ethnicities represented 5% in both samples. Some of the 2009 respondents were contacted and interviewed using cellular phones, although cellular interviews made up less than 10% of the 2009 sample. Respondents' mean age of 43 was identical across both datasets. The gender distribution of respondents was skewed towards women, who made up 59% of those interviewed in 2000 and 56% in 2009. The later sample included a higher percentage of respondents who reported a household income of over $50,000/year, increasing from 44% in 2000 to 62% in 2009. This was also true for the percentage of respondents in the process of obtaining a college degree, which rose from 22% in 2000 to 28% in 2009. The number of respondents with graduate degrees also increased from 16% to 19% in 2009. While the demographics of the two samples were not totally comparable, Falk and Needham state that both samples were weighted with U.S. Census data, although they do not reveal which Census data was consulted (e.g. 2000 or 2010).

Sampling Limitations

The core claim developed by Falk and Needham (2011) is that the population of Los Angeles underwent an increase in scientific knowledge from 2000 to 2009 that can be attributed to the California Science Center's impact: 'findings from this research provide strong evidence that the California Science Center directly and significantly contributes to science learning, interests and behaviors of a large subset of the L.A. community' (Falk & Needham, 2011, p. 11). For this claim to be upheld the 2000 and 2009 samples must be equivalent; otherwise, observed changes over this 9-year timeframe may instead be attributed to other (non-impact) factors, such as increases in income and education levels between the two samples, factors clearly unrelated to the California Science Center. In this section we will raise questions about (1) whether Falk and Needham's two samples are comparable to one another and, (2) whether they are sufficiently representative samples to support population-level generalizations. We begin by questioning the equivalence of the 2000 and 2009 samples, using a detailed consideration of three variables: Ethnicity, income and educational attainment.

Upon closer examination of U.S. Census data, the claim that Falk and Needham's (2011, p. 4) samples were 'representative of the diversity of greater L.A. residents' is erroneous. One demographic category in particular was significantly underrepresented in both 2000 and 2009, making the samples unrepresentative whilst introducing a high risk of sampling bias. Hispanic/Latino residents represented 29% of respondents interviewed in 2000; nearly a decade later, this figure *decreased* to 24%. This represents a significant underrepresentation of Hispanic/Latino residents living in L.A. during the study's timeframe. According to the United States Census Bureau, in 2000 Hispanic/Latino residents represented 46.5% of the total Los Angeles population, in 2010 this figure *increased* by 2 per cent to 48.5% of the population (U.S. Census Bureau, 2000, 2010). If Falk and Needham had used a probability sample that proportionally represented the target population, then Hispanic/Latino residents would not be so heavily underrepresented in both samples. For other researchers considering employing a population sampling approach, we recommend using a random sampling procedure stratified by key variables such as ethnicity, education and income to ensure a more representative sample.

The overrepresentation of higher-earning respondents is another indicator of sampling bias that casts doubt on the representativeness of Falk and Needham's (2011) samples. In 2000, the percentage of respondents earning more than $50,000 annually was 44%, in 2009 this figure increased substantially to 62%. According to U.S. Census data, these figures do not represent the true number of Los Angeles residents earning more than $50,000 a year. According to Census data (U.S. Census Bureau, 2000), in 2000 this figure was actually 38% of L.A. residents, and based on a 5-year estimate between 2008–2012, 50% of residents reported earnings over $50,000 (American Community Survey, U.S. Census Bureau, 2008–2012). Falk and Needham (2011, p. 4) state that 'the weighted samples were comparable […] to each other, with the exception that the 2009 sample included slightly higher percentages of respondents with higher incomes'. However, we regard an 18% increase in the number of higher-earning respondents sampled in 2009 as more than 'slight'. It means the sample skews towards higher-earning respondents, with those earning more than $50,000 a year overrepresented by 12% in the 2009 sample (American Community Survey, U.S. Census Bureau, 2008–2012). This skewness towards higher-earning respondents is a major threat to the validity of the authors' claims because, as is reported in their 2013 paper, higher income is one of the strongest predictors of self-reported understanding and interest in science. Indeed, it was later reported that respondents who 'had an annual income over US $50,000 were more likely to consider themselves as knowing a moderate amount or great deal about science and technology rather than little or nothing about these fields' (Falk & Needham, 2013, p. 441). Specifically, they found that higher-earning individuals were 1.72 times more likely than lower-earning individuals to report knowing a moderate or great deal about science and technology. Taking this into consideration, the oversampling of higher-earning respondents not only undermines the representativeness of the samples, but also brings into question the assertion that the California Science Center had a positive impact on respondents' self-reported understanding and interest in science. That is, higher income could have been a more significant factor than Science Center attendance in accounting for more positive attitudes towards science in 2009 (although statistics on the relative contribution of income were not presented in the article).

Another predictor variable that could explain part of the aggregate increase in respondents' self-reported understanding and interest in science from 2000 to 2009 is educational attainment. Respondents sampled during the second wave of data collection had obtained a higher level of education than those surveyed in 2000.

The number of respondents who had obtained a college degree increased from 22% in 2000 to 28% in 2009. Falk and Needham's 2009 sample also saw an increase from 16% to 19% in the proportion of respondents with a graduate degree. Given U.S. higher education generally requires science courses as part of the 'general education requirement' regardless of major, such educational attainment could be a confounding variable in Falk and Needham's attribution of long-term impact to the California Science Center. Unsurprisingly, Falk and Needham's (2013, p. 438) bivariate analysis of the relationship between formal schooling and self-reported knowledge about science and technology 'showed that those with a higher level of education felt they were significantly more knowledgeable about these fields'. In addition to gaining enhanced exposure to science learning, those who have obtained a higher level of education may also take a greater interest in science-related news items and programmes, increasing their exposure to sources of science learning in various ways that contribute to the self-perception of understanding science.

Shifting to the bigger picture, there is reason to question whether Falk and Needham's sampling approach yielded probability samples that would support their generalizations about the 'L.A. public', 'L.A. adults' and 'those in the L.A. area'. We can begin here with the question that determines whether a probability sample has been achieved: Did all adult residents of Los Angeles have an equal probability of being selected for participation? Clearly they did not, as everyone living outside the five selected communities within Los Angeles had a 0% chance of selection. The severity of the sampling bias incurred by only sampling these five communities could only be estimated by knowing precisely how closely these communities' characteristics align with the general L.A. population. However, Falk and Needham (2011) do not provide these details. What makes this five-communities sampling method more problematic is that a nine-year period in a diverse city such as Los Angeles is likely to see significant population turnover at the level of individual communities. This makes it more likely that the 2000 and 2009 samples are incomparable. Moreover, as can be seen from the examples discussed above, there is ample basis for skepticism about the representativeness of each of these two samples as well.

Evaluating the Research Design

The majority of existing research literature evaluating informal learning institutions relies heavily on post-visit self-reports as the main mechanism for measuring impact. However, self-reports are a particularly fraught method for this kind of impact measurement, as even the most reflexive of individuals would have great difficulty accurately self-assessing the impact of encountering one component of the science-learning infrastructure, as well as identifying a specific source from which their knowledge or interest in science was derived. Many of the cognitive biases affecting such autobiographical memory are well established in the methodological literature (e.g. Tourangeau et al., 2000).

In order to measure the impact of visiting the Science Center respondents were asked to indicate their level of agreement with 4 ‘impact’ statements using a Likert scale from 1 (strongly disagree) to 5 (strongly agree):

- I learned one or more things that I never knew before
- My understanding of things I already knew was strengthened or extended
- I came away with a stronger interest in some areas of science or technology
- It changed my attitudes or behaviors to be more positive toward science and technology

Measurements were taken across both data sets, and results indicated that almost every adult who visited the Science Center agreed that a visit resulted in an increased understanding of science and technology. Respondents in the 2009 sample were ‘significantly more likely to agree that as a result of visiting the Science Center, they learned one or more things that they did not know before, their understanding of things that they already knew was strengthened, and their attitudes or behaviors were more positive towards science or technology’ (Falk & Needham, 2011, p. 7). Respondents’ level of agreement between 2000 and 2009 increased for three of the four impact statements, although the mean level of agreement for the statement, “I came away with a stronger interest in some areas of science or technology” decreased from 3.97 to 3.55. In response to an additional 14 items that were added to the 2009 survey, an overwhelming majority (95%) of respondents agreed with the statement: “my understanding of science or technology was strengthened or extended by my visit to the California Science Center”. Other statements recording impact included: “my curiosity about science and technology was increased by visits to the California Science Center” (85% of respondents agreed), and, “I learnt at least one thing about science or technology that I never knew before” (94% agreed). Falk and Needham (2011, p. 10) describe how ‘most of these respondents also reported increases in other dimensions of science and technology learning, including increases in the affective dimension of curiosity, interest, and appreciation’.

The Limitations of Self-reporting Impacts

Many perfectly good survey questions involve requests for respondents to self-report information. These questions ask respondents to access their memories, feelings or thoughts, edit that information internally, and then select a response option from the survey form. Some self-report questions are perfectly reasonable, for example: ‘How satisfied are you with your visit to the science center?’. This self-report question is appropriate because a respondent could be expected to have existing views to report. Poor quality self-report questions, however, ask respondents to conduct self-assessments of their own characteristics and capabilities that they could not reasonably be expected to judge accurately. Self-report questions can also be problematic when they require respondents to be self-aware and undergo a complicated internal editing process. For example, questions asking, ‘Did you learn anything during your visit to the science center today?’ (‘Yes’ or ‘No’) would require visitors to (1) call up memories of the entire visit, (2) identify moments from that visit in which new information was acquired and, (3) identify that acquired information as ‘learning’. This may be an unrealistic expectation of the respondent, inflating the likelihood of errors (deviation between what actually happened and its representation in survey data). Using self-reports as a proxy for measuring learning outcomes also suffers from the followings flaws:

- *Low in validity*. While this question does measure something (e.g. self-confidence relating to science and technology topics), it does not measure its intended concept of actual science and technology knowledge.
- *Low in reliability*. Science and technology are multi-faceted domains, encompassing thousands of different sub-domains, fields of practice and particular technologies. When one person thinks of “science”, they might be thinking of human cloning or neuroscience. Another person’s mental representation of “science” might focus on earthquake detection or climate change (or simply a man with white hair in a lab coat!). Given this range of representations, the most high profile, recently mentioned or personally familiar aspect(s) of science and technology would likely become the basis for a respondents answer. This means that respondents are each essentially answering different questions, depending on which aspects of science and technology are most prominent for them.
- *Bias risks overestimating knowledge*. Social desirability (and ego) may drive some respondents to overestimate their knowledge.
- *Bias risks underestimating knowledge*. Some respondents may not recognize their knowledge as “knowing something” (e.g. it may just be taken-for-granted as “the way it is”) or being about science and technology. For example, they might have in-depth knowledge about why and how their heating unit works at home, but not recognize such knowledge as relating to science and technology.

Beyond the general limitations in the structure of the impact measurement approach employed by Falk and Needham (2011), the specific survey questions used also deserves close scrutiny.

Respondents were asked to indicate their level of agreement with items such as, ‘my understanding of science or technology was strengthened or extended by my visit to the California Science Center’ and ‘my curiosity about science or technology was increased by visits to the California Science Center’. The former question is quadruple-barreled as it forces four different pathways into one question: (1) science understanding strengthened, (2) science understanding extended, (3) technology understanding strengthened, and (4), technology understanding extended. The second question is double-barreled with the inclusion of both ‘science’ and ‘technology’, but it also introduces further ambiguity by referring to multiple ‘visits’ (plural). For example, it is unclear how someone should answer if they felt that on one visit their curiosity increased, but on others it did not (or even declined). The other two outcome statements are also problematic. Among other limitations, the statement, ‘I learned at least one thing about science or technology that I never knew before', leaves open the risk that a respondent 'learned' something incorrect that is being counted here (e.g. 'I learned that global carbon emissions are making the planet's climate more stable'). Similarly, we have no way of knowing if agreement with the following statement is actually positive, as it is too ambiguous: 'after visiting the California Science Center, I found myself thinking about some aspect of science or technology'. For example, if people found themselves thinking about the incomprehensibility of some aspect of physics due to baffling explanations they encountered in the Science Center, they could accurately agree with the above outcome statement. The self-report survey questions used by Falk and Needham to measure learning outcome provide a clear example of the misuse and poor practice of survey of survey design.

Acquiescence Bias

Beyond such straightforward question design flaws, taken as a whole the outcome statements used in this study also introduce the risk of *acquiescence bias*. It has long been established in survey methodology that when respondents are given cues such as the 'implied direction of the question' and previous questions, responses can be 'biased by acquiescence (the tendency to agree)' (Tourangeau et al., 2000, p. 5; Cannel et al., 1981). That is, when there is a whole series of positive statements about an object, it signals to respondents that the researchers are expecting or hoping that they will agree with those statements. Indeed, prior methodological research has shown a clear tendency for people to agree with Likert scale statements. Furthermore, respondents who perceive researchers as being of a higher social status will, out of social convention or courtesy, endorse any assertion made in question, regardless of its content (Krosnick, 1999). This bias can be avoided by reverse coding half of the questions. For example, 'I enjoyed my experience visiting the Science Center' could be reversed to, 'I found my visit to the Science Center unpleasant'.

Failure to follow this basic principle of survey design makes research using similar Likert scale items susceptible to acquiescence bias. Yet, there is further reason to be skeptical regarding this particular study's findings. Methodological research has found that status differential in the form of lower social status a common cause of survey acquiescence: 'The lower the status of the respondent, as measured by the occupation of the head of the household, the greater the frequency of acquiescence' (Lenski & Leggett, 1960, p. 465). Indeed, Falk and Needham's (2011, p. 7) own analysis revealed that 'lower income respondents were […] significantly more likely to agree with most statements, especially about the Science Center providing new ideas or techniques, changing attitudes about science or technology'. However, this was not recognized as a possible sign of acquiescence bias by Falk and Needham. Further methodological research found respondents completing surveys via telephone were also more likely to exhibit acquiescence than respondents participating in face-to-face interviews (Calsyn, 1992), casting further doubt on any inferences drawn from these results.

Reporting Impact on Behalf of Another

A related, but further fraught practice is to ask respondents to report on another person’s knowledge, feelings or values. This is a common problem in research that asks parents or teachers to report on the experiences, attitudes or knowledge of their children or pupils, rather than collecting data directly from the children themselves.

Falk and Needham (2011) sought to measure the Science Center’s impacts on children by asking parents to assess and report on cognitive and affective outcomes. Parents were asked to indicate whether their child had obtained an increased understanding of science and technology after visiting the Science Center. They were also asked to report on their children’s development of appreciation for science and whether the Science Center experience had enhanced their children’s chances of future success. Parents generally agreed with the positive statements about the impact the Science Center had on their children, with 87% reporting that the visit had increased their children’s understanding of science and technology. 45% believed the visit had increased their child’s understanding “a lot”. Apart from the obvious ambiguity and unreliability in expecting different parents to judge what counts as “a lot” of learning, it appears parents were asked to provide a single assessment of whether learning had occurred for all their children: what if one child learned “a lot”, another “a little” and a third “nothing”? Are parents really likely to be making a considered judgment here? Asking parents to provide an off-the-cuff assessment of their child’s learning is even more prone to error than expecting them to accurately judge their own learning outcomes. Assessing another individuals’ comprehension and storage of new knowledge encountered at the Science Center is an unrealistic expectation of respondents, and an unreliable method of evaluating children’s understanding of science and technology.

Falk and Needham reported that 80% of parents agreed that there was an increase in their child’s appreciation toward science and technology due to visiting the Science Center. However, Falk and Needham provide no evidence of how they operationalized this outcome or ensured that ‘appreciation’ was interpreted in a similar way by the various parent respondents. Even if parents did have a shared understanding of this outcome, appreciation is an internal psychological phenomenon that, in this instance, only the child could be expected to self-report with any degree of accuracy. The same goes for the other child-oriented questions reporting on increased ‘curiosity’, ‘inspiration’ and ‘interest’.

Even more unrealistically, respondents were asked to report whether they believed a visit to the Science Center enhanced their child’s chances of future success in life (79% agreed that it did). Clearly it is impossible for parents to know whether a visit to a Science Center has increased a child’s life chances, and it is poor survey research practice to ask questions about content that respondents could not reasonably be expected to know. Therefore, this instance of reporting on behalf of another’s future life chances is much more likely to represent survey response biases of the kind discussed previously than any meaningful Science Center visit impact. In sum, asking parents to assess the cognitive and affective outcomes of visiting the California Science Center on behalf of their children is an unreliable method of assessing learning outcomes, let alone future life chances.

The Limitations of Indicator-Based Impact Evaluation

To circumvent the need to rely exclusively on self-report data, Falk and Needham (2011) created a 'marker' to measure the Science Center experience. 'The idea was to find a learning equivalent of a radioactive tracer; something that in and of itself may or may not be highly important, but which could be considered an indicator of something greater that was meaningful' (Falk & Needham, 2011, p. 3). A 'marker' was defined as a single science concept, the understanding of which can be attributed to the California Science Center. Using the concept "homeostasis" as the marker, Falk and Needham aver that any increase in understanding of this principle amongst the L.A. public over the years can be attributed to the Science Center. The reason for selecting homeostasis is that those who visited the newly designed Science Center had the opportunity to watch a 10-minute show about the physiological process, featuring an animatronic woman named Tess and her animated sidekick Walt. The purpose of the show was to 'tangibly and engagingly teach visitors this important, but relatively poorly understood scientific concept' (Falk & Needham, 2011, p. 3). Using this 'marker', Falk and Needham hoped to provide empirical evidence that a visit to the California Science Center directly contributed to public understanding of science. In so doing, they aimed to transcend the limitations of using self-reports for impact measurement.

Using the homeostasis marker as an impact indicator falls short firstly because no valid baseline measurement was developed in order to gauge whether actual learning had occurred. Falk and Needham instead inferred a baseline from research they conducted with visitors to the Science Center in 1998. This 1998 visitor-only sample was asked to define homeostasis prior to entering the Science Center. In this earlier study, 7% of the 1998 visitor sample was deemed to have correctly defined homeostasis. This 7% figure was considered a conservative estimate of the baseline for L.A. public's understanding of homeostasis. Thus, it is inferred that 'the percentage of those in the L.A. area able to correctly identify homeostasis prior to opening of the Science Center can be assumed to have been 7% or less' (Falk & Needham, 2011, p. 8). We would challenge the use of this 1998 sample as an estimate for the baseline of the L.A. public's understanding of homeostasis for number of reasons, including: (1) the baseline sample excludes non-visitors to the California Science Center, and (2) the self-selected sample is unlikely to be representative of the wider Los Angeles population, and is certainly not a probability sample and (3) there is no evidence provided that the same standards for determining a correct definition were applied consistently and reliably across the 1998, 2000 and 2009 datasets. Indeed, the reliability of the scoring procedure for an acceptable definition of homeostasis is not demonstrated for the 1998, 2000 or 2009 studies. What were the criteria for an acceptable (i.e. correct) definition? How many different coders were involved in making these judgments? Were the same coders used at each time point? How was reliability ensured? In methodological terms, this kind of scoring would be considered a form of content analysis (Krippendorff, 2013; Neuendorff, 2002). Good practice in content analysis requires the reporting of inter-coder reliability statistics to show the level of error present in the scoring. That is, how highly correlated are the scores of different coders if they analyze the same content independently using the same criteria? Without gathering and presenting evidence of a reliable scoring procedure, this entire outcome measure is put in doubt.

Finally, the results of the homeostasis marker do not support the narrative that the California Science Center delivered long-term positive learning impacts for the L.A. population. In 2000, 10% of respondents sampled could provide an acceptable definition of homeostasis, nearly a decade later this figure doubled to 20%. However, 75% of those who provided an acceptable definition of homeostasis in 2000 reported they had visited the Science Center; in 2009, only 61% of those offering an acceptable definition reported visiting the Science Center. Although Falk and Needham highlighted that there was a doubling in the proportion of respondents able to correctly define the marker concept, significantly fewer of these respondents had actually visited the California Science Center. This means that the reported increase in respondents providing acceptable definitions from 10% in 2000 to 20% in 2009 cannot plausibly be attributed to the influence of the Science Center. The authors’ suggestion that the change over a decade in the L.A. public’s understanding of the concept homeostasis provides strong evidence that the Science Center was responsible for improving public long-term science knowledge and understanding is simply mistaken. Clearly other factors are at work in this claimed increase in understanding of homeostasis.

Evaluating the Statistical Analysis

Clearly the limitations of Falk and Needham’s (2011) study are many and various. We do not have the space for a full review of the statistical methods employed in the study. In brief, more sophisticated statistical tests such as multiple linear regression or generalized linear mixed models would have been more appropriate to account for the relative contribution of a series of independent variables that could have contributed to the outcomes Falk and Needham measured. Moreover, while effect sizes are reported to a limited extent, their implications are not reflected upon in the body of the article. For example, the table illustrating ‘differences in [the self-reported] amount informed about science and technology based on whether respondents had visited the Science Center’ (2011, p. 8) employs a *t*-test measure to compare the level of self-reported feelings of being informed about science amongst Science Center visitors and non-visitors. While there is a difference between visitors and non-visitors on this outcome variable both in 2000 and 2009, the effect sizes are remarkably small. The reported effect sizes for the difference between visitors and non-visitors was $r_{pb} = 0.18$ in 2000 and $r_{pb} = 0.17$ in 2009. These effect sizes mean that whether or not someone visited the California Science Center only accounted for 3.24% (2000) or 2.89% (2009) of the variance in “feeling well informed” about science and technology. Given that this statistical test is merely correlational, this difference might be expected to be much greater as those who feel well informed about science may be more likely to want to visit a Science Center. Regardless, the very small level of variance in the outcome variable that is explained by whether someone visited the Science Center is not commented on at all in the paper, nor are the effect sizes for other independent variables such as educational attainment or income level provided for comparison.

Aside from the relatively unsophisticated nature of the statistical analysis, Falk and Needham (2011) tend to frame their findings of correlations between Science Center visiting patterns and self-reported knowledge as evidence of impact. For example, they frame a relationship between visiting the Science Center and self-reported knowledge in science and technology as evidence that the Science Center increases public understanding of these subjects: ‘the more frequently an individual visited this Science Center, the greater their self-reported perception that they were well-informed about science’ (Falk & Needham, 2011, p. 8). This quote suggests that visiting the Science Center results in feeling better informed about science and technology. However, it is equally plausible that the causal direction of this relationship could be reversed: feeling better informed about science and technology could lead people to want to visit science centers. Indeed, throughout the article, correlations are interpreted in the most favorable possible light for claiming that the Science Center is delivering positive impacts. At this juncture, a basic precept of statistical analysis bears mentioning: Correlation is not causation.

Evaluating the Study’s Claims in Light of Methodological Limitations

This methodological review of Falk and Needham’s (2011) attempt to measure the long-term impacts of visiting a science center is not comprehensive. However, we have identified major issues that are important for researchers to consider when conducting this kind of study in future. To conclude this article, we briefly highlight the main claims made in this study, and the associated methodological issues we have identified up to this point.

Falk and Needham set out to address the research question, ‘Does visiting the California Science Center impact public science understanding, attitudes, and behaviors, and if so, in what ways?’. This research question is not effectively addressed for a number of reasons. Firstly, they claim that their results show ‘the Science Center is having an impact on the L.A. community’ (Falk & Needham, 2011, p. 9). Such a generalized claim cannot be upheld when there are too many methodological and theoretical limitations. The samples were unrepresentative and introduced potentially confounding variables that were not accounted for in the analysis (i.e. higher income and educational attainment). Meanwhile, the impact measures are only based on self-report survey questions that are poorly designed. The use of self-reports to measure learning impacts was an unreliable approach, and the survey design is fraught with limitations. For example, the exclusive use of positively framed survey items clearly increases the risk of acquiescence bias.

Moreover, the homeostasis marker does not support the suggestion that the Science Center delivered long-term educational impact. In regards to theoretical considerations, Falk and Needham never thoroughly showed how they isolated and measured one learning experience (such as attending the Science Center) and how this experience interacted within a complex and multidimensional learning infrastructure. They also never specified how they controlled for the influence of other sources of learning, as highlighted in our assessment of the homeostasis marker providing evidence of other variables.

Summarizing their findings about the long-term impacts of L.A. Science Center attendance on children, Falk and Needham (2011, p. 9) state, ‘Although responses of parents about their children’s experiences at the Science Center were second hand and thus need to be viewed with some caution, they were overwhelmingly positive’. As discussed above, there is obvious ambiguity and unreliability in expecting different parents to judge cognitive outcomes on behalf of their children. Asking parents to provide on-the-spot assessments of their children’s learning is even more prone to error than self-reported learning outcomes. Failure to follow basic principles of survey design introduced high levels of acquiescence bias, something that was unrecognized by Falk and Needham. The survey’s susceptibility for acquiescence bias may offer an explanation for the overwhelmingly positive responses found for both adults self-assessments and their reporting of the learning outcomes of children.

Falk and Needham (2011, p. 10) contend that, ‘The homeostasis marker allowed this research to move beyond some of the problems with self-reported data and show that a visit to this Science Center directly contributed to public understanding of science’. Although this marker was a useful attempt to circumvent the limitations of solely relying on self-report data, it was unsuccessful. No suitable baseline measurement was taken, Falk and Needham do not provide any evidence of a reliable scoring procedure used to assess whether learning had occurred, and the results from the indicator measurement did not support the authors’ conclusion that the Science Center had a positive impact. Nor does this measure establish causality, merely correlations.

Conclusion

Even if you will never personally conduct a long-term impact evaluation of informal science education activities, it is valuable to be a savvy consumer of this kind of evidence as it comes to you from various sources (including a high impact peer-reviewed journal, in the present case: Journal of Research in Science Teaching). This essay is intended to serve as a reminder of the importance of following established methodological procedures. Our aim is not to introduce new methodology here, but to issue a clarion call for researchers taking on long-term impact evaluation studies to use the hard won insights of social scientists working to improve survey and evaluation methodology. The article that is the focus of this critique is not unique in employing problematic research methods and inferences. However, the article touts its methods as an effective way of achieving the difficult task of long-term impact evaluation of informal science learning activities, a claim we challenge in this essay.

This brief review of a notable attempt to measure the long-term impacts of visiting a science center is far from comprehensive. However, we have identified important issues for researchers to consider when conducting this kind of study in future. The most plausible option for directly measuring learning outcomes is with a repeated measures design targeting the same individuals before and after visiting the Science Center (e.g. Moss, Jensen, & Gusset, 2015). Alternatively, an experimental design could be employed with a random assignment of participants to treatment and control groups. Such designs would provide a legitimate basis for drawing inferences about impact (Wagoner & Jensen, 2014). Instead, Falk and Needham (2011) employed cross-sectional surveys with first- and third-person self-reports to evaluate learning outcomes, an approach fraught with methodological limitations. Alternatives to self-report measurements include direct measurement (including open-ended data) before and after the 'intervention' of a science center visit, coupled with longer term follow-up measures including the same individuals. Longitudinal data analysis using population surveys that include both visitors and non-visitors would be an excellent (if costly) option for this research as well, but crucially the data collection would need to follow the same individuals over time to avoid the risk of sampling bias at any stage in the data collection making the results incomparable across time. There is a strong basis for these kinds of approaches in the social scientific methodological literature. This existing literature should provide the starting point for future studies of both short- and long-term informal learning impacts.

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Chapter 14
Utilizing Indicator-Based Methods: 'Measuring the Impact of a Science Center on Its Community'

John H. Falk and Mark D. Needham

We have been generously provided an opportunity to write a rejoinder to Jensen and Lister's chapter published in this volume. From the outset, we want to make it clear that we consider such dialogue healthy and constructive for the field. We appreciate the opportunity to clarify the points made by Jensen and Lister and thank this book's editors for the opportunity to do so.

Jensen and Lister admirably summarized our original article (Falk & Needham, 2011). According to Jensen and Lister, the main issue at hand was our use of a conceptual marker as an "indicator" of science learning as a way to "circumvent the need to rely exclusively on self-report data" (Jensen & Lister, this volume). To clarify, we did not utilize this marker approach merely to circumvent self-report data. As stated in our article (Falk & Needham, 2011), our primary motivation for using this approach was because of challenges related to attribution, which self-report does not adequately address. Given the cumulative nature of learning, it is difficult for anyone to accurately determine exactly where or when they actually learned anything. As a result, we selected a single concept, homeostasis, that could be used as the learning equivalent of a radioactive tracer; "something that in and of itself may or may not be highly important, but which could be considered an indicator of something greater that was meaningful" (Falk & Needham, 2011, p. 3). Jensen and Lister raised three basic concerns with our approach: (a) the validity of our baseline dataset, (b) the reliability of our procedures for coding this marker

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across the three samples, and (c) that results do not support our conclusions. We address each of these concerns in this rejoinder.

Jensen and Lister questioned the validity of our use of 7% as a baseline estimate of the Los Angeles (L.A.) public's knowledge of homeostasis in 1998. As Jensen and Lister themselves summarized in their commentary and we also acknowledged in our own article, this figure was derived using a different methodology than was utilized in the subsequent two samples; 2000 and 2009 data were derived from random telephone surveys of the L.A. population, whereas 1998 data were from a random sampling of the first month's visitors to the newly re-opened California Science Center (CSC) containing the exhibition related to homeostasis. However, as we originally stated and as Jensen and Lister reiterate, this 7% was a conservative estimate of public knowledge of homeostasis because, if anything, the understanding of science among the L.A. general public was almost certainly lower than that of those who self-selected to visit a science center. As suggested by our own data (Falk & Needham, 2011) and that of others (e.g., Falk et al., in press; Friedman, 2008; NRC, 2009), those who self-select to visit free-choice learning institutions such as the CSC tend to be more predisposed toward, interested in, and knowledgeable of science related topics than is the general public. Thus, it is highly unlikely that more than 7% of the L.A. population would have been able to accurately define this homeostasis marker if asked at the time. Jensen and Lister claimed that "no valid baseline measurement was developed," but we were forthright in our original article that "no true baseline was collected … but a useable baseline was created" (Falk & Needham, 2011, p. 8). Although our 1998 estimate is indeed not a true baseline, using this 7% figure represented a higher than would be expected bar to overcome. Although we obviously cannot definitively prove this was the exact baseline percentage, this figure appears to fit the expected trend line in growth in the knowledge of the concept of homeostasis among the L.A. population, assuming that changes in understanding of this concept demonstrated by research at the CSC did in fact make a contribution over time to the public's understanding of this one, somewhat obscure concept. As reported in our original article, the proportion of individuals in L.A. who were correctly able to define this concept increased to approximately 10% in 2000 and 20% in 2009.

An arguably more substantial concern raised by Jensen and Lister is the reliability of the way that understanding of homeostasis was measured. Here, we need to offer a *mea culpa*, as we regrettably did not sufficiently detail our methodology in the article (Falk & Needham, 2011), nor reference the technical report in which the full methodology was described (Falk & Amin, 1999). That said, the absence of a full discussion in the paper did not mean we failed to apply good research technique in practice. Accordingly, we present that methodology here. The first step was to ensure validity of measurement and to accomplish this we engaged a team of five subject-matter experts (all human physiology professionals); each of whom was tasked with developing a scoring rubric for defining homeostasis. From their transcripts, a single rubric was developed around the concept of homeostasis. This rubric was then shown to all five experts who agreed that it was an acceptable definition—"homeostasis is the balance or equilibrium that organisms or cells strive to maintain." To ensure reliability, two new and different subject-matter experts were identified who, along with the first author, were shown the expert's rubric and asked if they had any clarification questions. These three individuals were then presented with a randomly selected subset of one-third of the 1998 survey responses to the question "could you please tell me what you think homeostasis is" and asked to independently categorize responses as either "correct" or "incorrect" based on the expert rubric developed in step one. Results were compared among these three individuals, any initial disagreements in scoring were discussed, and a collective agreement was reached on how to slightly amend the scoring rubric. Each of these three individuals then independently scored a second third of responses using the slightly revised rubric. Inter-coder reliability was 95%. All subsequent data (e.g., 1998, 2000, 2009) were then scored by the first author using the same rubric. Although we did not report all of these methodological details in Falk and Needham (2011), and thus Jensen and Lister had grounds for questioning the reliability of our approach,we believe these additional details address the concerns raised.

Jensen and Lister's final concern was that results of the homeostasis marker do not support our claims that some changes in understanding of this concept among the L.A. public can be attributed to visiting the CSC. In particular, they pointed out that a larger percentage of the 10% of the L.A. public who could correctly define homeostasis in 2000 had visited the CSC (75%) compared to 2009 when 61% of the 20% of correct respondents had visited the CSC.[1] Further analysis, however, suggested that although this (χ^2 = 4.92, p = .026), the phi effect size (w) was only 0.13. Using guidelines from Cohen (1988) and Vaske (2008) for interpreting effect sizes, the magnitude of this difference was "small" or "minimal," respectively. In fact, these discrepancies between years in the number of respondents who defined homeostasis correctly but had not visited CSC versus the number who defined it correctly and had visited CSC represented a difference of less than a dozen individuals, or just slightly more than 1% of the total sample; well within the margin of error. The bottom line is that perhaps this difference could slightly undermine the strength in the basic argument that we make, but given the minimal effect size and small number of people associated with this difference between years, we are inclined to believe that this inconsistency is more likely to be a minor blip in the data, and the observed growth trend in understanding of this single concept amongst the L.A. public (7% in 1998, 10% in 2000, 20% in 2009) if not wholly, is likely largely attributable to visiting the CSC.[2] Importantly, as initially reported, individuals in both 2000 and 2009 who were able to correctly define this homeostasis marker were statistically more likely to have visited the CSC.[3]

Taken together, we refute Jensen and Lister's assertion that our research is methodologically flawed because we did not follow established research procedures. Although we acknowledge that our final conclusions can be debated (as would be true in any study), the basis of this debate should not be flaws in methodology; these we believe were sound. Of course when all is said and done, the larger issue relates to whether it is a reasonable idea to use a conceptual marker (e.g., homeostasis in the current case) as an indicator of the effects of an educational intervention. We remain unwavering in our belief that use of such a tool, in tandem with other research approaches, is indeed worthwhile. As previously stated, the inherently incremental and distributed nature of science learning makes attribution of learning from a single institution or event extremely challenging. Most individuals develop science understanding, as well as science interests and identities, through an accumulation of experiences from various sources at different times (e.g., Barron, 2006; Ito et al., 2013; Lemke, Lecusay, Cole, & Michalchik, 2012; NRC, 2009; OECD, 2012; Renninger & Riley, 2013; Stocklmayer, Rennie, & Gilbert, 2010). As shown by our data and discussed in our original article (Falk & Needham, 2011), even individuals who ostensibly benefited from exposure to the homeostasis "lesson" presented at the CSC were still likely to attribute their initial learning to the place where they first encountered the concept (i.e., school). So, is the sole use of such indicators sufficient to demonstrate the impact of an institution such as a science center? The answer, of course, is no. Does use of such indicators enrich our understanding of how and what people likely learn in free-choice settings? The answer, we believe, is unequivocally yes. Collectively, the several types of data we collected—self-report, factual knowledge questions and indicator—provided a rich snapshot of the likely effects that visit experiences at the CSC had on the general public's science interest and learning.

That is by no means to suggest that other methodological approaches for addressing this topic are not only possible but might even under certain circumstances be preferable, including the repeated measures approach that Jensen and Lister advocated (i.e., panel data targeting the same individuals pre and post visit). In fact, we as well as others have used this approach in other studies (e.g., Falk & Storksdieck, 2010; Ito et al., 2013; Leinhardt, Crowley, & Knudson, 2002; Lemke et al., 2012). However make no mistake, this approach too is subject to methodological and theoretical issues. Panel samples may become less representative over time as the population changes and as panel members drop out (Groves, 1989; Taplan, 2005). Panel designs may also be prone to certain forms of measurement error, such as "conditioning" and "seam" bias (cf., Groves, 1989; Lavrakas, 2008). Also relevant in this particular context is the potential problems associated with imposing highly contrived experimental designs on individuals participating in a free-choice learning experience (Falk et al., in press; Lemke et al., 2012; NRC, 2009). The reality is that any effort designed to investigate something as complex as the long-term impact of a particular science experience, regardless of setting, will face methodological challenges. In part, this is because all methodologies have both benefits and constraints, independent of the rigor with which they are applied. The indicator methodology described in our article (Falk & Needham, 2011) is no exception. In the final analysis, all researchers need to be ever vigilant for lapses in reliability and validity, but as a community we will make little intellectual progress if we attempt to restrict our investigations to a singular vision of research purity.

Notes

[1] A fourth, 2015 data point has just been collected since the publication of (Falk & Needham, 2011) using the exact same methodology as 2000 and 2009. Seventeen years after opening, correct responses to the question about homeostasis continued to climb, from 20% in 2009 to 36% of L.A. adults in 2015. This rise parallels a second long-term trend, growth in the percent of L.A. adult residents having visited CSC at least once, rising from 40% in 2009 to 67% in 2015. Also, in 2015 the percent of those in L.A. able to correctly answer this question who had previously visited the CSC was 76% of correct respondents; statistically identical to the percent in 2000 (Falk, J.H., Pattison, S., Livingston, K., Meier, D., Bibas, D., Fifield, S. & Martin, L. (in prep.). Contributions of science centers in Los Angeles, Philadelphia and Phoenix to public science understanding, interest and engagement).

[2] The new data collected in 2015 seem to support this conclusion.

[3] Also the case in 2015.

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Part IV

Bridging the Gap Between Formal and Informal Educators

Chapter 15
Visualising Social Network Structures in the Training of Professional Learning Communities of Educators in Informal and Formal Settings

Jakob Egg, Suzanne Kapelari and Justin Dillon

Introduction

In the 20th century, the main goal for science education in Austria was to deliver content knowledge which was often considered to be solid reproducible facts. Those able to accumulate and reproduce this knowledge were considered well prepared for a scientific carrier. Twenty-first century science education, however, is no longer valued only by those wishing to go into scientific or scientific related careers but by all members of an educated society. Supporting every child to become "*scientifically literate*" is now more than a slogan amongst science educators and curriculum planners and science education authorities (Hodson, 2008, p. 23).

Science education reform initiatives have been supported by the European Union's FP7 Funding Programme Science and Society aimed at implementing a "Renewed Pedagogy for the Future of Europe" (Rocard et al., 2007). Program designers put a strong emphasis on Inquiry Based Science Education (IBSE) as a kind of remedy for the problems traditional science teaching has caused such as young people's low interest in science topics (Sjøberg & Schreiner, 2010) and in choosing science related careers (OECD, 2006). Although IBSE is still a container concept which includes many different facets and approaches (Capps & Crawford, 2013; Minner, Levy, & Century, 2010), implementing any IBSE approach requires a more or less profound change in how science is taught.

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Science classes in Austria are still predominately characterised by teachers using questions in classroom discourse to scaffold student thinking and help students to construct scientific knowledge. Students very rarely experience opportunities to design and conduct experiments or investigations themselves. According to school heads questioned in the course of the 2006 PISA study, most 15 year-old students attend schools that provide Learning Outside the Classroom (LOtC) learning activities such as visits to museums, science centres or national parks (Grafendorfer & Neureiter, 2009).

A range of projects funded by the European Commission between 2007 and 2014 were developed and implemented in Austria and in many other EU member states. They tested different approaches to support the implementation of IBSE on a large scale by developing teaching material and teacher-training courses and teacher/school networks and partnerships amongst schools and LOtC institutions. The latter approach was founded in the programme design that called attention to LOtC organisations as very "significant actors in science education" (Rocard et al., 2007, p. 10).

However, research has shown that LOtC institutions are reluctant to engage in systemic educational reform efforts and in evaluating their educational programmes systematically (Phillips, Finkelstein, & Wever-Frerichs, 2007). Hence Tran and King (2011) argue:

> Without a shared knowledge base underpinning practice it may be argued that the pedagogical support provided by educators in the LOtC setting is inherently compromised. Furthermore a lack of an explicitly articulated body of knowledge raises concerns as whether the field can become a profession and further develop its practice (p. 282).

In addition professional development offers for LOtC educators are rare in Austria and in many other European countries.

It is a challenging exercise to benefit from the great potential LOtC science institutions have in K12 science education (Phillips et al., 2007). However, students benefit most if their teachers count on pre and post-processing of LOtC visits (Cox-Petersen, Marsh, Kisiel, & Melber, 2003). As the majority of students, not only in Austria, but in many OECD countries experience school visits to LOtC institutions (PISA, 2006) a promising way to improve science teaching and learning is to consolidate science teachers and LOtC educators to establish a shared understanding of inquiry based science teaching inside and outside the classroom.

This chapter will report on our experiences as a partner in the European FP7 Project INQUIRE: Inquiry Based Teacher Training for a Sustainable Future (2010–2013, www.inquirebotany.org). The main goal for this project was to support teachers and botanic garden and natural history museum educators to become reflective practitioners and to share their knowledge and experience via establishing social relations amongst each other. The Austrian INQUIRE professional development courses (IPDC) involved teachers and LOtC educators from different backgrounds. This study was designed to provide insight into how the social networks amongst course participants developed and to what extent the knowledge gained by monitoring and analysing this process via social network analysis could be used by the course management to improve participants learning experience.

Conceptual Framework

Traditional professional teacher development schemes have come under criticism for their inability to promote teacher learning in ways that impact on outcomes for the diversity of students in the classrooms (Hattie, 2009). Criticism is directed to in-service training that follows approaches based on an external view of what knowledge and skills teachers need to be equipped with a separation from the teacher's daily work or a setting that focuses on an individualistic development practices (Timperley, Wilson, Barrar, & Fung, 2007). Timperley and colleagues reviewed 97 individual studies and groups of studies that had substantive student outcomes associated with teacher professional learning and development. They found a set of criteria that distinguishes effective contexts for promoting professional learning. Besides other effective contexts "opportunities to participate in a professional community of practice were more important than place [school based or off-site with teachers from different schools]" (p. 25). The authors concluded that it is not enough to simply comply all these criteria but to reflect on the quality of each individual one when it comes to developing and running successful professional development courses.

Communities of Practice

In 1991, Jean Lave and Etienne Wenger published their book, 'Situated Learning: Legitimate Peripheral Participation' and introduced an epistemological principle of learning which was termed 'Situated Learning' which is often referred to a learning in a 'Community of Practice (CoP)'. The authors explained their theory of learning through an apprenticeship model by which newcomers to a community learn from other participants, during which time they are allowed to take over more and more tasks in the community and gradually progress to become 'masters' and enjoy full participation. This earlier perspective implied that "legitimate peripheral participation in a community inevitably leads to full socialisation, thus resembling earlier socialisation theories following Vygotsky" (Handley, Sturdy, Fincham, & Clark, 2006, p. 643). Members of a CoP are expected to develop a mode of belonging and an identity in practice. However, later both authors admitted that various forms of participation are both possible and fruitful and that becoming a full participant might not be aspired by all members of such a community. The concept of CoP has been similarly taken across social, educational and management science and is currently one of the most articulated and developed concepts within broad social theories of learning (Barton & Tusting, 2005).

However, hardly do know little about how these social networks develop in CoP-based professional development courses: who the experts, novices or the key players are; whether they change in course of time; or, whether a particular social network structure is more fruitful for the individual learner than another.

The Social Network Perspective

Social network theory assumes that each individual and its actions are embedded in social networks. Interactions between actors in a network draw them into this relationship (Herz, 2014). An actor's position in a network determines, in part, the constraints and opportunities this individual will encounter (Borgatti, Everett, & Johnson, 2013). The embeddedness argument emphasizes the importance of concrete personal relations in generating trust and cooperation (Granovetter, 1985). Network theory bears resemblance to Lave and Wenger's (1991) approach to learning as a deepening process of participating in a community of practice: "Over time this collective learning results in practices that reflect both the pursuit of our enterprise and the attendant social relations" (Wenger, 1998, p. 45).

So far the social network approach is popular in fields such as sociology, economics and anthropology. Research on teachers' social networks has received much attention in the last 10 years (Baker-Doyle & Yoon, 2011; Coburn, Mata, & Choi, 2013; Coburn & Russell, 2008; Penuel, Riel, Krause, & Frank, 2009) as "this vantage point offers interesting association for educational research when it comes to investigating social processes of learning, change and socialisation" (Herz, 2014, p. 242).

Network Analysis

Network analysis deals with the relationships between more than two actors: "A social network consists of a finite set or sets of actors and the relation or relations defined on them" (Wassermann & Faust, 1994, p. 20). Actors and their actions are incorporated in social networks. The central principles underlying the network perspective are:

- Structural relations are the key orienting principle;
- Linkages between actors are representing social resources;
- The structural relations should be viewed as dynamic processes; and,
- Changes in micro-level choices are also applied to the macro-level structural relations (Hennig, Brandes, Pfeffer & Mergel, 2012; Knoke & Yang, 2008; Wasserman & Faust, 1994).

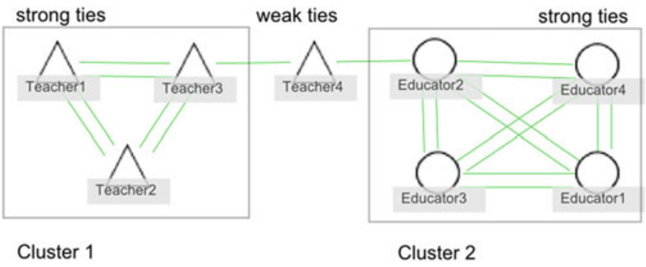

Fig. 15.1 The drawing shows the schematic representation of a cluster with teachers and a cluster with educators. The members of every cluster are highly connected. Weak ties connect the two clusters

Learning processes in network terms need the transfer through ties between actors in the social network. One classification involves the distinction between strong and weak ties (Granovetter, 1973). Granovetter defined tie-strength as a function of frequency of contact, reciprocity and friendship. Strong ties are frequent contacts, often friendly and include reciprocal favours but weak ties are distant and infrequent contacts and do not necessarily have affective content.

In the schematic representation (see Fig. 15.1) the members of every cluster are strongly connected based on the concept of homophile, which means that actors prefer having relationships with others of the same status (McPherson, Smith-Lovin, & Cook, 2001).

Weak links could be important for sharing new knowledge between, for example, teachers and LOtC educators. By bridging usually disconnected actors or subgroups weak ties enable the flow of new information (Granovetter, 1973). The transfer of knowledge through weak ties is efficient, if the knowledge is explicit, independent and the level of codification is low (Hansen, 1999). Furthermore Burt (2004) demonstrates the advantages of bridging structural holes with weak ties in the case of managers, who have more innovative ideas to solve upcoming problems.

If the knowledge is dependent with a high level of codification (that is, fully documented, complex knowledge) the knowledge transfer needs more assistance, because the recipient of knowledge needs some additional information of the larger system and the specific correlations. Here strong ties assume a greater supportive role with better access than weak ties (Granovetter, 1982).

Research Question

The Austrian INQUIRE Professional Development Courses (IPDC) involved teachers and botanic garden and natural history museum educators from different socio-cultural backgrounds. Therefore our research focus was on the following questions:

- How do ties between teachers and LOtC educators develop in course of a nine month training course?
- Does the knowledge about a particular network structures at a given time during the course has the potential to improve participants learning outcomes?

Methodology

The Austrian INQUIRE professional development course (IPDC) was offered by the University Botanic Gardens in Innsbruck. Our design tried to translate six out of seven criteria for efficient professional development published by Timperley and colleagues (2007) into practice. We put emphasis on an extended period of time to provide opportunities for individual and group learning. IPDCs comprised three face-to-face Modules, each lasting 16 h (see Fig. 15.2). In between, participants were invited to join the INQUIRE-Café (see Fig. 15.2) at the botanic garden and exchange and discuss their experiences and ideas in an informal setting. Science education researchers and scientists provided external expertise. Participants were asked to elaborate reflective case studies on student learning and explore how theoretical knowledge addressed in the course proved valuable in real-world situations. These case studies were presented and discussed in the third Module (see Fig. 15.2). We dedicated extensive time for a prevailing discourse. Extra meetings at the botanical garden and social group building activities during face-to-face Modules were offered to support CoP development. In addition, all resources, documents and tasks were accessible on the online File-Sharing-Platform Dropbox. Our approaches were consistent with current science and science education research findings and recommendations of professional bodies.

Course participants learned about the INQUIRE training courses via the official in-service teacher training programme (printed an online version) published twice a year by the Pedagogical College Tirol and via the Austrian LOtC network (Science Center Network Austria). In addition, private links to LOtC institutions and

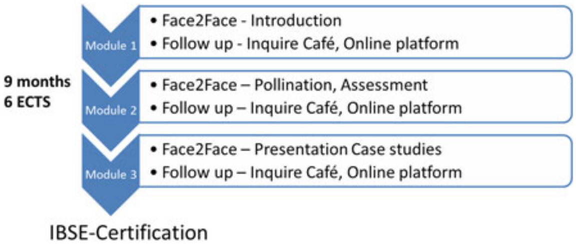

Fig. 15.2 Organizational structure of the INQUIRE Professional Development Courses (IPDC). The courses were designed to involve educators over a 9-month period of part-time study. Each course was worth 6 ECTS (European Credit Transfer System)

Table 15.1 The description of the INQUIRE professional development training course participating teachers and LOtC educators in Austria

Category	Name	Number
Number of participants	School teacher	8
Gender	Female	7
	Male	1
Institution	Primary school	7
	Secondary school	1
Experience	Years	0–35

Category	Name	Number
Number of participants	Informal educator	8
Gender	Female	6
	Male	2
Institution	Botanical garden	1
	Environmental education center	2
	Nature park	5
Experience	Years	0–12

teachers were used to inform prospects. The main goal was to end up with a heterogeneous group of teachers and botanic garden, museum and environmental educators sharing a wide range of experience and expertise.

Two INQUIRE training courses were run between 2011 and 2013. This study uses data from the second INQUIRE professional development course (IPDC2) and involves 16 participants (see Table 15.1).

Although the course evaluation included a mixed-methods design and additional data were gathered by means of pre- and post-test questionnaires, interviews and pre- and post-concept maps (Novak, 1990), this chapter reports on findings gathered via social network analysis (Carolan, 2013; Jansen, 2006; Rehrl & Gruber, 2007).

Social Network Analysis

Two essential parts of a social network are actors and the relations between them. Actors may be persons or groups. In this regard, training course participants are considered as social actors represented by nodes. The relationships between these actors are represented by linkages (ties). The logical data structure is based on a questionnaire completed by course participants before and after each course Module (see Fig. 15.2). Answers are given in relation to already existing relationships and teamwork and the desire to work together with certain participants. The first level of analysis is the egocentric network followed by the second level which is the socio-centric visualization of developments in the entire network and completed by a socio-centric analysis to depict different pattern of interactions.

The egocentric network. The egocentric graph is formed by targeting one actor (ego), including all other actors (alters) to which the ego is connected. Figure 15.3

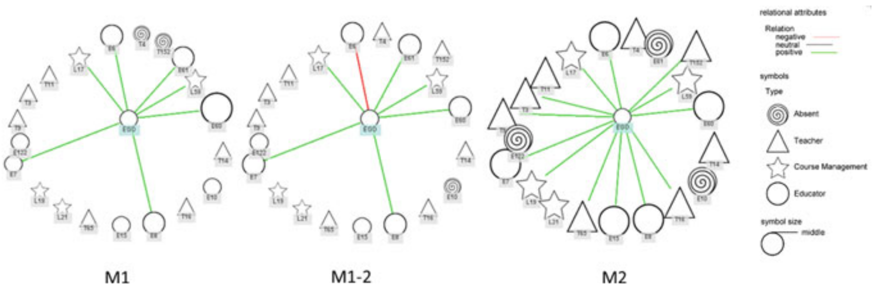

Fig. 15.3 Egocentric network of educator (E12) at the beginning of the Module 1 (M1-1), at the end of the Module 1 (M1-2) and at the beginning of Module 2 (M2)

gives an example of how such an egocentric network pattern of one LOtC educator (E12) developed from the beginning of Module 1 to the end of Module 2.

Socio centric visualisation. By using the information of all course participants' egocentric networks, the total network of the IPDC2 could be illustrated. In order to describe the number of linkages between the nodes in relation to the maximum number of possible linkages, the parameter density (D) was calculated. The parameter reciprocity (R) is an indicator for the mutuality of the relations in the egocentric network (i.e., if there is a linkage between two actors in both directions).

The socio-centric analysis. As a final step, a socio-centric analysis was applied to depict different patterns of interactions within the CoP network. This process enabled us to find out who the key players in the group are. The analysis of hubs and authorities was used to find out the position of the actor gained through relations. This calculation was based on the eigenvector-centrality. A high hub-factor means that this actor establishes multiple relations with actors who own a high authority-factor. Therefore a hub actor is very important, because other actors need this hub actor to get access to authorities. A high authority-factor means that this actor is being integrated from actors with high hub-factors (Borgatti, Everett, & Freeman, 2002). The software used for evaluation and visualisation of SNA was VENNMaker 1.3.2 and UCINET 6.461.

Results

Egocentric Networks of Individual Participants

Example of egocentric networks of IPDC2 participants (Table 15.2) are shown in Figs. 15.3 and 15.4. The relations between an ego and a set of alters is the focus of egocentric network analysis.

Table 15.2 shows that all participants who established two or more ties at the end of Module 2 (M2) handed in a case study while only two out of six participants who established less than two ties at the given time finished the course successfully. Participant (E12) is an educator and knows other LOtC educators and the course

Table 15.2 Egocentric network of participants at the beginning of the IPDC2 Module 1 (M1-1), at the end of the Module 1 (M1-2) and at the beginning of Module 2 (M2)

Nr.	Cat.	Ego-Code	Number Alteri M1	Alteri M1 categories	Number Alteri M1-2	Alteri M1-2 categories	Number Alteri M2	Alteri M2 categories	Case-study
1	E	E61	4	4x E	6	1x E, 3x T, 2x L	n.a.		No
2	E	E6	4	4x E	4	3x E, 1x T	0		No
3	E	E7	0		3	3x E	3	3x E	Yes
4	E	E8	6	6x E	6	5x E, 1x T	5	3x E, 2x T	Yes
5	E	E10	3	3x E	n.a.		n.a.		No
6	E	E12	7	5x E, 2x L	7	5x E, 2x L	13	5x E, 5x T, 3x L	Yes
7	E	E60	6	5x E, 1x L	0		5	4x E, 1x T	Yes
8	E	E15	0		3	3x E	4	3x E, 1x T	Yes
9	T	T65	1	1x T	2	1x T, 1x L	1	1x T	No
10	T	T3	0		6	3x E, 3x T	n.a.		Yes
11	T	T4	n.a.		5	1x E, 4x L	0		Yes
12	T	T9	0		3	2x E, 1x T	2	1x E, 1x T	Yes
13	T	T11	1	1x E	4	3x E, 1x T	3	2x E, 1x T	Yes
14	T	T14	1	1x T	1	1x T	n.a.		Yes
15	T	T16	0		0		0		Yes
16	T	T152	n.a.		0		7	2x E, 1x T, 4x L	Yes
17	L	L19							
18	L	L17							
19	L	L21							
20	L	L59							

Number of connections to alters, classification of the alters in the categories Educator (E), Teacher (T), Course Management (L) and Submission of the Case-Study

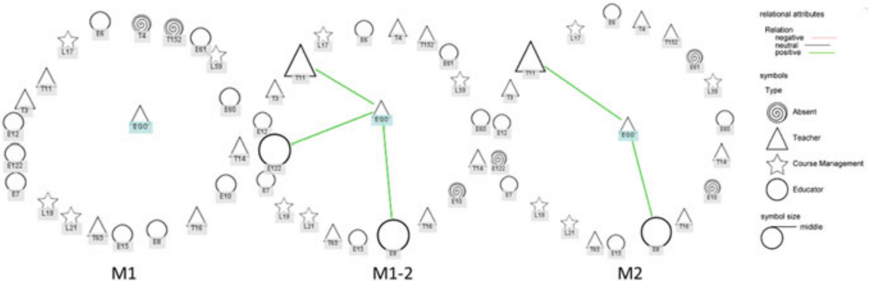

Fig. 15.4 Egocentric network of a teacher (T9) at the beginning of the Module1 (M1-1), at the end of the Module1 (M1-2) and at the beginning of Module 2 (M2)

management for personal and professional reasons at the beginning of the course already. The number of relations E12 (Fig. 15.3) increased considerably. In Module 1 and up to the end of Module 2, E12 established six new relations, five of which were with teachers. There was a negative relation at the end of Module 1 indicating a dissonance (marked in red).

Participant (T9) was a teacher and had no relation with any other course participant at the beginning of the course. T9 established ties with two educators and one teacher by the end of Module 1. At the end of Module 2, one relation to a teacher and one relation to an educator was established sustainably.

Socio-centric Visualization of Developments in the Total Network of the IPDC2 During the Training Course

(a) *Considering positive and negative linkages*

At the beginning of IPDC2, participants reported few relationships (linkages) between one another (Fig. 15.5). As some of the participating educators had already known each other before the beginning of the training course, relations between these educators dominated the social network. The parameter reciprocity (R) is an indicator for the mutuality of the relations in the network and shows that relationships are experienced as two-way roads. Of all relationships already established at the beginning of the course, 54% were reciprocal (R).

In order to describe the number of linkages between the nodes in relation to the maximum number of possible linkages, the parameter density (D) was calculated. By the end of Module 1 (Fig. 15.6) new relations were established and the density (D) increased from 10 to 13%. At the same time R decreased to 18%. R declines in a network, if newly-established relations are not reciprocal or some participants were absent. At the beginning of Module 2, D was 10% and R increased to 39% (see Table 15.3). R is growing, if the number of mutual relations has been increased throughout the entire network (Figs. 15.7, 15.8 and 15.9).

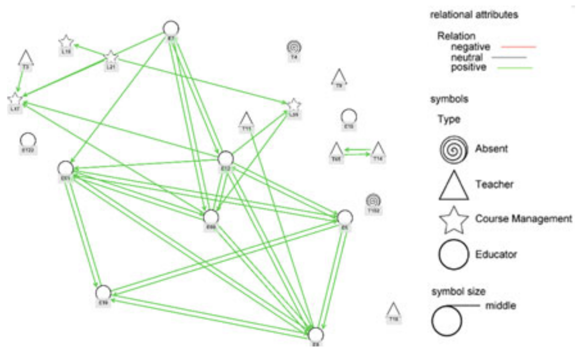

Fig. 15.5 Total social network of IPDC2 at the beginning of Module 1 including positive and negative linkages (M1-1)

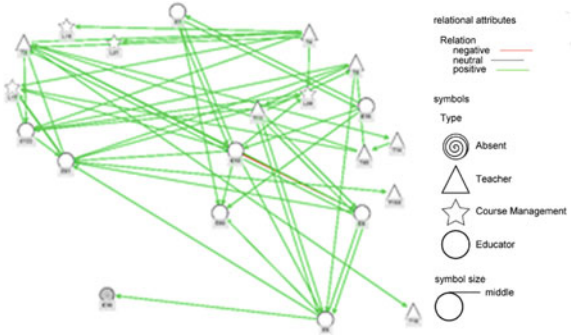

Fig. 15.6 Total social network of IPDC2 at the end of Module 1 including positive and negative linkages (M1-2(a))

Table 15.3 Analysis of the total social network of IPDC2 in respect to Density (D) and Reciprocity (R)

Parameter	Date						
	M1-1	M1-2(a)	M1-2(b)	M2(a)	M2(b)	M3-1	M3-2
D (%)	10	13	33	10	20	9	11
R (%)	54	18	27	39	25	9	7

M1-1: at the beginning of Module 1; M1-2(a): at the end of Module 1; M2(a): at the beginning of Module 2; M3-1: after presentation session 1; M3-2 after presentation session 2. Positive and negative linkages were evaluated. For M1-2(b) and M2(b) positive, negative and neutral linkages were evaluated

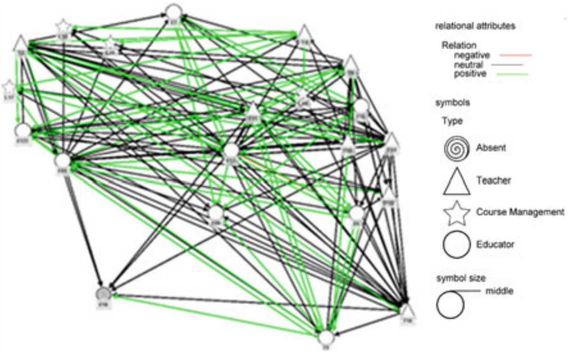

Fig. 15.7 Total social network of IPDC2 at the end of Module 1 including positive, negative and neutral linkages (M1-2(b))

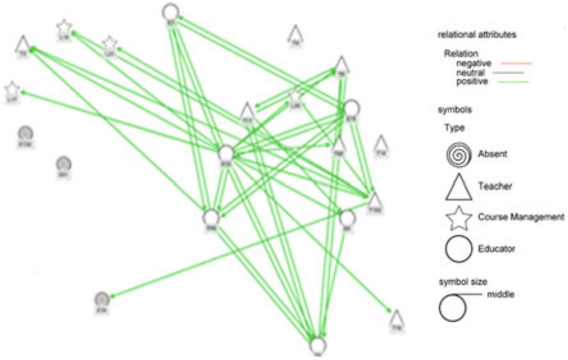

Fig. 15.8 Total social network of IPDC2 at the beginning of Module 2 including positive and negative linkages (M2(a))

At the very end of the course, Module 3 (M3) participants presented their case studies in two separate presentation sessions (Figs. 15.10 and 15.11). As there was no compulsory attendance for both of the sessions, some participants were absent from both events. Nonetheless, D reached similar values to Module 2 with 9 and 11%, respectively. R was below 10% (see Table 15.3).

At presentation session 1, the reciprocally-linked subgroup of the botanic garden educators (E6, E8, E10, E61) was absent (Fig. 15.10). Two members (E10, E61) of this subgroup were already absent from Module 2. At presentation session 2, the only member of this subgroup to present a case study was E8. E8 listed linkages to the absent educators E6, E10, E61 (Fig. 15.11). Although the subgroup was only represented by one member, the linkages to the absent members were still there. All participants who successfully completed the course were present at Module 2. Participants who missed Module 2 entirely or parts of it did not complete their case study successfully.

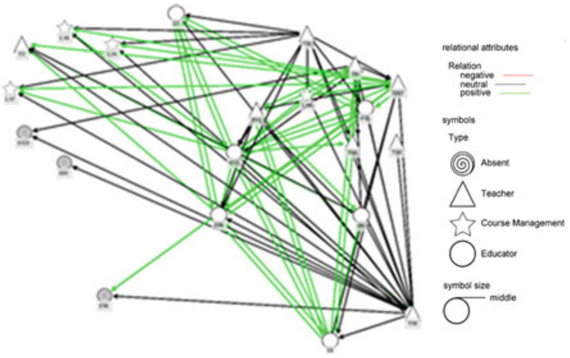

Fig. 15.9 Total social network of IPDC2 at the beginning of Module 2 including positive, negative and neutral linkages (M2(b))

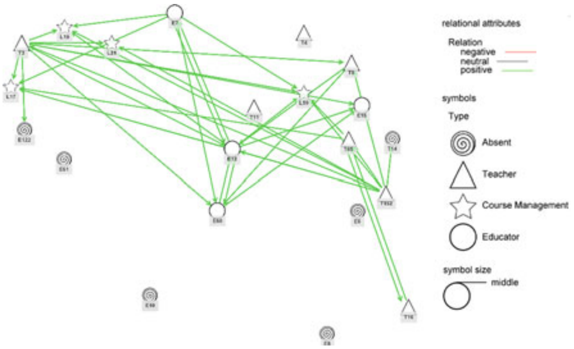

Fig. 15.10 Total social network of IPDC2 after presentation session 1, including positive and negative linkages (M3-1)

(b) *Considering positive, negative and neutral linkages*

For M1-2(b) and M2(b), positive, negative and neutral linkages were evaluated. A neutral relation means that working together with another person is desirable for a specific person but it is not being practiced actively at this point of time.

At the end of IPDC2 Module 1 (M1-2(b)), the number of relations increased considerably and the Density (D) increased from 10 to 33% (see Table 15.3). It should be noticed that this number includes positive, negative and neutral relations. The percentage of reciprocal relations (R) amongst persons decreased to 27%. At the beginning of Module 2 (M2(b)), the density of the network decreased to 20%. There are significantly fewer neutral relations. 25% of the relations are mutual (see Table 15.3).

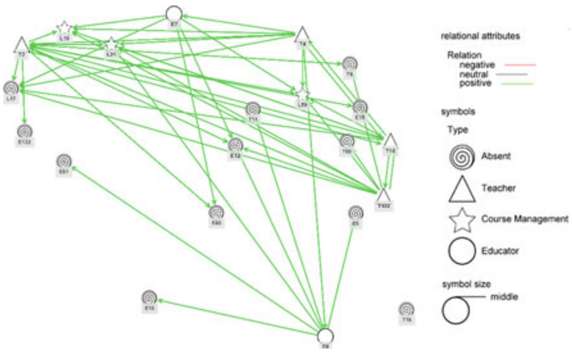

Fig. 15.11 Total social network of IPDC2 after presentation session 2, including positive and negative linkages (M3-2)

Depict the Process of Key Players' Development

Hubs—considering positive, negative and neutral linkages

Analysis of positive, negative and neutral linkages at the end of Module 1 (M1-2) showed that one educator and one teacher were representing hubs. In the beginning of Module 2 (M2) there was one educator representing a hub (see Table 15.4).

Authorities—considering positive, negative and neutral linkages

At the end of Module 1 (M1-2), two educators and one teacher were identified as authorities. At the beginning of Module 2 (M2), authorities were represented by five educators and two teachers (see Table 15.5). The development of the social network during the progression of the course revealed the risk of losing a subgroup of educators in Module 2 because they were absent in Module 2. The loss of the entire subgroup then had to be reported at presentation session 1 (M3-1). At presentation session 2 (M3-2), one member (E8) of this subgroup was present because this

Table 15.4 Hub-factor of specific actors in IPDC2

Number	Date				
	M1-1	M1-2	M2	M3-1	M3-2
1	E12	E12	E12	T3	T3
2	E60	T4		T152	T152
3	E8			E7	T4
4				E12	T14

Only actors are listed who reach at least 50% of the highest hub-factor in the course. M1-1: at the beginning of Module 1; M1-2: at the end of Module 1; M2: at the beginning of Module 2; M3-1: after presentation session 1; M3-2: after presentation session 2. Positive, negative and neutral linkages were evaluated

Table 15.5 Authority-factor of specific actors in IPDC2

Number	Date				
	M1-1	M1-2	M2	M3-1	M3-2
1	E61	E12	E15	L17	L19
2	E8	T11	E60	L59	L17
3	E60	E6	T3	L19	L59
4	L17		E8	T16	L21
5	E12		E7	E12	E12
6	E6		T9	E60	T14
7			E6		T3
8					

Only actors are listed who reach at least 50% of the highest hub-factor in the course. M1-1: at the beginning of Module 1; M1-2: at the end of Module 1; M2: at the beginning of Module 2; M3-1: after presentation session 1; M3-2: after presentation session 2. Positive, negative and neutral linkages were evaluated

educator (E8) had written a case study in collaboration with a teacher from outside the subgroup. E8, identified as hub and authority in Module 1, had an additional social relation outside the subgroup and could therefore produce the case study in a mixed team of one teacher and one educator.

Discussion

In 2007, the Rocard Report: ‘Science Education now, a renewed pedagogy for the future of Europe’, was published to support science education reform and forged a new direction by asking science and mathematics teachers, teacher trainers, LOtC institutions and formal educational systems across Europe to implement inquiry-based science education (IBSE) on a large scale. Inquiry-based science teaching (IBST) and learning is not necessarily a new, innovative approach and a remedy for all problems but an abstract concept. Capps and Crawford (2013) recently concluded that “today there is still no consensus as to what it [IBSE] actually is and what it looks like in the classroom” (p. 525).

Dillon (2012) argues that there is no such thing as the one and only scientific inquiry approach. Thus it is challenging for practitioners to make the abstract theory based concept of IBSE concrete and establish an individual content and context specific understanding of IBSE even if science education research and popular scientific literature and IBSE teaching material is provided on various online platforms free of charge. Practitioners are supposed to develop a in depth understanding of the science content and the specific knowledge gaining processes related to this content. In addition they need to develop a profound understanding of how to scaffold inquiry based learning efficiently when dealing with heterogeneous groups of students populating science classes and LOtC workshops. Thus it is unavoidable that practitioners establish a critical and reflective approach and look closely at whether their IBSE approach is successful in supporting student learning. However this is a complex and challenging task and our hypothesis was that mixed groups of teachers and LOtC educators have the potential to trigger social learning processes and will support practitioners to develop their understanding of IBSE. Tran and King (2011) argue that in terms of teaching science in a LOtC context a distinct body of knowledge and pedagogical practice has been established amongst educators working in the field. A few of these educators are aware of the various strategies they use or their relative efficacy, however, this body of knowledge is usually neither recognized nor shared by educators working across various institutions and settings. The INQUIRE professional development course provided a platform to share this knowledge not only across LOtC institutions but also with teachers from various backgrounds. Participants take these opportunities and establish ties with colleagues from the other "cluster" (see Fig. 15.3). E12, for example, had relations with colleagues at the beginning of the course already and focused on establishing new relations with teachers in particular.

Many training activities provide space for course participants, teachers and educators alike to adopt a positive attitude towards reflective practice as a tool for improving educational practice. Most teachers were already familiar with evaluating their practice at the beginning of the course while most LOtC educators did not have any experience in designing a case study or collecting data to reflect on. At the end of the course, three out of four participants who did not hand in a case study were educators. These educators did not establish ties with other participants who may have helped them to overcome the barrier of dealing with such a 'strange terrain'.

Shulman and Shulman (2004) noted that an on-going interaction between an individual professional and the community leads to a shared knowledge of the learning community which finally offers members the opportunity to confirm, interconnect and develop their professional knowledge. Our research focuses on how the relationships between teachers and LOtC educators develop over time. A better understanding of the social interactions is of central importance, because the individual actions can be explained with knowledge about the social network of the actor, but at the same time individual actions also change the social network (Granovetter, 1985). Analysing a social network in which participants have interest in getting in contact with others shows a dynamic web of relationships between actors to seek information, resources, support and beneficial opportunities (Borgatti & Foster, 2003; McPherson, Popielarz, & Drobnic, 1992). At the beginning of the course, the social network was dominated by the course management and additionally by LOtC educators who already knew each other for professional or personal reasons. Some participants were isolated or linked only to the network by a single relation. As early as the end of the first Module, all participants appeared to be integrated into the IPDC-network.

The strength of the ties between teachers and LOtC educators is one important dimension as a source of social capital. According to Hansen (1999) these ties facilitate problem-solving and the transfer of tacit, complex, or fine-grained information between these different professional domains. Granovetter (1982) argues that strong ties in the total network are supportive if dependent complex knowledge needs to be transferred. In addition the level of integration of all participants enables opportunities for knowledge transfer and access to resources across different professional domains. Direct contacts and more intensive interactions allow actors to get a better understanding to expand their professional knowledge. Participants with multiple relations, especially with strong ties to participants with a high authority factor, are central points by acting like a knowledge broker. A sub group connected via a hub or hubs to another subgroup or to the total network has a distinct advantage in the knowledge transferring process (Hansen, 1999; Kleinberg, 1999). In contrast participants with a high authority factor have multiple inbound relations and a tendency to behave passively; they react rather than act to transfer their knowledge (Hansen, 1999; Kleinberg, 1999).

The INQUIRE training course was asking participants to develop a complex understanding of IBSE and did not provide a simple copy and paste strategy. Thus strong ties amongst participants were assumed to be helpful. The dynamic of the INQUIRE course network shows the important role of the hubs connecting sub-groups and single participants. Participants acting as an authority are changing during the training course dependent to the course situation. Especially in the early stages of the training course, characterised by high reciprocity (R) and low density (D), the network dynamics remain uncertain in terms of which participants are really acting as an authority. However the integration of all teachers as well as LOtC educators into the social network during the first Module of the professional development course enables a range of opportunities.

All participants who successfully completed the IPDC were present for Module 2. Participants who missed Module 2 entirely, or parts of it, did not complete their case study successfully. This finding indicates that the social embeddedness of participants during the IPDC is a crucial factor for completing the course. Granovetter (1985) describes the importance of this so-called ‘embeddedness’. The more intensely educators, teachers and experts work together on the process of creation of new knowledge, the more knowledge is transferred amongst them (Huberman, 1993). The positions of the key-actors can be identified and supported. The development of the social network during the progression of the course revealed the risk of losing a subgroup of educators in Module 2. Personal support of the key-actor of this subgroup made it possible to avoid the loss of the whole subgroup. Booth and colleagues (2004) argue that CoP cannot be prescribed or installed to facilitate learning processes. They need to develop naturally and can be guided or supported by people interested in their development. By applying Social Network Analysis (SNA), the INQUIRE course management was able to identify and monitor important factors considered influential in CoP development:

- Hubs and authorities were identified in the initial stage;
- The reasons for absences of specific participants were gathered;
- Absent hubs and authorities were supervised intensively;

- Care was taken to achieve creative and innovative work in heterogeneous small groups;
- Topics for case studies were chosen by participants individually;
- The course management offered support/coaching during all stages of the course;
- In between Modules, participants were encouraged to exchange ideas and experience as well as to nurture their social network at the INQUIRE-Café;
- The training course lasted for an extended period of time to enable group members to establish social links.

Timperley and colleagues (2007) emphasised the importance of social learning in the context of Professional Learning Communities for effective in-service teacher training. We assume that SNA is an appropriate means to gain insight into the social dynamics of learning communities and thus a helpful tool to monitor their social development, to take notice of upcoming risks, and to act accordingly. More extensive research is necessary to provide sufficient evidence whether SNA will be an effective tool to improve CoP based course designs while work is in progress.

However, SNA does not tell us anything about what kind of knowledge is shared whether is helpful for the recipient or whether the knowledge content is understood accordingly in particular when it is shared amongst people with a different professional background. As learning processes are very complex and highly diverse endeavours they are difficult to observe and analyse. We experienced social network theory as a fruitful tool to interpret our observations. However, it will be important to gather more data about what is actually shared via these ties. This process will help us to understand better what makes some ties more fruitful than others and what reasons for teachers are to establish ties with educators and vice versa and whether and how mixed groups of professionals have the desired positive impact on individuals learning outcomes.

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Chapter 16
Professional Development: Targeted On-the-Job Trainings

Chance Sanford and Victoria Sokol

Informal science learning environments consist of a vast array of institutions such as museums, nature centers, science centers, aquaria, and zoos. These institutions are not just places within our communities in which individuals and families spend leisure time, but are integral components to the contribution of science literacy in our nation.

> Scientific literacy is more than factual recall; it involves a rich array of conceptual understanding, ways of thinking, capacities to use scientific knowledge for personal and social purposes, and an understanding of the meaning and relevance of science to everyday life (Bevan et al., 2010, p. 12).

Much research and debate has surrounded the issue of scientific literacy in America, especially as compared on a global scale to other countries. As a result, there has been tremendous focus on improving science education in schools through the enactment of various policies at both state and federal levels. However, Falk and Dierking (2010) argue that “Average Americans spend less than 5 percent of their life in classrooms, and an ever-growing body of evidence demonstrates that most science is learned outside of school” (p. 486). In addition, the National Science Teachers Association ([NSTA], 2012) states, “more than half of a child’s waking hours are spent outside of school” (p. 2). If Americans are indeed deriving the vast majority of their science knowledge and understanding through out of school experiences, “it will take a combination of resources, expertise, timeframes, and learning designs to support and expand science literacy in today’s world” (Bevan et al., 2010, p. 12). As a result, no one type of institution, formal or informal, can meet the demands required to create a scientifically literate public. Therefore, national dialogue should not focus exclusively on formal science education, but recognize the opportunities available outside the classroom for science learning

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(Bevan et al. 2010; Robelen, 2011a, b). Formal education should capitalize on these opportunities, and develop collaborations with informal science institutions in order to better educate students in the realm of science.

Importance of the Collaboration Between Formal and Informal Learning Environments

Many of the nation's leading educational organizations support the development of collaborations between formal and informal science institutions as a way to improve science education in schools. The National Science Education Standards state, "… the classroom is a limited environment. The school science program must extend beyond the walls of the school to the resources of the community" (as cited in Kisiel, 2010, p. 96). Additionally, the Institute of Museum and Library Services suggests "build a fabric of social agencies that facilitates lifelong learning among learners of all ages and circumstances. This fabric should weave together all institutions…including schools, libraries, and museums—into a 'seamless learning infrastructure'" (as cited in Kisiel, 2010, p. 96). Both of these position statements are supported by the NSTA (2012) who "advocates for informal learning opportunities for all students and recommends expanding these opportunities…" (p. 1). These organizations, along with numerous other researchers, recognize the important and critical contributions informal science institutions can make in improving the science education of children.

Research has shown the contributions informal science institutions make towards improving children's science education are numerous. Among the impacts these institutions have are increasing student interest in science topics and thus potential career choices in the STEM fields, an increase in teacher knowledge and science teaching skills, and providing learning experiences not typically available with the formal school setting, thereby allowing students to make connections with real-life science.

Increasing Student Interest

Informal science institutions are often thought of as fun, relaxing, and entertaining places to visit as evidenced by the large number of visitors annually to science museums, aquaria, and zoos across the nation. However, visitor education is typically an integral part of each institution's mission and is often a leading component seen in the exhibits, tours, and programs conducted at these institutions daily. Often education occurs without the direct realization of visitors as they are encouraged to explore exhibits and venues in fun and interactive ways, which is often not how we perceive education occurring, particularly in a formal education setting. Robelen

(2011b) asserts the unique advantage and strength of these institutions is that they bring abstract concepts to life with hands-on, engaging activities and exhibits, thus sparking a curiosity and passion for science formal classrooms frequently fail to do by employing teacher-led, lecture based instruction. Creating a passion for science and inspiring students to develop a deeper interest in science is especially important. Falk and Dierking (2010) cite research by Robert H. Tai and associates, as well as the National Research Council, who found children's attitudes towards science are impacted not only by their free-choice learning experiences, particularly those occurring in early childhood, but that they also occurred primarily during out-of-school time. Not only did these experiences "jump-start a child's long-term interest in science topics" (Tai, as cited in Falk & Dierking, 2010, p. 490), they also "appeared to be the single most important factor in determining children's future career choices in science" (National Research Council, as cited in Falk & Dierking, 2010, p. 491).

Developing an early interest in science is a key element to continuing to keep children engaged in science learning not just throughout the duration of their schooling, but also throughout their lives. "Mounting evidence shows that early engagement, even through informal pathways, eventually can lead to careers in the STEM fields of science, technology, engineering, and mathematics more surely than top grades in school" (Sparks, 2011, Interest vs. Grades section, para. 1). However, interest in science cannot be sustained through simply one exciting experience outside of school, but must be maintained and supported through formal education experiences. Bevan and Semper (2006) argue, "ambivalent attitudes towards and perceptions of science are largely forged by school experiences with science" (p. 1). According to the NSTA (2012), "Informal settings create opportunities for students and others to develop interest, readiness, and capacities to pursue science, technology, engineering, and math (STEM) learning in school and beyond" (p. 2). Collaborations between formal and informal institutions are an excellent avenue to develop and sustain student interest in science, promoting a lifelong interest in science. While not all students demonstrating an interest in science will pursue careers within the field, these collaborations will also contribute to an overall more scientific literate society.

Providing Unique Experiences for Students

Creating and maintaining student interest in science cannot be accomplished strictly through experiences in informal science learning institutions alone. Informal learning institutions lack the "time, sequencing, and consistency necessary for learners to systematically develop the foundations for deep conceptual understanding" (Bevan et al., 2010, p. 13). Formal educators still remain responsible and accountable for much of a student's understanding and application of knowledge of many subjects, including science. However, research reveals that many formal educators, particularly those at the elementary level, struggle when it comes to teaching science. These educators struggle to meet time constraints, develop meaningful hands-on experiences, and generally lack a strong foundation of science knowledge to confidently present information and engage students in science (Kisiel, 2013). Informal science institutions can provide the tools for formal educators to overcome many of these obstacles within the classroom.

Informal science institutions provide a multitude of resources that allow students to engage in hands-on science. These materials and resources may consist of permanent and temporary exhibits, unique artifacts and instruments, or everyday tools used by scientists. They include "tactile, kinesthetic, and three-dimensional exhibits, objects and experiences that may afford different kinds of engagement and even understanding than can be developed in schools" (Bevan et al., 2010, p. 13). Many of these items would be impossible to utilize within a classroom space, and others are simply too expensive and cannot be procured for use due to budgetary restrictions. Informal science institutions are uniquely positioned to provide these resources and their corresponding experiences to both teachers and students.

In addition to stimulating student interest in science, informal science programs utilize methods and instructional practices that boost student achievement in STEM subjects (Thomasion, 2012). These activities include hands-on work, stimulating inquiry through organized activities, participating in a group project, and authentic scientific investigations, among others (Melber & Cox-Peterson, 2005; Thomasion, 2012). By providing these resources and corresponding programs and experiences that allow students to utilize these resources, informal science institutions are helping formal educators meet the learning needs of students in a low-cost, less time intensive approach, allowing formal educators to focus on instructional elements better suited to the classroom environment.

Increasing Formal Educator Knowledge

Time and budgetary constraints are only one obstacle formal educators face in inspiring a passion for science in their students. A strong foundation of science knowledge often hinders teachers from providing meaningful science experiences, as many educators lack the confidence to incorporate science within their curriculum.

> Recent statistics show that only about 4 percent of U.S. school teachers of kindergarten through second grade (K-2) majored in science or science education as undergraduates, and many took no college-level science courses at all (Falk & Dierking, 2010, p. 487).

Considering that research has shown a child's interest in science begins at an early age and these experiences can be "the single most important factor in determining children's future career choices in science" (Falk & Dierking, 2010, p. 490), it is not a surprise we are falling behind the global curve in STEM fields when our teachers do not possess adequate knowledge to teach science to our children.

Informal science institutions are uniquely poised to help educators increase their knowledge of science content. Studies have shown collaborations between informal science institutions and formal education systems can "advance teachers' conceptual understanding in science and support teachers' integration of inquiry and new materials into the classroom" (Bevan et al., 2010, p. 14). As a result, teachers can feel empowered to "make better decisions about science instruction by increasing their understanding of…science content, scientific processes, and pedagogical models" (Melber & Cox-Peterson, 2005, p. 118). By increasing a teacher's subject matter knowledge, their comfort level and confidence in transmitting this information in creative and engaging ways to their students is thereby increased. Ultimately, this increase in teacher effectiveness results in a positive correlation between classroom performance and student achievement in STEM fields of study (Thomasion, 2012; Bevan & Semper, 2006).

Maximizing Collaboration Potential

Although there is a wealth of research to support the development of collaborations between formal and informal science institutions, there is also sufficient evidence to indicate formal educators do not utilize the resources provided by informal science institutions to their maximum potential. Bevan and Semper (2006) cite a recent study by The Center for Informal Learning and Schools (CILS) in which 500 informal science institutions were surveyed, and of these, "75% reported that they offered structured programs for schools (beyond a standard field trip program), more than half of these programs were underutilized by their local school systems" (p. 3). Additional statistics state approximately three quarters of informal science institutions in the United States have programs specifically designed for school audiences, but that these programs typically have excess capacity and can accommodate more participants (Community for Advancing Discovery Research in Education [CADRE], 2011).

Programs provided by informal science institutions are abundant, but are being under-utilized by formal educators because they often do not recognize the value inherent in these programs. We argue one of the solutions in overcoming this obstacle is the professional development of informal science educators. As evidenced in a recent study at the Houston Zoo, the utilization of best practices, classroom management, and engaging presentation style of the informal science educators led teachers to associate their view of the instructors with the value of the program (Sanford, 2014). By producing a professional field of informal science educators with strong foundations not just in science content, but also in learning theories, instructional strategies, assessment techniques, and other aspects of the formal education community (Bevan & Semper, 2006; Bevan et al., 2011), informal science educators and their corresponding institutions and programs will be positioned to be viewed as integral, necessary components to everyday science learning within the formal education system.

Houston Zoo Study

A study was conducted at the Houston Zoo in 2012 to determine teachers' perceptions of their students' engagement in science in their classroom after attending a field experience at the Houston Zoo. This study sought to build upon the knowledge base about the connections between the formal and informal science education fields as identified earlier in this chapter. This study and its results, described here in detail, provide further evidence professional development of informal science educators is relevant and necessary, not only to the informal science institutions, but also to formal educators attending programs at the institutions.

Fifty-eight teachers were administered an online survey by the researcher three weeks after having participated in an educational class at the Houston Zoo. The educators' schools vary by geographic location, demographic information, student population, and Texas Education Agency's state accountability ratings. The districts and schools represented in the study include public school districts in the Southeastern region of Texas, as well as private schools in the same region. A modified version of the preexisting Student Participation Questionnaire was used for the survey instrument, and focused on questions pertaining to effort and initiative of students in the classroom, and included a series of open-ended questions (Finn, Pannozzo, & Voelkl, 1995). The questions on the Student Participation Questionnaire asked teachers to rate their perceived changes in student behavior in science after participating in an educational program at the Houston Zoo. The open-ended questions were designed to explore the relationship between students' engagement in science in their classroom and participating in a class at the Houston Zoo, as well as to inform leadership practices at both informal science institutions and schools.

Data collected from the surveys were analyzed in two phases, quantitatively and qualitatively. The Likert scale-based questions were analyzed through determining frequency and percentage per response, and were then summarized per question into two categories: effort scale and initiative-taking scale. In order to analyze the open-ended question portion of the study, the researcher conducted a horizonalization of the significant statements made by the teachers, and then grouped these statements into themes prior to writing a composite description of the phenomenology (Creswell, 2013). Although the response rate was low, the researcher also looked at emerging themes, and compared the responses with that of current research.

Results

Evidence of engagement in science once back in the classroom after participating in an educational program at the Houston Zoo was seen both in the results of the Likert scale-based questions, and indicated by the responses of the open-ended questions received through the online survey. Finn, Pannozzo, and Voelkl (1995) associated positive learning behaviors with behaviors related to student engagement in the classroom and analyzed them on two scales, effort and initiative-taking. The average response rating for behaviors associated with the effort scale is 3.38, while the average rating for behaviors associated with the initiative-taking scale is 3.62. While the quantity of results do not allow for a statistical analysis to determine significance, observationally, this denotes the teachers saw a slight increase in positive learning behaviors, associated with effort and initiative, in science back in the classroom.

In addition to the Likert scale questions, the participants were asked to respond to an open-ended question about engagement in science once back in the classroom. Seventeen of 27 teachers responded to the question, and eight teachers identified these themes: *excitement about science* (answering questions more frequently, wanting to write about the Zoo upon returning to school, etc.), *connectedness* (connecting what was learned at the Zoo to the information studied in class), and *science as a career option.*

Two additional open-ended questions were posed to the educators in order to provide information for informing leadership practices. In reference to the extent the program impacted their students, nineteen teachers responded in which three themes emerged: *motivation*, *hands-on interactive activities with animals*, and *instructor excellence*. Of these common themes, five teachers noted motivation, eight noted the hands-on interactive activities with animals, and two noted instructor excellence. When asked about the extent to which the educators would recommend the program to other teachers, eighteen teachers responded as recommending or highly recommending the program.

Discussion

The results from the open-ended questions help to explore this observational relationship in student engagement in science as a result of the Houston Zoo education program. Axelson and Flick (2010) noted student engagement in the classroom could be associated with such characteristics as involvement and interest in the classroom instruction and connections to the subject matter taught, which were common themes presented by the educators.

In theme one, *excitement about science*, approximately 45% of the teachers indicated the excitement in science the students exhibited upon returning from the field experience were tied to specific behaviors of increased connectedness to the subject matter through the desire to write about and do reports on animals, and the level and quantity of questioning increasing. These behaviors, coupled with the teachers' observations, indicate the strong, positive impact the education program had on the students' interest and involvement in the classroom.

The second theme, *connectedness*, describes the increase students made in connecting classroom science to what they learned while at the Houston Zoo. The teachers identified these connections to science through specifically mentioning the connections to material taught, as well as an increase in the detail added to class discussions and the expansion of knowledge through use of science-specific vocabulary.

In this study, academic relevancy was shown through the third theme, *science as a career option*. In 2011, Crumpton and Gregory described an aspect of student engagement termed academic relevancy, a student's connection of the material learned in class to their real life experiences and how it is personally meaningful. Educators commented that students identified working at a zoo or in science as an option as a result of attending the program.

Informing Leadership Practices

One of the intents of this study was to inform leadership practices related to zoo education programs and student engagement. When describing the impact the field experience had on their students, educators described a truly *motivating* experience. The teachers commented the students came away wanting to pursue careers in science, asking more science related questions in class, and wanting to learn more when they got back to the classroom. All of these positive learning behaviors and interest in classroom instructional information are reflective of elements of both behavioral and emotional student engagement (Fredricks, Blumenfeld, & Paris, 2004).

A second point the teachers described when referring to the impact the field experience had on their students was the focus on *hands-on, interactive activities* conducted during the Houston Zoo program. The teachers described seeing and touching animals they otherwise would not have the opportunity to interact with brought the learning to life and helped students build personal connections to the material they were learning. The practice of utilizing live animals as part of the Houston Zoo educational programs is a purposeful experience, and the outcomes are in line with previous research.

Lastly, a point indicated by the teachers as a reason for them to extend a recommendation of the field experience to another educator, was the *instructional excellence*. The teachers commented specifically on the informal science educators' abilities of classroom management, engagement, and presentation skills. This is important for institutions to note the value the teachers placed on the instructional practice during the field experience.

Conclusion

School leaders make choices. By whatever decision-making model they use, principals have to decide on how the dollars they are allocated would be best used for the students' learning and achievement in their schools (Epstein, 2009). As this study shows, zoo education programs are a way to generate a renewed interest in a topic, motivate the students to engage in science class through their work and questions, and expose students that might not otherwise have an opportunity to visit a zoo to a novel environment in which they might learn about additional career options. Therefore, school leaders should support research-based, high value, low cost educational experiences with community partners that truly can complement and reinforce student learning.

Informal education leaders should continue to focus on facilitating collaboration with formal education leaders. As the results of this study showed, the class at the Houston Zoo was a motivational experience for the students, and their teachers reiterated this point through their comments regarding the impact it had on the students. Therefore, one could see how informal educators may be seen primarily as a motivator, serving simply as an inspirational source rather than a critical contributor to science literacy however, if value was placed on collaboration with the formal teachers, the extent to which student learning occurs could potentially increase (Patrick, Matthews, & Tunnicliffe, 2011).

One of the significant implications for informal science educational leaders from this study is in regard to the professional preparation of their instructors. The teachers associated their view of the instructors with the value of the program, as well as their recommendation to others to participate in the same program. Therefore, informal science educational leaders would behoove themselves to focus on the professional development of their staff, and more specifically the instructional strategies that best engage learners of all ages. The value educators associate with good instruction in the classroom is not only important for the connection to the formal classroom environment, but also to continue to be able to effectively market programs to school leaders.

Professional Development for Informal Science Educators

Informal science educators play a vital role within their institutions, as they are the conduits of science knowledge and information to all visitors, not just the formal education sector. They are often responsible for engaging audiences through a variety of program types including experiments, formal classes, story telling, theatrical productions, professional development for educators, and more. Brisson et al. argue, "Most ISE institutions have staff with considerable experience and expertise in translating and packaging science stories into forms that engage, entertain, educate and even empower school groups and the general public" (2010,

p. 15). Within the formal education realm alone, informal science educators provide unique inquiry learning environments, design curriculum adjuncts, and lead teacher professional development (Bevan, 2003). Bell et al. argues that informal science educators influence learning experiences in a number of ways. They may model desirable science learning behaviors and help learners develop and expand scientific explanations and practice, in turn shaping how learners interact with science, with one another, and with educational materials. They may also work directly with science teachers and other education professionals, who themselves are responsible for educating others (as cited in Ball, 2012, p. 21).

With such an essential role in the development of the public's science literacy, it is imperative for informal science educators to have the necessary knowledge and skills to make the most significant impact on visitor experience (Evans, Simms, Bader, Hunt, & Tran, 2011).

Background and Experience of Informal Science Educators

Based on the research presented in this chapter thus far, it is apparent informal science educators bring a vast array of skills and knowledge to their profession. Research has shown this diversity is a result of the varied backgrounds and experiences of informal science educators. Tran references several studies that found these professionals not only had varied science backgrounds but also possessed a range of credentials from formal teaching certificates to no educational training whatsoever (2007). Although this immense diversity has created a field of professionals which excel at igniting in others a passion for science, it "may also contribute to the poor definition and recognition of their roles and expertise recently voiced by educators in the US, as well as the lack of common understanding about what constitutes best practice reported in research" (Tran, 2007, p. 1). Many informal science institutions have a unique mix of staff as part of their educational team but often lack scientific depth and currency in educational best practices; staying abreast of current research in both domains is challenging, as a uniform approach for teaching and maintaining this knowledge base for such diverse staff is difficult to implement. This, in turn hampers communication both within the informal science community, as well as with formal educators and other audiences (Brisson et al., 2010; Tran, 2007). While these variations may serve as strengths in terms of program creativity, passion, and institution specific missions, it is also a hindrance to the profession as whole. Without a shared professional language and adherence to best practices, particularly in terms of teaching, informal science educators lack the ability to properly connect to audiences. For the formal education audience, this may mean the inability to connect to school curriculum, develop shared educational goals with formal educators, and ultimately fail to market impactful science educational programs to school districts.

Limited Job Training

Assimilating a workforce with such varied and diverse backgrounds and experiences into a profession which Dragotto, Minerva, and Nichols deemed, "combines teaching with event planning, drama, project management, grant writing, marketing, market research, and expertise in a specific content area" (as cited in Tran, 2007, p. 2) is difficult at best. However, the informal science education field does not possess a professional certification process, and often many institutions offer limited or no professional development for their educators. With a work scope of educational responsibilities that envelops all components of an institution's educational agenda, regardless of how directly the tasks relate, it seems that on the job training would be insufficient in helping informal science educators to achieve these vast goals (Tran, 2007). Many informal science educators learn to teach programs through curriculum review, observations of peers, and trial and error (Tran, 2002). With such a broad spectrum of audiences and program types, the development of best teaching practices through the accumulation of knowledge and experience alone is a daunting task.

While on the job experience and the resulting lessons learned is valuable in any field, the level of impact reached during the early stages of an informal science educator's career would be far higher if it was based on a strong foundation of educational pedagogy and best practices. In addition, while learning from peers with a differing knowledge base and background can help to provide a larger pool of resources and information, it also means there is no consistency in knowledge or implementation between professionals, and thus institutions, within the same field. With limited opportunities for developing professional skills and knowledge, as well as remaining current within the field, informal science educators will not be able to maximize their contributions to science literacy (Ball, 2012).

Resulting Challenges

While informal science educators have worked to fine-tune their teaching skills through experience, many base their teaching model "on the pedagogical practices of classroom teachers" (Plummer & Small, 2013, p. 2). Plummer and Small (2013) cited the use of didactic, educator-directed instruction, transmission-mode instruction, and factual recall that utilizes simple yes/no questions based on various research studies. This type of teaching in which information is merely disseminated to students, is a direct result of the lack of professional certification and continuing development of informal science educators. Educators are modeling their teaching based on their own personal experience with education, as well as observations of peers (who most likely had similar experiences within the education system).

> Resemblance of the museum lessons to school lessons, in design and discourse, may be an obstacle to nurturing interests in science and learning…simply mimicking that which is offered by schools devalues the expertise and capabilities of the educators and of the museums themselves (Tran, 2006, pp. 94–95).

With little to no exposure to current education best practices, informal science educators lack the ability to adapt their teaching techniques and strategies to create the most effective programs.

In Tran's 2002 study, students in informal science institution classes were primarily taught through the utilization of physical opportunities to introduce and reinforce concepts. These lessons provided limited mental engagement for students, instead relying primarily on activities that focused on knowledge acquisition and comprehension. While noted as hands-on activities, they were not "'minds-on' as they did not allot time and opportunity for students to interact with, explore, or inquire about the items" (p. 94). Tran cites a study by Marek and Methven in which "students learning science by a show-and-tell format exhibited significantly lower conservation gains and use of descriptive words than students taught via the learning cycle which took on an explore-talk-explore format" (2002, p. 88). Educator-centered, transmission-mode teaching, is not consistent with what is recognized with the literature as the most effective teaching method nor is it supported by the *National Science Education Standards* (Tran, 2002).

> The overall assumption was that students generated connections between concepts and content if provided the necessary information and prompts, which was consistent with their [informal science educators] belief that teaching was sharing of information, and the educator played the role of information provider in the learning process (Tran, 2002, pp. 95–96).

While Plummer and Small (2013) point to research which shows visitors recall enjoyable, engaging experiences at museums long after their visit, they also highlight a study by Davison and colleagues in which students who participated in informal science institution classes "found the lectures from the zoo educators to be the least enjoyable part of their experience" (p. 10). While content and information is an important component in any lesson, it cannot be the "single most important factor in teaching, then it would not be necessary to require the new lineage of classroom teachers to pursue their teaching license" (Tran, 2002, p. 100).

Informal science educators are often well versed on science content, particularly content specific to their institutions, and focus on utilizing this content knowledge as a way to engage students through hands-on activities to create lasting memories and inspiration for future learning. However, their "lack of familiarity with the research literature on science learning, especially classroom science, means that many informal educators…may not be attending to key features of science learning…" (Bevan & Semper, 2006, p. 6). As a result, program curriculum is often piece-meal, less descriptive in terms of curriculum standards and learning objectives, and lacking in student-centered instructional methods (Bevan & Semper, 2006; Brisson et al., 2010; Tran, 2002). Informal science educators have made an effort to improve their programs through program evaluations as evidenced by the increasing number of research proposals submitted to the National Science Foundation (NSF) in recent years (Sparks, 2011). But a study conducted by the Program in Education, Afterschool, and Resiliency at Harvard University and McLean Hospital revealed that none of the widely used evaluation tools for informal science "met all five of the NSF's five domains of informal learning: engagement and interest, attitude toward science and behavior, content knowledge, competence and reasoning, and career knowledge and acquisition" (as cited in Sparks, 2011, Better Alignment section, para. 1). The widespread use of educator-centered teaching, poorly designed curriculum, and demonstrated knowledge gaps regarding learning in informal environments, clearly indicates informal science educators lack the necessary training to effectively promote science literacy.

Recommended Solutions

The resolution of these challenges is simple. In order to create effective collaborations between formal and informal institutions, informal science educators need access to established certification and continuing professional development opportunities so they may not only advance their personal career aspirations, but also so they may educate the public effectively and become true ambassadors of science literacy (Ball, 2012). Informal science educators are not only responsible for interpreting science and inspiring passion in visitors to their institutions, they also "prepare and train formal educators, who then help to create scientists and a STEM-literate populace" (Brisson et al., 2010, p. 7). Bevan and Semper (2006) advocate "working with the formal education system is key…to increase public engagement with science and to engage a more culturally and socio-economically diverse public than it currently engages" (p. 2). This cannot be done without a better understanding of the formal education system on the part of informal science educators. Without this knowledge and understanding, they lack the necessary skills to create and deliver effective science programming.

For the growth of the informal science education field, a shared body of knowledge and skills to support educators' practice, a certification process for newcomers, and a variety of continuing professional development in the workplace is needed (Evans et al., 2011; Plummer & Small, 2013). Informal science educators themselves have identified interactions with colleagues at other institutions and conferences, reading professional journals and books, and knowledge of learning and science content, and teaching and presenting as valuable resources for success within their field (Plummer & Small, 2013; Sutterfield & Middlebrooks, 2000; Ball, 2012). However, few institutions provide opportunities for professional development, sustained or otherwise, despite recommendations to the contrary. The NSTA "recommends an increase of support for informal science educators so they are able to continually improve their professional practices by expanding opportunities for their own professional learning, including (but not limited to) how they can collaborate with schools and teachers to advance student engagement with and pursuit of science" (2012, p. 3).

> Informal science educators
> often find ourselves in a place where another language is spoken…The science center field needs more 'bilingual' educators – professionals who can speak the school language and design school programs that build on the strengths of informal education (Bevan, 2003, para. 2 & 9).

Professional development for informal science educators should include a focus on standards-based reform, current theories of learning, particularly as it relates to informal learning environments, program design and evaluation, and other components that address the context of the formal education community (Bevan, 2003; Bevan & Semper, 2006; Bevan et al., 2010). In addition to leading to a better understanding of the formal education system, and therefore the creation of programs more effective in inspiring and creating the next generation of STEM leaders, professional development can also lead to institutional growth and better staff retention (Bevan & Semper, 2006; Sutterfield & Middlebrooks, 2000). While informal science institutions face time constraints, financial restrictions, and other barriers to providing quality, consistent professional development, these obstacles can be overcome through the use of various research-based trainings and development.

Finding the Balance

Institutions looking to initiate change will often rely heavily upon professional development as a mechanism by which to drive such change. Guskey (1994) argued every modern proposal to reform, restructure or transform institutions of learning utilizes professional development. However, as mentioned previously in this chapter, informal science education institutions often deliver professional development haphazardly without thought placed toward the end result. As such, institutions need to have an understanding of effective professional development in regards to both the institution and the individual adult learner.

As an organization, an institution will undoubtedly place a greater interest on results, be it financial, learner impact, or participant satisfaction. This leads institutions in most instances to often advance quickly through necessary training in order to achieve results as soon as possible while limiting the cost to the institution (Sanchez, 2012). Guskey (1994) describes that in business, organizations can use similar processes across different locations to produce the same product; however, this notion of uniformity does not work in informal science education. In informal science education, even similar programs that share common goals may still need to follow very different processes in order to achieve similar results.

If an institution is planning on utilizing professional development either to initiate a change or to train employees, they must consider research-based characteristics of and approaches for effective professional development. Cormas and Barufaldi (2011) conducted a comprehensive search for information concerning considerations that should be made for effective professional development, and conducted an analysis of the results, as well as validating them with experts in the field. This resulted in sixteen research-based characteristics, seen below.

1. Teachers' discipline-specific knowledge is increased.
2. Teachers understand how students learn and what are effective teaching strategies within a specific discipline.
3. Teachers understand how students learn and what are effective teaching strategies.
4. Teacher effectiveness and student achievement outcomes are used to determine whether professional development has worked.
5. Requires resources (money and time).
6. Professional development is ongoing.
7. Professional development occurs in day-to-day contexts of teachers.
8. Uses effective teaching strategies.
9. Coherent/aligned with school/district/state goals.
10. Teachers provide input into professional development design; professional development is engaging and relevant.
11. Involves collaboration between teachers and others.
12. Generates further collaboration or projects.
13. Treats teachers as professionals.
14. Promotes teacher self-reflection.
15. Uses inquiry as a teaching style.
16. Increases teacher ability to meet needs of diverse learners.

This list provides institutions with guidelines by which to analyze their professional development programs or approaches. While not all professional development must include all sixteen characteristics, those that contain all or most have a greater impact on results (Cormas & Barufaldi, 2011).

It is important to note professional development cannot be seen as a one-size fits all solution, but instead should take into account the diverse backgrounds and experiences of the participants (Bouwma-Gearhart, 2012). As such, institutions should continue to focus on providing quality professional development experiences that build upon the diversity of its workforce. Desimone (as cited in Stewart, 2014, p. 30) identified five key features that should make up quality professional learning activities for educators: content focus, active learning, coherence, duration, and collective participation. Through focusing on content, educators increase their understanding of how students learn specific subject matter information. By keeping the learning active, educators are focused on reviewing data and learning together through an observation and feedback loop. Coherence provides a "big picture" outlook by tying the professional learning to both the educators' professional experiences and their belief system. The duration of professional learning needs to be ongoing, and should involve educators who are in similar teaching

Table 16.1 Professional development (PD) activities and relation to depth of learning (Smith, as cited in Stewart, 2014, p. 31)

PD approach	PD activities	Objective	Core feature
Reading about a resource or method	Individual	Build awareness	Content focus
Training	A single workshop	Build knowledge	Content focus
Professional development	Multiple session workshops	Change practice	Content focus, active learning, duration, linked to teacher beliefs and standards
Professional learning	On-the-job, in a community of practice	Change theories and assumptions	Learning in the workplace, using student data, learning through experience, learning through reflection

situations. When these elements are considered in professional development planning it allows for opportunities for improvement over time.

Even with the above considerations in mind, institutions still must evaluate the types of professional development and the effectiveness each will provide in relation to the results they desire. Building upon Desimone's (as cited in Stewart, 2014, p. 30) key features of professional development, Smith (as cited in Stewart, 2014, p. 30) identified four common activities within professional development and related them to different professional development approaches, as seen in Table 16.1. The first two activities, individual and attending a single workshop, are passive learning opportunities. Unfortunately, unless these opportunities are related back to the workplace, the impact is minimal on the educator (Stewart, 2014). However, the last two activities, multiple session workshops and on-the-job training, are active by nature and allow for practice in the learning environment. This focus on creating changes to professional practice over time has been shown to improve instruction (Stewart, 2014). Taking this all into account, institutions will have a better idea of how to allocate time and resources as they plan for growth and/or change.

A New Framework for Professional Development in Informal Science Learning

Based on the research presented by Smith (as cited in Stewart, 2014, p. 31) and Cormas and Barufaldi (2011), we propose adapting elements from, and building upon, a framework for professional development presented by Hochberg and Desimone (2010) for informal science learning as shown in Fig. 16.1. Since results and/or change are the ultimate goals for institutions, as well as individuals within the institution, these are the outcomes identified in this framework. In order to

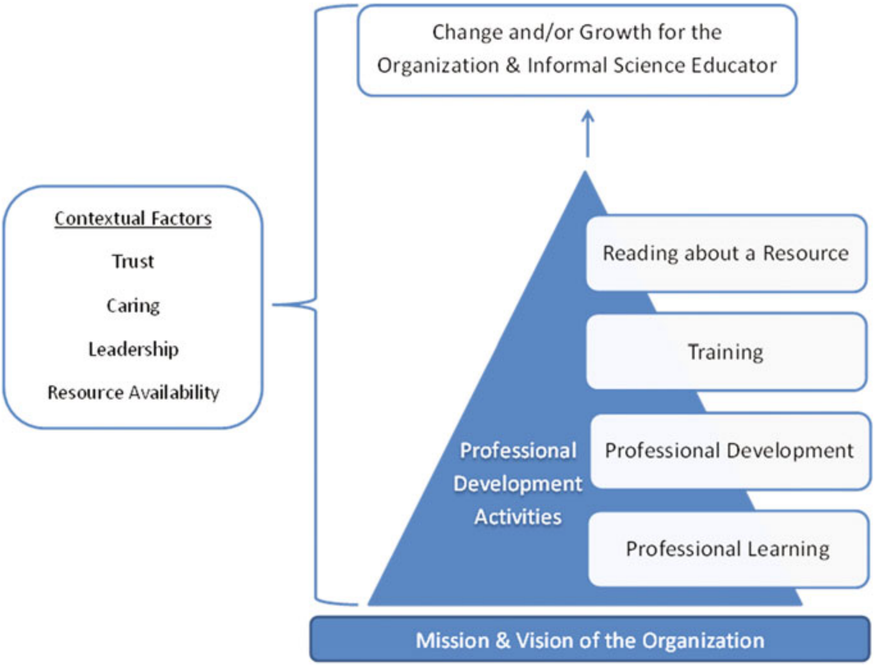

Fig. 16.1 Framework for professional development in informal science learning

leverage professional development activities to drive changes and results, they must be built upon the foundation of an institution's mission and vision. This ensures professional development activities are all aligned into one cohesive plan for success using research-based approaches that mirror those of the formal education environment.

To drive success through professional development, the primary method must be professional learning. Professional learning activities are job-embedded, interactive, sustained, practical, and conducted in a collegial environment (Fogarty & Pete, 2010). For example, an institution may desire introducing elements that reach more learning modalities into programs. As a result, the institution holds an internal workshop with all staff responsible for teaching the programs. Afterwards, the staff discusses together how they could implement what they have learned. As the staff begin introducing the modalities into the programs, they then journal about their experiences. After a few weeks of implementation, the staff regroups, shares successes, discusses opportunities for improvement, and continues the cycle of implement, reflect, discuss, and change.

While professional learning should be the foundation by which professional development is integrated into the institution, there are other activities, when used cohesively, can assist in the growth of the institution. As identified in Fig. 16.1, professional development should be used the most following professional learning.

In this context, professional development is attending multiple workshops on a subject matter or strategy over time (Stewart, 2014). Just as professional learning allows for practice, so does professional development; however, the one distinction here is there is not a cycle of implementation, reflection, discussion, and change in a collegial environment. That is not to say professional development could not be used in this fashion, but typically institutions do not have the capacity to send all staff to multi-time period workshops. However, if an institution wanted to leverage a professional development and move it into a professional learning opportunity, the institution could have staff members who attended the professional development perform a workshop on what they learned and then move into the cycle for professional learning.

The final two tiers of the professional development activities pyramid in Fig. 16.1 are to be used the least. Trainings are defined as one-time workshops, and reading a resource is as described (Stewart, 2014). As with professional development, these passive learning activities can be moved into the professional learning category, when utilized in the correct context. Trainings can be shifted into this category in the same manner as professional development. While reading about a resource can be an individual activity that will not have the impact of a professional learning activity, it is good to encourage employees to continue to read current research on informal science learning. To move this activity into a professional learning activity, an institution could set up a monthly timeframe in which a different employee presented a current research article to the other employees. The group could discuss what they had read, brainstorm ways in which the research could be applied, utilize the current research over the following few weeks, and then come back together to reflect.

Contextual Factors. Considering the foundation by which an institution aligns its professional development activities is important, but equally important is the context in which the learning is facilitated. It is because of this that we propose the following contextual factors for the framework in Fig. 16.1: trust, caring, leadership, and resource availability. Contextual factors for this framework are focused on getting to know the employees of the institution, both personally and professionally, as well as identifying the barriers and constraints of resources as it pertains to the institution utilizing professional development to drive growth and change. In our framework, trust is both related to competence and character the employees have in the institution and the institution in the employees. Trust is both earned and learned as together the employee and institution head in the same direction with the same goal. This is why it is critical that foundation of activities be aligned with the institution's mission and vision. Trust will then manifest itself as the employees trust the leadership to move everyone toward a common goal, and when provided with the appropriate framework, the institution trusts the employees to learn and grow toward that goal. Caring is also very important to utilization of professional development for growth and change. An institution and leader must care about the employees' personal and professional growth. Caring about an employee's overall growth results through listening to employees' needs for successful current and future performance, where they envision themselves professionally in the future, and how you might be able to assist them in reaching their goals. By establishing trust and caring, an institution establishes their community of learning based on the growth of its employees.

The final two contextual factors, leadership and availability of resources, are dependent upon the institution. Leadership in our framework is a process by which leaders inspire a shared vision through modeling, encouraging, and enabling others to act. This helps to provide the framework in which a professional learning community can prosper. If there is not a strategic plan to reach the vision, then providing professional development would result in a "shotgun" approach where nothing is targeted (Abilock, Harada, & Fontichiaro, 2013). Resource availability refers to the institution's capacity to provide professional development activities. As written previously, these are job-embedded, and as such, can take on many different forms. It is common in not-for-profit sectors to have limited resources to devote to sending individuals to participate in a series of workshops or individual trainings. However, there are ways, as described previously, to leverage some low-cost options and shift them into professional learning opportunities.

Putting It All Together. How does it look when an institution is utilizing this framework? First, an institution will need to determine its overall goal or elements they are seeking to change by leveraging professional development. This can come as a result of conducting a needs analysis or SWOT (strengths, weaknesses, opportunities, and threats) analysis. Once the institution has determined the overall goal, it can then send out a survey to its employees. Survey questions should be twofold: (1) they should be geared toward the employee in regards to their current position, including challenges they face and where they would like to be professionally, and (2) they should ask the employee what type and examples of professional development they enjoy. This approach, if used when developing a plan for institutional change and/or growth, demonstrates to the employee their input is valued and helps create buy-in with the employees as the institution grows/changes. Using the results from the needs analysis and employee survey, the institution can create individual training plans for each employee. The training plans should include components that are applicable to all employees, thus building the professional learning community, and some components that should be applicable to the growth of the individual. These training plans are then reviewed frequently with the employee to ensure everyone is clear with the institution's direction. Therefore, the individual training plans are flexible and can adjust as the institution needs to change or grow, and/or the professional growth of the employee needs to move in a different direction.

A New Era for Informal Science Educators

Research regarding the importance of collaborations between the formal education system and informal science institutions is abundant. It has been repeatedly shown these collaborations increase student interest in science, provide unique experiences for students, and increase the science knowledge of formal educators. Effective collaborations can impact students' career choices at an early age and inform the leadership practices of school administrators, all leading to a population more engaged in science. However, successful collaborations are not widespread. Despite the creative and experienced informal science educators working to engage visitors and inspire a passion for science at informal learning institutions around the nation, this group of educators cannot effectively promote science literacy due to a lack of a shared knowledge base and skills. The solution to this challenge is the development of professional development for informal science educators that can be applied across a diverse group of informal learning institutions and staff.

Informal learning institutions must utilize research-based considerations and approaches for effective professional development, while also building on the institution's workforce diversity. In order for informal science institutions to create a cohesive professional learning community, it is important for these institutions to utilize a strong framework. The basis of this framework is the mission and vision of an institution, fortified by professional learning opportunities and supplemented with additional elements such as training and reading current research. Contextual factors, including caring and trust, play an important role as well. The utilization of this framework results in the creation of institution-wide goals for change/improvement that can be realized through group and individual professional development components.

Informal science educators are a unique group of professionals that strive to inspire a passion for science in millions of visitors to informal learning institutions each year. Despite their boundless enthusiasm and excitement, their current impact on the population is small as a result of a loss of connectedness with one of their biggest audiences—students and formal educators. With focused professional development across institutions, informal science educators could drive innovation and change across the nation and help to create a highly science literate America.

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Chapter 17
Multiple Approaches to Using Informal Science Education Contexts to Prepare Informal and Formal Science Educators

Emily Hestness, Kelly Riedinger and J. Randy McGinnis

Research-based understandings of how people learn science—both within and outside of school—can provide valuable guidance to approaches to the preparation of science educators. Knowing that learning transcends contexts, and that children spend a relatively small portion of their lives in formal school settings, the science education community has recognized that a significant amount of science learning takes place in informal science learning contexts (National Research Council, 2000). It follows, then, that it is not only educators working in formal school contexts, but also those working in informal contexts, who must be well prepared to guide learners in scientific sense-making. Educators in out-of-school, or informal, science education contexts are likely to share many of the same (and some unique) professional goals and needs with their school-based counterparts related to science teaching and learning. Therefore, we see value in re-imagining collaborative approaches to the professional preparation of science educators across both formal and informal science education contexts. Further, we believe that such approaches are most transformative when they draw on our expanding understandings of how people learn science, and the ways in which these understandings are translated within the science education community into reform-based science education goals.

In *A Framework for K-12 Science Education*, a document outlining recommendations for science education in formal and informal settings, the National Research Council (2012) articulated several key goals for today's science learners. These include the ideas that learners should: appreciate science; engage in public discussions on science-related issues; become informed consumers of scientific

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information; learn about science outside of school; and become prepared for careers potentially related to science, engineering, and technology (National Research Council, 2012, p. 1). If science educators in both formal and informal science education settings aspire to these goals, science educator preparation approaches for both settings must consider ways to equip educators with relevant understandings and skills. Research on the preparation of formal and informal science educators suggests certain areas of crossover between educator preparation for these two realms. However, there are also dimensions unique to formal and informal science teaching contexts that may likewise require specialized approaches and considerations.

One perspective on the shared and distinct emphases of formal and informal science learning environments emerges in the National Research Council's strands of science literacy frameworks (National Research Council, 2007, 2009, see Table 17.1). The four-strand framework introduced in *Taking Science to School* (National Research Council, 2007) focused on the goals of formal science learning environments, including fostering learners' development of proficiency in science content knowledge, scientific inquiry skills, understanding of science as a way of knowing, and engagement in scientific practices and activities. The six-strand framework presented in *Learning Science in Informal Environments* (National Research Council, 2009) built on these goals and highlighted the additional realms in which informal science education environments may be of unique value to science learners, including the affective domain (e.g., excitement, interest, and motivation to learn science) and identity development (e.g., as a learner of science; as "someone who knows about, uses, and contributes to science" (p. 4). The commonalities between these frameworks further underscore the potential for collaboration between formal and informal science educators, and the need for preparation programs that strengthen their abilities to address mutual, research-based science learning goals. The additional features of the informal science education framework (Strands 1 and 6) highlight the need for transformative approaches to educator preparation that maximize the unique affordances and emphases of informal learning environments—an effort that may offer benefits for informal and formal science educators alike.

In this chapter, we posit that innovative approaches to educator preparation—particularly those that transcend typical connections between formal and informal science education, may have the potential to further the mutual science education goals articulated in *A Framework for K-12 Science Education* (National Research Council, 2012). In doing so, they may also highlight the unique dimensions of science learning emphasized in informal science education environments, particularly affective dimensions (interest, excitement, and motivation to learn science) and identity development in science (National Research Council, 2009). We begin with a review of the literature on the use of informal science education contexts for science educator preparation. We then turn to a description of four distinct science educator preparation approaches that we have developed and implemented as science teacher educators in universities in the United States. Each approach connected educator preparation and informal science education, to promote the

Table 17.1 Strands of science learning from the National Research Council's Learning Science in Informal Environments (2009) and Taking Science to School (2007)

Learners in informal environments		Students who are proficient in science	
Strand 1	Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world	Strand 1	Know, use, and interpret scientific explanations of the natural world
Strand 2	Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science	Strand 2	Generate and evaluate scientific evidence and explanations
Strand 3	Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world	Strand 3	Understand the nature and development of scientific knowledge
Strand 4	Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena	Strand 4	Participate productively in scientific practices and discourse
Strand 5	Participate in scientific activities and learning practices with others, using scientific language and tools		
Strand 6	Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science		

professional learning of science educators entering formal or informal science teaching contexts. After describing these multiple approaches, we discuss their connections to research on educator preparation and to the strands of science literacy emphasized in informal science education. We conclude with brief reflections on our own learning and suggested avenues for future research.

Literature Review

We begin with a review of literature that examined the use of informal science education contexts and approaches to support the preparation of science educators. We focus in particular on themes from the literature on the preparation of informal science educators, and the ways in which these themes overlap with and diverge from the literature on formal science educator preparation.[1]

The preparation and professional development of educators in informal science education contexts is a growing area of study (Allen & Crowley, 2014; Ash & Lombana, 2012). To advance the field of informal science education, there is a need

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[1] For a review of the literature on using informal science education contexts to support the preparation of formal science educators, see McGinnis et al. (2012).

for research-based approaches to support the intellectual and practical growth of educators in informal settings (Tran, Werner-Avidon, & Newton, 2013), who have, in the past, often not been well supported as professionals (Allen & Crowley, 2014; Bevan & Xanthoudaki, 2008; Castle, 2006; Cox-Petersen, Marsh, Kisiel, & Melber, 2003). Researchers have noted the scarcity of opportunities for informal science educators to engage in professional development (Bevan & Xanthoudaki, 2008), particularly related to building skills that support the types of pedagogies they are expected to use in their teaching contexts (Castle, 2006). Without treating informal science education as a professional undertaking requiring the development of particular knowledge, practices, and values, the perception (by some) may be perpetuated that the work of informal science educators does not constitute a "real teaching job" (Tran et al., 2013, p. 342). In order to support the expansion of quality preparation and professional development for educators in informal science education settings, it is useful to examine existing research in this area.

Overall, this body of literature has suggested that while some aspects of formal teacher preparation can apply to the preparation of informal science educators, the field must also attend to the unique features of informal science education contexts and of learning within them. Key themes from the research on the preparation of informal science educators include: the influence of prior teaching and learning experiences, the importance of modeling research-based teaching practices, promoting reflective practice, the value of communities of practice, and the unique aspects of informal science education contexts that matter for the preparation of informal science educators. We now turn to a discussion of these ideas.

Influence of Prior Teaching and Learning Experiences

Research on the preparation and professional development of informal science educators has highlighted several aspects of formal teacher preparation applicable for preparing educators to work in informal settings. A major challenge highlighted in the literature for both formal and informal science educator preparation is the tendency of educators to conceptualize teaching according to their prior experiences as learners (Allen & Crowley, 2014; Bevan & Xanthoudaki, 2008; Grenier, 2005). As Allen and Crowley (2014) noted, educators tend to rely on familiar epistemologies and pedagogies, which may often be didactic and teacher-centered. While some evidence has countered this view, noting that teaching science in informal settings entails creativity and complexity beyond the didacticism that is often portrayed in research literature (Tran, 2007), the need for confronting embedded assumptions around teaching and learning remains. This is especially true if informal science educators are to consistently adopt reform-based approaches to teaching and learning (i.e., participatory, inquiry-based methods) (Allen & Crowley, 2014). In the absence of opportunities to learn and practice new approaches, informal science educators may revert to employing the teaching methods they experienced themselves in school (Bevan & Xanthoudaki, 2008;

Grenier, 2005). Bevan and Xanthoudaki (2008) argued the importance of directly addressing these prior conceptualizations of teaching and learning through professional development, stating that such approaches have the potential to "transform the nature of learning and teaching in museums, making it more inclusive, more relevant, and more impactful for more members of our communities" (p. 108).

Modeling Research-Based Approaches to Foster Learning

In addition to confronting pre-existing assumptions about teaching and learning, research on the preparation and professional development of informal science educators highlights the importance of introducing and modeling research-based pedagogies (Allen & Crowley, 2014; Ash, Lombana, & Alcala, 2012; Bevan & Xanthoudaki, 2008; Grenier, 2005), so that informal science educators can begin to build "a new repertoire of practices" (Ash et al., 2012, p. 25). For informal science educators, Ash et al. (2012) took a constructivist stance, advocating the modeling of teaching approaches that help to scaffold learner understandings. In doing so, they suggested, informal science educators might move away from a view of teaching as *providing information*, to one of teaching as diagnosing learner understandings and responding strategically in ways that support growth. They emphasized that informal science educators "must come to understand that there are important lessons to be learned in interaction with learners, that learners say and do many non-scripted interesting things, and that the 'best' strategy can differ according to the kind of interaction one may be seeing" (p. 25).

Bevan and Xanthoudaki (2008) likewise noted the value of modeling constructivist approaches to teaching and learning, such as introducing methods of assessing and responding to the understandings that learners bring to informal science education contexts. However, they also argued that informal science education contexts demand a particularly situated approach, such as one that considers the development of learners' *conceptual agency* (Greeno, 2006), and the ways that learning emerges through activity and interaction in informal science education contexts. Such a focus, Bevan and Xanthoudaki (2008) argued, would require museum educators to employ pedagogies that allow learners to participate in the processes of science [a recommendation well-aligned with the Next Generation Science Standards, (NGSS Lead States, 2013)], promote learning from and with others, make connections with learners' everyday lives, and foster reflection and personalized meaning-making. As Tran et al. (2013) found in evaluating a professional development program for informal educators, participants valued having such desired pedagogical approaches modeled by facilitators. This enabled informal science educators to begin reflecting on, analyzing, and modifying their own practices. Tran et al. further emphasized the need for striking a balance between structure and flexibility, so that informal science educators could consider the ways that the approaches modeled might be best applied in their unique settings.

Valuing Reflective Practice

As in research on formal science teaching, research on the preparation and professional development of informal science educators has emphasized the value of educator reflection (Allen & Crowley, 2014; Ash & Lombana, 2012; Ash et al., 2012; Bevan & Xanthoudaki, 2008; Tran et al., 2013). Ash et al. (2012) described reflection on practice for informal science educators as "engaging in thoughtful discussion and introspection, individually, within small groups, and through large group dialogue, focusing on what has been observed, what is being learned, about the learners who are being observed, and what the museum educator learned about their own role within the interaction" (p. 24). While many would agree that reflective practice is valuable for teaching in informal settings, informal science educators may have few opportunities to truly engage in it (Ash et al., 2012).

Several research-based examples of professional development models suggest specific approaches to engaging informal science educators in reflective practice. The first example is Ash and Lombana's (2012) REFLECTs model. In this model, which the authors employed with museum educators, participants engaged in teacher-research and practiced the skill of *noticing*—attending to what learners are actually doing in museums, and using these observations to make pedagogical decisions—via the use of videotaped teaching episodes in informal environments. After participation, museum educators were more attentive to learners' activities in informal learning environments; felt a greater sense of self-efficacy, empowerment, and agency; were more sensitive to the resources learners bring to the learning context; and were better able to enter into dialogue with visitors (Ash & Lombana, 2012). Ash and Lombana suggested that these transformations had the potential to help participants "become change agents in their own museums" (p. 47).

Tran et al. (2013) also reported on a pilot of a reflection-oriented professional development program for informal educators called Reflecting on Practice (RoP). The approach, which was implemented at 10 informal science education institutions, involved informal science educators in discussions and activities related to learning research, their own teaching practice, and the implications of research for their roles as informal science educators. Participants engaged in reflective tasks such as video analysis and discussion of their interactions with visitors, journaling, and online discussions. In analyzing the results of the study, Tran et al. identified four key supports that made the RoP program successful. These included a structured yet flexible curriculum, the modeling of teaching approaches to aid educator reflection, broad participation (professional development done "in-house" so that all staff could participate), and an organizational culture that supported learning. Where such supports were present, the reflection-focused program had the potential to foster positive changes in educators' behavior, thinking, language, and participation (Tran et al., 2013).

A final approach to fostering educator reflection is evident in Allen and Crowley's (2014) use of debrief meetings with museum educators following program facilitation. Debrief meetings, which took the form of guided focus groups, gave museum educators opportunities to identify and share specific strategies that were helping to promote visitor engagement and learning, while emphasizing the value of reflecting on teaching experiences, receiving and providing feedback, and learning from colleagues' experiences.

Valuing Communities of Practice: Shared Practices and Shared Vocabulary

Research on the preparation and professional development of informal science educators clearly emphasizes the importance of communities of practice (Allen & Crowley, 2014; Ash et al., 2012; Tran et al., 2013), in which newcomers gradually become more central participants. Much research in the area of informal science education draws upon sociocultural theory (Lave & Wenger, 1991; Rogoff, 2003), focusing on the centrality of interactions (among visitors, between visitors and museum educators, between visitors and exhibits) in informal science learning contexts (Ash et al., 2012). However, specific to research on the preparation and professional development of informal science educators, there is a strong emphasis on the interactions of informal science educators with one another, as well as with broader communities.

In their work studying the use of debrief meetings among informal science educators, Allen and Crowley (2014) noted that developing communities of practice could help informal science educators to "challenge dominant notions of teaching and learning together, differentiate practices and strategies for engaging different kinds of audiences, and [engage in] ongoing professional development through conversation and reflective practice" (p. 101). In particular, Allen and Crowley emphasized the need for a common language and shared practices amongst informal science educators. This point has been similarly emphasized by other researchers, such as Tran et al.'s (2013) *use of common language* and *changes in practice* as indicators of successful professional development in informal science education settings. Likewise, it is evident in Ash et al.'s (2012) statement that, "It is common for members of the same community to 'speak' the same language, to develop similar practices as well as to share aspects of identity, such as social norms, communication patterns and expectations… Communities of practice theory is a powerful context of mutual practices of 'speaking the same language'…" (p. 27).

Beyond promoting the development of communities of practice amongst informal science educators, some researchers have highlighted the value of communities of practice for connecting informal science educators with colleagues beyond their informal science education settings. For example, Halversen and Tran (2010) described a partnership between informal science educators and university-based ocean scientists though a college course, Communicating Ocean Sciences to Informal Audiences (COSIA). The course involved collaboration between informal educators and practicing scientists in teaching inquiry-based science to graduate and undergraduate marine science students, as well as practicum experiences at informal science education institutions. Halverson and Tran suggested that the partnership benefited informal science educators' understanding of scientific research and scientific community, their ability to enhance the science content in the programs they taught, and the ways in which they viewed themselves —and came to be viewed by others—as having professional expertise. From this experience, Halversen and Tran distilled lessons learned for fostering inter-institution communities of practice, such as the importance of selecting participants with shared values and goals; viewing knowledge and tools as assets to be shared and build upon by all members of the community; cultivating a culture of honesty, open dialogue, and respect; and establishing clearly defined goals toward which all members can contribute.

Unique Dimensions of Teaching in Informal Science Education Contexts

Though there may be variability from one context to another, many themes from the literature on the preparation and professional development of informal science educators overlap considerably with findings and recommendations for formal science teacher education. However, it is important to acknowledge the unique dimensions of informal science education contexts that may influence educator preparation in these settings. Bevan and Xanthoudaki (2008) mentioned, for one, the diversity of backgrounds typical of informal science educators themselves, who may differ considerably in age, experience, training, skills, and interests. For example, some may have classroom teaching experience, others may be drawn to the work because of their subject matter backgrounds, and some may come from entirely different disciplines. While this diversity can and should be considered an asset, it creates unique challenges for differentiating professional development experiences in ways that address and build on the uniquely diverse experiences of the group.

Another aspect of diversity in informal science education contexts, for which educators must likewise be prepared, is the diversity of the learners with whom they will interact. While formal science educators typically specialize in working with one age group, and within one discipline, informal science educators must often be prepared to interact with a wide range of learners with varying backgrounds, interests, and abilities; and around varying topics of inquiry that may arise within the informal science education setting. To prepare for this work, Tran et al. (2013)

emphasized the value of embedding professional development within informal science educators' specific workplaces. In commenting on the preparation of informal educators in art museum settings, Ebitz (2005) agreed that educators must have experiences serving the diverse audiences that visit the museum. He further highlighted the diversity of knowledge necessary for working in such informal settings, such as an understanding of relevant content, of learning theories (e.g., constructivism), of the curriculum and practices of American schools (if interacting with school groups), of practices for evaluating visitor experiences in museums, and of the use of appropriate technologies within the learning environment. While many of these skills are likewise required for educators in formal settings, the ways in which they play out are likely to be influenced by the features of the particular informal science education contexts in which they occur.

Summary

Emerging research on the preparation and professional development of educators in informal science education settings offers a number of key insights. First, there is a need for initiatives that support informal science educators' professional growth. In their absence, not only do informal science educators often lack opportunities to reflect on and adapt their practice, but also, some may perceive their work as lacking legitimacy. Findings from the body of research on the preparation of educators in informal settings has pointed to themes that are also relevant to formal science education, but that may play out differently in informal contexts. These include confronting assumptions about teaching and learning, modeling research-based pedagogies in professional development, engaging in reflective practice, and fostering communities of practice. While these notions likewise apply to formal settings, unique aspects of informal contexts such as the diverse backgrounds of educators and visitors and the distinct nature of teaching and learning in informal settings require contextually-specific approaches, especially professional development embedded within informal science educators' own teaching contexts.

Educator Preparation Using Informal Science Education Contexts: Four Approaches

We now turn to a description of four approaches to science educator preparation that we implemented which utilized unique aspects of informal science education contexts. We describe each approach, including their contexts, educator preparation methods, and outcomes.

Approach 1: An Informal Science Education Internship Experience for Undergraduate Elementary Education Majors Preparing to Teach in Formal Settings

Context. The first model of educator preparation we highlight took place within the context of a formal teacher education program that infused elements of informal science education. We developed and tested this transformative model of educator preparation as part of our involvement in a National Science Foundation-funded research project, Project Nexus (see www.drawntoscience.org). The purposes of the project were to: build a transformative teacher preparation continuum model for upper elementary and middle school science teachers; implement the model within diverse teacher education contexts; increase the number of elementary education majors who concentrate in science and the number of qualified upper elementary and middle school science teachers, particularly from underrepresented groups; research and evaluate the model's effectiveness; and disseminate the model locally and nationally.

Methods. A key element of the teacher education model was the infusion of informal science education through an optional internship in an informal afterschool science program for elementary aged students, Hands On Science Outreach (HOSO). The program took place within local elementary schools and was designed for small clustered groups of students by grade level. Developers of the HOSO program designed an original 3-year cycle that focused on themes emphasized in national standards documents for science education, including *Patterns*, *Energy*, and *Structure and Change*. During the 8-week afterschool internship, participants co-facilitated the HOSO's *Structure and Change* curriculum, focusing on weather and geology concepts. Learning activities with children included science-focused games, toys, music, arts and crafts, and experiments. After each learning session, materials were sent home with each child to encourage further exploration.

Internship participants included 25 teacher candidates at varying stages (1st, 2nd, or 3rd year) of their 4-year elementary education program. These participants were selected through an application process that screened for interest and commitment. Each intern was placed with a trained adult leader to co-facilitate the program with 2nd–3rd grade learners (ages 7–9) or 4th–6th grade learners (ages 9–12). Prior to working with learners, interns participated in an adapted version of the HOSO adult leader training. They received activity guides that emphasized inquiry, hands-on learning, and investigation. Teams of interns and adult leaders also received kits of materials for the activities in the guides. Interns received an honorarium for successful internship participation, and adult leaders received an honorarium for observing and evaluating interns' facilitation of the program.

Outcomes. In researching the potential influence of the informal afterschool science internship, we sought to gain insight into the research questions: (1) How and in what ways did the experience influence undergraduate teacher candidates' beliefs of science teaching and of themselves as teachers of science? (2) In what ways, if any, were the teacher candidates' professional identities aligning with reform-based practices? We were especially interested in investigating the ways in which the experience of teaching in an informal science education context might shape participants' mental models of science teaching and learning, as well as their development of professional identities as future teachers of science.[2]

To investigate our research questions, we collected data through the use of participant drawings before and after the informal afterschool science education internship. Participants responded to the prompts, *Draw yourself teaching science* and *Draw your students learning science*. We coded the drawings using a coding scheme that encompassed the main goals of the Hands On Science Outreach program: hands-on science, collaboration, and inquiry (a detailed description of our approach to drawing data analysis is available at www.drawntoscience.org). For a subset of 10 participants, we conducted a member check through a series of three emails, asking open ended questions regarding the drawings, personalized questions based on our interpretations, and direct questions about how the internship influenced their ideas about science teaching and whether they viewed the experience as worthwhile.

We observed a number of changes in teacher candidates after their participation in the informal science education internship experience (see Katz et al., 2011). First, we noted changes in interns' thinking about science teaching and learning, particularly, a greater understanding of transformative pedagogy (e.g., hands-on learning, collaboration, and inquiry). We also noted changes in interns' thinking about themselves as future teachers of science, including a more sophisticated view of their ideal selves as teachers of science and their professional identities. Participants likewise became more confident and enthusiastic about teaching science. Taken together, we believe that these outcomes offered support for the goals of reform-based science education. In particular, we believe that the informal science education internship benefited participants by engaging them in transformative science teaching methods; providing them with opportunities to observe and participate in the implementation of hands-on, inquiry-based, and collaborative science activities with learners; and encouraged them to shift away from a view of didactic instruction.

Approach 2: An Innovative Science Methods Course for Undergraduate Elementary Education Majors Preparing to Teach in Formal Education Contexts

Context. As a continuation of the Project Nexus model, we implemented an innovative science methods course that blended formal and informal science education for elementary education majors (see Riedinger, Marbach-Ad, McGinnis,

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[2] For a description of the details of this study, please reference Katz et al. (2011).

Hestness, & Pease, 2011). This initiative grew out of the positive outcomes from the informal science education internship experience (Approach 1). The innovative elementary science methods course was implemented at a large Mid-Atlantic university and integrated reform-based recommendations such as active learning, collaboration, discussion, and inquiry-based instructional strategies. In addition, we made an effort to incorporate aspects of informal science education such as student choice, connecting with students' interests, using varied assessment strategies, and integrating informal science education resources.

Methods. A major innovative component of the course was specific sessions devoted to blending formal and informal science education. For one class session, informal science educators were invited as guest speakers. The speakers shared their unique perspectives on science education and pointed out the defining characteristics of informal learning environments. Each of the informal science educators shared resources with the teacher candidates and discussed strategies for incorporating the resources in their classroom science lessons. For example, one of the informal science educators brought a live owl to the classroom and demonstrated how science content could be taught through encouraging students to make observations and ask questions. The other educator shared family science calendars produced by her afterschool program, Hands On Science Outreach (HOSO). She encouraged teacher candidates to use the science activities included in the calendar in their own classrooms as a means to engage elementary students in hands-on, inquiry-based science. A later session focused on virtual field trips through exploring the online exhibits and learning activities on the *Marian Koshland Science Museum of the National Academies of Science* website (www.koshland-science-museum.org). Participants worked in small groups to visit the museum's virtual exhibits related to climate change. Students engaged in discussions and reflected on the experience while considering strategies for using virtual field trips in the classroom with students.

Outcomes. Our study of the influence of the innovative science methods course on teacher candidates was guided by the following research question: "*To what degree are science teacher candidates' attitudes and beliefs toward science and science teaching and learning influenced by the infusion of informal science education in an innovative science methods course?*" The qualitative and quantitative data that we collected and analyzed provided evidence that the course resulted in positive outcomes for teacher candidates. Teacher candidates' responses on an attitudes and beliefs survey demonstrated positive changes on several measures such as their beliefs about the nature of science, beliefs about science teaching, and their confidence to teach science.

During interviews, teacher candidates suggested that they believed there were benefits to including informal science education, and planned to incorporate some of the strategies discussed throughout the course in their future elementary classrooms. An analysis of materials collected throughout the course (e.g., lesson plans, journal entries, and course reflections) demonstrated that teacher candidates gained awareness and appreciation of informal science education. For instance, teacher candidates connected with informal science education on lesson plan assignments by incorporating relevant websites, bringing guest speakers to their classrooms, providing opportunities for students to choose assignments and topics that were interesting to them, and by taking students on field trips. The survey findings, interview data and course artifacts provided potential evidence that the innovative science methods course had an influence on teacher candidates' attitudes and beliefs about science and science education.

Approach 3: A Course on Connecting Formal and Informal Science Education for Graduate Elementary Education and Environmental Education Students

Context. The third educator preparation model we highlight was a graduate course offered as part of a series of university-based special topics courses. Graduate students from the university's Elementary Education program as well as environmental education students from the Environmental Studies department enrolled in the course. The motivation for the development of the course grew out of the Project Nexus initiative that blended informal and formal science education for science teacher preparation (Approaches 1 and 2). An objective of this course was to extend the Project Nexus model and consider further ways to connect formal and informal science education. Specifically, the content of the course focused on strategies for bridging formal and informal science education.

Methods. Development of the course was guided by the following learning objectives: (1) Provide students with a foundational knowledge of informal science education and research regarding the benefits of blending formal and formal science education; (2) Prompt students to review and critically evaluate current initiatives and collaborations between formal and informal science education; (3) Assist students in locating and evaluating informal science education learning materials and resources; (4) Guide students in planning instructional activities that bridge formal and informal science education settings; and (5) Encourage connections between formal and informal educators within the course.

With these objectives in mind, the asynchronous, online course was developed and delivered through a series of three learning modules (see Table 17.2). Where appropriate, students were prompted to engage in discussions and collaborative sharing with one another through online tools provided in each module. The first module was intended to provide participants with an overview of research on learning in informal science education contexts as well as the documented and predicted benefits of making connections with formal classrooms. In the second module, students learned about strategies for connecting formal and informal science education and critiqued specific examples of collaborations between classrooms and informal science education contexts. The final module prompted students to reflect on the content as well as apply what they learned in the course to create a final project.

Table 17.2 Overview of course syllabus

Topics	Sample components
Module 1: Informal science education	
• Defining and characterizing informal science education • Benefits of connecting formal and informal science education	• Participate in citizen science project; reflect on the experience and discuss strategies for incorporating citizen science in classrooms • Visit to informal science education
Module 2: Connecting formal and informal science education	
• Strategies for connecting formal and informal science education (taking field trip, virtual field trips, citizen science projects, outdoor science, school/community gardens, science fairs and competitions, podcasts and apps, animals in the classroom, outreach programs, guest speakers, family science events) • Review of sample collaborations between classrooms and informal science education programs and organizations	• Virtual field trips • Review of local resources (e.g., outreach programs, guest speakers, field trip opportunities, science competitions) • Compile a list of local resources for connecting formal and informal science education • Lesson plan and assessment development
Module 3: Museum-school partnerships	
• Successful museum-school partnerships • Teacher professional development in informal science education settings	• Readings on museum-school partnerships • Final project options (e.g., design a family science night, grant proposal, field trip guide) • Course reflection

Outcomes. Overall, students stated that they found the course effective and suggested that one strength was the introduction the course provided to instructional resources that they could use in their classrooms and informal science education settings. An area for further reflection and consideration was the goal of fostering collaborations between formal and informal science educators. Although the instructor made a concerted effort to create connections between the educators, few of the students engaged in collaborative work with other educators. At the conclusion of the course, none of the students indicated an interest in pursuing collaborations with other educators or in creating a partnership with a local informal science education context. In their study of collaborations between schools and informal science education organizations, Bevan et al. (2010) identified several documented challenges to developing and sustaining collaboration, including funding, time, and system differences (between informal science education organizations and schools). Possibly, constraints such as lack of time, funding resources, or emphasis on testing and other content areas (i.e. focus on math and science) may have limited students' motivation to develop collaborations. However, more work and research in this area to foster collaboration between formal and informal educators is warranted.

Approach 4: A Course on Informal Science Education for Graduate and Undergraduate Education and Environmental Science Students

Context. The final approach we describe was a university course for graduate and undergraduate Education and Environmental Studies majors who identified as informal science educators. The course was designed to introduce prospective and novice informal science educators to education research and practice in the field of science education.

The development and implementation of this course stemmed from findings of the Project Nexus model (Approaches 1 and 2 previously described). An aim was to not only address the needs of formal educators, but to also provide preparation for informal science educators using a visionary approach. That is, the course aimed at addressing 21st century goals for learning and was linked to current standards and recommendations for preparing science educators.

Specific objectives of the course were to: introduce students to key issues in informal science education; engage students in analyzing, critiquing and applying theoretical perspectives of learning to understand how people learn across learning environments; prompt students to critically analyze and discuss informal science education programs and exhibits through a theoretical perspective; encourage students to explore a scientific topic in depth and use research and theory from the field of informal science education to develop and implement an activity; guide students in applying assessment and evaluation methodologies to analyze the success of informal science education activities, programs, and exhibits; and foster reflection skills among students to develop a cadre of reflective practitioners.

Methods. The focus of the course was to introduce students to key ideas in the field of science education and, in particular, informal science education. The course sessions were situated in the context of local informal learning environments to fully immerse students in informal science education as a means to gain an understanding of learning in these contexts. A majority of the course sessions took place in local informal science education settings and students were encouraged to visit additional venues as for various course assignments. Each week, students read and discussed current articles and research related to the field of informal science education (Table 17.3). Periodically, local informal science educators were invited to serve as guest speakers during on-campus class sessions. For example, educators from an aquarium were guest speakers during the "*Designing and Planning an Activity*" session and shared their experiences developing and implementing new programs and activities at the aquarium.

Class sessions held at local informal science education settings incorporated discussion of course readings and materials as well as presentations and conversations with educators and other staff. The session on exhibit design included a presentation by the exhibit design team at the aquarium, followed by an annotated tour of their latest exhibit. For one session held at a children's museum, students were divided into groups and invited to implement inquiry-based activities with

Table 17.3 Overview of course session topics

Session 1: Introduction to informal science education **Students select and visit an ISE setting*
Session 2: Theoretical perspectives
Session 3: Scientific literacy **Class session held at the NC Aquarium at Ft. Fischer*
Session 4: Learning theories
Session 5: Scientific inquiry **Class session held at the Children's Museum of Wilmington*
Session 6: Designing and planning an activity/program **Guest speakers from the NC Aquarium at Ft. Fischer*
Session 7: Nature of science and socioscientific issues **Peer conversation activity*
Session 8: Program and exhibit design **Class session held at the NC Aquarium at Ft. Fischer*
Session 9: Assessment and evaluation **Class session held at Airlie Gardens*
Session 10: Exemplary ISE settings and programs **Students select and attend a program at an ISE setting*
Session 11: Learning conversations, fostering discussion **Class session held at Cape Fear Museum of History and Science*
Session 12: Issues of social justice, culturally responsive pedagogy
Session 13: Connecting formal and informal science education **Guest speakers from the NC Aquarium at Ft. Fischer*
Session 14 & 15: *Final presentations at the NC Aquarium at Ft. Fischer*

several preK-3 school groups visiting the museum. Throughout the course, students were prompted to engage in reflection through discussion prompts and journal entries.

Assignments were designed to expose students to various types of informal science education settings while also providing scaffolding to create and implement their own program at the aquarium at the end of the semester. One assignment required students to visit or attend four informal science education venues or programs of their choice over the course of the semester and complete journal entries associated with each visit. Students were encouraged to visit a diversity of settings (e.g., museums, botanical gardens, zoos, youth programs, park programs, planetariums) for each observation and journal entry to gain a broad perspective of the types of informal science education settings and programs offered. Journal prompts encouraged students to make observations of the exhibits or programs, critique the exhibit or program through a specific lens (e.g., scientific inquiry, learning conversation, exhibit design), and then reflect on the experience as well as their development as an educator.

Outcomes. Students particularly enjoyed the practical application of the course assignments and the class sessions held at local informal science education settings.

For example, one student commented, “The project at the…aquarium—I think it is awesome that we actually get to apply everything we learn in the course, and actually create our own program. It is a challenging experience. I also like the theory portion of the course, albeit challenging and something I was not familiar with prior to taking this class. I think it is important to introduce students to educational theories and theories on learning, so that lesson and program development is substantiated in research” (Course participant, end-of-course evaluation).

Observations of students’ programs and activities highlighted the importance of educators’ beliefs and the link between educators’ beliefs and their practices. Despite students generally indicating an understanding of the current research-based practices and pedagogy, the delivery of many of the programs and activities were still didactic in nature. Though students developed plans that encouraged active learning, discussion, and inquiry, when actually implementing the programs, they reverted to prior beliefs and practices. This points to a need to further challenge prospective informal science educators’ beliefs and to provide ongoing professional development as these educators continue to develop as professionals.

Discussion

The multiple models of science educator preparation we have described connect with and add to themes from existing literature on the preparation of informal science educators. They also provide examples of the ways in which approaches to educator preparation that incorporate informal science education can support the strands of science literacy unique to these contexts. In doing so, they may help to foster current goals of science education [as articulated in *A Framework for K-12 Science Education* (National Research Council, 2012)] in new ways.

Connections to Literature on Informal Science Educator Preparation

We begin with a discussion of the ways in which the science educator preparation approaches relate to the literature-based themes of the influence of prior teaching and learning experiences, modeling research-based approaches, valuing reflective practice, valuing communities of practice, and the unique dimensions of informal teaching contexts.

Influence of prior teaching and learning experiences. In reflecting on our experiences designing and implementing educator preparation approaches that incorporate, to varying degrees, informal science education settings and approaches, we saw potential evidence of the influence of participants’ prior teaching and learning experiences. Researchers who have commented upon educators' tendency to conceptualize teaching according to their prior experiences as learners (Allen & Crowley, 2014; Bevan & Xanthoudaki, 2008; Grenier, 2005) describe the tenacity of didactic, teacher-centered visions of teaching and learning, and the value of confronting such views through transformative approaches. In some cases, we found that the teacher preparation approaches previously described appeared to prompt educators to rethink their assumptions about science teaching and learning. For example, before pre-service educators participated in the afterschool informal science education internship (Approach 1), their responses to the prompt "*Draw Yourself Teaching Science*" were more likely to reflect teacher-centered visions of science education than their post-internship responses. This suggested to us that participants may have been moving away from didactic, lecture-based views of science teaching.

However, during the graduate course for informal science educators (Approach 4), observation of participants' teaching suggested that in practice, participants tended to employ few active learning strategies. While participants had engaged in an iterative process of developing and refining their teaching plans; getting feedback from peers, professional informal science educators, and the course instructor; reflecting on and editing their plans—which, as written, reflected research-based active learning strategies—they often did not implement these teaching strategies in the moment. For example, they at times reverted to simply stating factual information, rather than asking planned open-ended questions that might have elicited more discussion amongst learners. While this may have been related to a variety of factors, such as approaches they saw modeled in their teaching contexts, we believe that prior teaching and learning experiences are likely to have played a role.

Our observations appear to support findings from the literature that suggest the long-term influence of educators' own teaching and learning experiences, and suggest that educators may require mentorship and practice in actually implementing teaching strategies that may counter the kinds of strategies they have previously experienced.

Modeling research-based approaches to science teaching and learning. In each of the described educator preparation approaches, we strove to model research-based pedagogies as suggested in the literature (Allen & Crowley, 2014; Ash et al., 2012; Bevan & Xanthoudaki, 2008; Grenier, 2005). In the university-based courses (Approaches 2, 3, and 4), for example, we sought to provide examples of ways participants could foster meaningful discussion in learning settings, working to make such strategies explicit by pausing at strategic points to discuss the approach being modeled. We likewise sought to integrate authentic assessments in lessons, and encouraged participants to do the same in the course assignments they completed, such as designing science lessons or programs.

In the informal afterschool science education internship (Approach 1), participants worked with adult leaders who had been trained in facilitating hands-on, collaborative, inquiry-based learning activities. It appeared that participants benefited from seeing research-based pedagogies modeled. For example, participants' post-internship drawings ("Draw Your Students Learning Science") (Approach 1) suggested that participants increased their understandings of transformative pedagogies. In addition to seeing research-based pedagogies modeled, participants in the graduate course for informal science educators (Approach 4) stated that they benefited from and enjoyed the practical applications of the course assignments that were held in informal science education settings. For example, participants could choose to plan a family science night with activities that made connections between home and classroom contexts, design a field trip program with pre- and post-visit activities, or plan and develop a school garden program. Through these assignments, participants were encouraged to incorporate the research-based strategies modeled in the courses.

While we believe that such activities have the potential to prepare educators well to implement research-based teaching strategies, and participants stated their intention to use the strategies in the future (e.g., Approach 2), the modeling did not necessarily influence participants' actual use of the strategies in their teaching practice. This observation supports that point that while modeling research-based strategies appears to be beneficial and necessary in the preparation of science educators, familiarity with research-based strategies is not the sole factor that influences participants' ability to integrate the strategies into their teaching practice.

Valuing reflective practice. As described in the literature on preparing informal science educators (Allen & Crowley, 2014; Ash & Lombana, 2012; Ash et al., 2012; Bevan & Xanthoudaki, 2008; Tran et al., 2013), we found it beneficial to encourage educator reflection. In reflecting on their own teaching practice, participants in the various educator preparation approaches we describe had opportunities to engage in individual written reflections as well as small group reflective discussions. For example, in the transformative science methods course that integrated informal science education elements (Approach 2), participants engaged in peer conversations around lessons they had developed. This entailed modeling learning activities for peers, receiving feedback, and reflecting on peer feedback as they made revisions to their work. Participants in the course also completed a series of individual journal writing activities on course readings and activities. In both this course and the afterschool informal science education internship experience (Approach 1), participants also engaged in reflection through the use of drawings. By completing drawings of their visions of science teaching and learning both before and after the educator preparation experience, participants were able to reflect on the ways in which their own conceptualizations of science education had changed over the course of the semester. The online course for formal and informal science educators (Approach 3) and the graduate course for informal science educators (Approach 4) likewise included a final reflection assignment that encouraged students to reflect on the course and the ways in which their thinking about science teaching and learning developed or changed over time.

By encouraging educators to reflect on their own teaching practice, as well as on their evolving understandings of what it means to teach and learn science, we hoped to address the concern voiced by Ash et al. (2012) that informal science educators may have few opportunities to engage in reflective practice. By practicing reflective strategies during educator preparation experiences, our intention was to encourage participants to carry these strategies into their future teaching practices. However, we cannot be sure whether this was the case, and acknowledge that there are likely to be factors within participants' teaching contexts that may either help or hinder their ultimate use of reflective practice strategies.

Valuing communities of practice. Researchers have noted the importance of communities of practice for the preparation and professional development of informal science educators, both amongst informal science educators (peers) and between informal science educators and wider groups of professionals (e.g., scientists, formal educators) (Allen & Crowley, 2014; Ash et al., 2012; Tran et al., 2013). In our approaches to educator preparation, we worked to foster communities of practice amongst peers—for example, through the use of peer conversations and feedback in the university-based courses (Approaches 2, 3, and 4). In several of the approaches, we sought to foster communities of practice between formal and informal science educators. For example, in the afterschool informal science education internship (Approach 1), interns (educators preparing to work in formal classroom settings) were paired with informal science education volunteers already working with learners in the afterschool setting. While this approach may have provided an opportunity to broaden participants' professional networks, we do not know the extent to which participants maintained these connections—or the practice of collaborating with educators in other science teaching contexts, such as informal science education environments.

In the course specifically focused on connecting formal and informal science educators (Approach 3), we experienced some challenges in helping the formal and informal science educators connect and collaborate with one another in communities of practice. Namely, few participants engaged in collaborative work with other educators when given the opportunity, and none indicated an interest in pursuing collaborations with other educators or creating partnerships at the end of the course. We posit that although all participants were part of the science education community, it is possible that they viewed their specific communities (school-based or based in ISE contexts) as distinct from one another. For example, norms and foci may differ from one context to the next (e.g., standardized testing in formal classrooms, greater focus on affective dimensions of learning in informal settings), and may account for some of the challenges we noted in fostering collaborative relationships.

Despite these challenges, we believe that opportunities to engage with colleagues within and beyond educators' specific teaching settings remain valuable in science educator preparation, however more research is needed regarding how to better foster and maintain productive professional relationships and connections between formal and informal science educators.

Unique dimensions of teaching in informal science education contexts. While research on educator preparation in formal and informal settings include a number of common themes, we recognize that informal science education has unique dimensions to be highlighted and addressed in educator preparation. In our educator preparation approaches that included formal science educators (Approaches 1, 2, and 3), participants learned how informal science education contexts could enrich their science teaching and learning practice. This included the use of pedagogical strategies emphasized in informal science learning settings such as hands-on learning, collaboration, and inquiry-based learning, as well as encouraging the integration of informal science education resources in their teaching (e.g., web-based informal science education resources, connections with local informal science institutions). In our educator preparation approaches that included informal science educators, including the online course (Approach 3), participants visited informal science education sites to get a better understanding of these contexts. In the course specifically designed for informal science educators (Approach 4), participants received feedback from practicing informal science educators as they designed programs or learning activities for a specific informal science education setting. This helped to increase participants' awareness of the specific contextual factors they would need to consider in designing their programs and activities—which had the potential to vary from one informal science education context to the next.

By working to foster participants' understandings of the unique emphases and approaches used in informal science education contexts, as well as the unique contextual factors to be considered in designing programs, we believe that both formal and informal science educators can benefit as professionals. Future work could examine the potential influences of educator preparation experiences for both formal and informal science educators that seek to emphasize the unique ways in which informal science education settings can foster science learning.

Connections to the Strands of Science Literacy Emphasized in Informal Science Education Settings

In addition to connections to the literature on preparing informal science educators, we noted connections between our approaches to science educator preparation and the strands of science literacy typically fostered in informal science education environments (National Research Council, 2009). As with traditional science educator preparation approaches, we sought to foster educators' development as professionals able to nurture learners' science content understandings, their abilities to evaluate scientific evidence, their understandings of scientific practices, and their understandings nature of science understandings—all science literacy ideas that are shared between formal and informal science learning contexts. In addition, we emphasized the science literacy strands of "Experienc[ing] excitement, interest, and motivation to learn about phenomena in the natural and physical world" (National Research, 2009, Strand 1) and "[Identity development] as someone who knows about, uses, and sometimes contributes to science" (National Research Council, 2009, Strand 6). Because these strands are uniquely emphasized in informal science education contexts, we posit that incorporating informal science education into educator preparation—both formal and informal—can offer aspects of professional growth that may not be typically emphasized in traditional approaches to educator preparation.

A focus on interest. Regarding Strand 1, or affective dimensions of science learning (e.g., excitement, interest, and motivation) (National Research Council, 2009), we sought to connect to participants' interests while also modeling ways they might connect to learners' interests in their future teaching contexts. Our main strategy for realizing this goal was incorporating many elements of choice into our teacher education approaches. Participating educators were able to choose directions for course assignments that aligned with their scientific interests, as well as what they saw as relevant to their goals as future science educators. For example, in the course designed for formal and informal science educators (Approach 3), participants were invited to visit informal science education settings of their choice and participate as citizen science volunteers for projects of their choice. In addition to being offered choices themselves, we encouraged participants to engage in interactions with learners that would help them to gain insight into learners interests, which they could weave into their science teaching in order to increase learners' excitement and motivation to learn. For example, in the afterschool informal science education internship, participants were encouraged to use questioning to connect with learners' individual interests and allow learners freedom to explore and investigate their own questions during hands-on science activities.

In general, we found value in approaches to science educator preparation that tapped into participants' own interests and likewise encouraged them to connect with learner interests. We believe that such approaches have the potential to increase formal and informal science educators' own enthusiasm for science and science teaching, which may have a ripple effect extending to the learners with whom they interact in their future teaching contexts.

A focus on identity. With respect to Strand 6, or identity development (National Research Council, 2009), we were particularly focused on participants' identity development as science educators able to foster learners' identities as people who know about, use, and contribute to science. Since our teacher education approaches included both formal and informal science educators, the identity development foci varied somewhat between the groups. For the formal science educators—such as those who participated in the afterschool informal science education internship (Approach 1) and the transformative science methods course (Approach 2)—our intent was to foster their professional identity development as educators who incorporated transformative pedagogies (e.g. hands-on learning, collaboration, and inquiry) and were able to enrich their teaching through the use of informal science education resources.

For the informal science educators, such as those who participated in the blended graduate course for formal and informal science educators (Approach 3), and those who participated in the graduate course specifically for informal science educators (Approach 4), our goal was to encourage participants to see themselves as professionals to the same extent that formal science educators in formal teacher preparation programs might. That is, we drew on research-based educator preparation strategies (reflective practice, use of research and theory lenses, fostering collaboration and communities of practice), while also attending to the unique aspects of becoming a professional in informal science education settings (e.g., through interactions and feedback from professional informal science educators).

In these ways, our intent was to engage in professional practices that encouraged all science educators—formal and informal alike—to see themselves as part of a community of practice and as having valuable contributions to make in the conversation and future development of science education.

Conclusions

In this chapter, we explored the emergence of key themes related to professional development and teacher education that were shared across formal and informal learning environments as a means to prepare and support science educators to enact science education policy goals (National Research Council, 2012). We described four innovative models for preparing both formal and informal science educators that sought to foster connections between both learning contexts as a means to further current science education reforms and standards. Our development of the courses was guided by the corpus of research related to preparing informal educators, as detailed in the review of literature. An aim of each of the course models that we have reported was to identify strategies for creating such connections and facilitating collaborations between science educators such that each context supports and complements the other. Further, integrating the approaches and drawing connections between contexts provided a way to prepare science educators while addressing the strands for scientific literacy detailed in *Taking Science to Schools* (National Research Council, 2007) as well as the strands specific to informal science education (e.g., interest and identity) included in *Learning Science in Informal Environments* (National Research Council, 2009).

Our intent in this chapter was to highlight the ways in which innovative models for science educator preparation that integrate formal and informal science education may have the potential to more fully address current goals and reforms in science education, particularly given that learning occurs across contexts and learners spend a relatively small proportion of time in formal classroom settings. However, our experience in developing and implementing each of the models pointed to a number of challenges and areas for further consideration. Lessons learned included: challenging educators' prior beliefs and learning experiences; encouraging ongoing reflective practice; addressing the challenges that limited collaborations between formal and informal educators; identifying additional strategies to foster meaningful collaboration between formal and informal science educators; and developing a shared community of practice for science educators across settings. Continued investigation in these areas, and additional research related to preparing science educators across settings to collaborate productively, are warranted.

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Chapter 18
Extending Classrooms into Parks Through Informal Science Learning and Place-Based Education

Jennifer D. Adams and Brett Branco

Picture an urban environment. While an elevated subway may come to mind, you may not think of this juxtaposed with a graceful snowy egret standing in a salt marsh or a mud flat dotted with snails as windsurfers sail by in the background. New York City is considered one of the busiest cities in the world and yet within its borders is a 25,000 acre wildlife refuge that hosts a large number and diversity of animal and plant species. The Jamaica Bay Wildlife Refuge is a part of the National Park Service Gateway Unit. Because of the expanse of water and marshlands, it is hard to believe you are still within the borders of a dense urban center. The refuge was established as a National Recreation Area in 1972 in order to "preserve and protect for the use and enjoyment of present and future generations an area possessing outstanding natural and recreational features" (Kornblum & Van Hooreweghe, 2010, p. 1). Through the subsequent decades the park has undergone periods of neglect and renewal and is currently an important recreational place for many communities in Brooklyn and Queens—those boroughs in which the park is located.

Science learning in connection to greenspace is often enacted from a "green curriculum" approach that is usually removed from the lived experiences of students, especially those who live in urban, multicultural contexts (Paperson, 2014). Environmental education frequently promotes the dominant Western cultural values of an idealized nature (Low, Taplin, & Scheld, 2005) and promotes a quantitative paradigm of pro-environmental behaviors. According to Low et al. (2005) "cultural values are our best indicators as to what people think and feel about a landscape such

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as a park" (p. 15). Thus the dominant cultural narrative assumes that there is a universal notion of how people should "behave" towards the environment; the ways that other cultures interact with parks and greenspaces are at best undervalued but all too frequently ignored. Science teachers and their students could play a critical role in changing how people view and relate to urban parks. In New York City, we have that opportunity in that we have a site for ecological place-based education that is steeped in the urban context. Teachers can facilitate experiences where their students use science as a lens to study the park and other urban greenspaces. This allows diverse students to take ownership of greenspaces that are usually perceived as being created by and for the dominant culture; White and middle-class.

Parks offer unique opportunities for authentic science learning in that students are able to interact with natural ecosystems and engage in authentic data collection practices, while enjoying being in the outdoors. Parks are spaces where lived experiences and science learning could come together in ways not afforded by brick and mortar informal science institutions. People use parks for recreation, relaxation, spiritual activities, and family gatherings and, for the most part, access to parks are free. Urban parks could play a key role in fostering positive intercultural interactions through the valuing of cultural histories and difference (Low et al., 2005) through the realization that people value greenspaces for different reasons and use these spaces in different ways. Science educators could play a pivotal role in fostering this relationship by introducing their students to these spaces in ways that allow them to build meaningful attachments and knowledge about the ecology and impacts of human interactions in parks.

The Millennium Ecosystem Assessment identifies three different ecosystem services—provisioning, regulating, and cultural—that describe the benefits humans receive from ecosystems. Cultural services is described as, "the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences" (Millennium Ecosystem Assessment, 2003, p. 58), with education values and sense of place as key examples. Moving towards promoting a discourse around the human, non-human and environment relationship that is more interdependent, a framework of place attachment could allow us to view our relationship with parks with co-dependency in mind; the need for stewardship of natural urban greenspaces in order to continue to reap the benefits that these greenspaces afford.

Greenspace is often a premium in urban settings. Thus, parks present opportunities for educators to facilitate experiences with nature that are unparalleled in the classroom and teach students about the interdependence between humans and their natural (and built) surroundings. Educating science teachers to use urban natural spaces to teach science could be a way of unifying cultures around the scientific resources found in natural spaces, while valuing the different ways that people use these same natural places and spaces to enact and maintain culture. If we think about the nature of place and how people form attachments with place, we could think about the role education could play in shaping the relationships that people have with parks, both as places of science learning and places of recreation.

Nature of Place and Place Attachment

A theoretical lens of place, place attachment and identity is salient to describe how teachers could form attachments to and build identities around places for science learning and place value on facilitating such experiences for their students. From a phenomenological perspective, Seamon (2014) describes place as "any environmental locus through which individual or group actions, experiences, intentions and meanings are drawn together spatially" (p. 12). Place is the context for the enactment of lived experiences; it is the "person-or-people-experiencing place" (p. 12), a complex, dynamic set of processes that continually define and redefine both places and people as it is very connected to the experience of being human (Malpas, 1999). People experience place, make meaning of place and form bonds or attachment to place through a lens of sense of place (Adams, 2013). Through this lens, people view place as a resource for enacting a particular activity that is often tied to an identity. Environmental psychologists describe sense of place in terms of place attachment and place meaning where place attachment is the bond that people develop with place; the extent to which place becomes a part of one's identity (Kudryavtsev, Stedman, & Krasny, 2012). Place meaning is the value that people place on or meanings that people ascribe to particular places (Kudryavtsev et al., 2012); this is also tied to identity as a place may symbolize a site to enact a particular identity (Adams, 2013). In extending this to teacher learning, a park may represent a place to enact an identity that is associated with a particular approach to teaching, for example an inquiry-based teacher, an environmentally-conscious teacher or a field-based teacher. Place attachment, place meaning, and place identity are all a part of the lived dialectics of our relationship with place.

In thinking about teachers' relationships to parks, we have found it helpful to weave between phenomenological and environmental psychological perspectives of place, experience and place-identity. Place attachment is a process as peoples' feelings towards, experiences within and the places themselves shift and change over time (Seamon, 2014). Seamon (2014) describes six processes that define peoples' changing relationship with places. Although he describes both generative and destructive processes, we are concerned with building teacher connectedness to the park through the generative processes. Table 18.1 provides a look at the processes as described by Seamon (2014) with a brief description of how these processes could be enacted in teacher learning experiences.

As these six processes demonstrate, developing a relationship with place requires not only encounters with the physical place (or idea of the place) but also encounters with people and other living and non-living agents that define a place. As place attachment and identity are intertwined, these processes could also provide a lens to describe how a place, like a National Park, can become an integral part of a teacher's identity and thus an important resource in her teaching. As "social boundaries can extend beyond geographical or management boundaries of a place" (Mihaylov & Perkins, 2014, p. 65), it is important to think about the relationship with teachers and the park as extending the boundaries of both. Social boundaries

Table 18.1 Place attachment and teacher learning (adapted from Seamon, 2014)

Process	Relevance to park and teacher learning
1. Place interaction-the typical goings-on in a place and involves a constellation of regular actions, behaviors, situations, etc. that typically unfold	Becoming familiar with the park as a place and the enactment of science teaching in the park; using the park as a resource for teaching—teaching in the park becomes a regular part of one's teaching practice; a regular place encountered in teaching and learning
2. Place identity-the process by which people associated with a place take up that place as a significant part of their lived experience; recognize the place as important to her individual or communal identity	Teacher views the park as a place to enact a particular teaching identity, to demonstrate who he is as a teacher
3. Place release-environmental serendipity of unexpected encounters and events	Unexpected encounters with nature (seeing an endangered animal, tasting an edible wild plant) learning interesting factoids about the park through informal discussions that evoke a feeling of having exclusive or insider knowledge; unplanned synergistic encounters with like-minded peers and park staff that lead to collaborative efforts
4. Place realization-the palpable presence of place; the distinctive characteristics of the place and the human beings who know and appreciate that place	Teacher recognizes the value of resources in the park (both the physical and human (i.e. Rangers) for STEM learning; teacher connects with other educators who share similar teaching values and feelings towards the park and similar places
5. Place creation-human action in relation to place; sense of commitment to maintaining, improving, advocating for the preservation or betterment of a place	Teacher actively becomes involved in civic engagement and actively involves her students; becomes engaged in STEM education curriculum writing and policy that emphasizes the park as a resource for STEM learning
6. Place intensification-power of policy, design, and fabrication to revive and strengthen place	Teachers develop lesson plans, units and curricula that connects learning standards to the resources of the park. The park values these resources and makes them publically available and design policy to facilitate field trips to the park

include social identities—these extend from one place to another and serve as brokers across the boundaries, linking one context to another.

Boundaries and diasporas structuring places and place attachment

A metaphor that adequately describes developing collaborations between different institutions is creolization, which Hall (1990) defines as a complicated process of cultural negotiation and transculturation. It is a converging of institutional cultures in order to create something new—program, activity or approach to learning—while remaining true to the strengths, values and mission of each institution. Through both professional development and deep engagement in the park with students, teachers develop place attachment with the park, while the park values the presence of schools and teachers and develops policy and pedagogy to intensify their experiences with the park as a place. Paragraph recent informal science learning literature has revisited the notion of boundaries, borders and boundary objects/activities to describe formal informal collaborations and partnerships (Kisiel, 2014). In informal science learning environments settings, these are objects (i.e. curricula or lesson plans) or activities (i.e. field trips or Citizen Science activities) that serve as points of negotiation of institutional cultures. The persons who work to develop such objects and activities are boundary crossers who, as Wenger (1998) describes, "find their value in spanning boundaries and linking communities of practice" (p. 154). Teachers gain the agency to access and appropriate the resources of the park to meet their goals of science learning and learning through professional learning experiences. As teachers engage in learning activities in the park, they are also changing the park to be a science-rich resource from an educational standpoint and change the approach that the park takes to education.

Classroom and Parks Meet at the Boundary

To form place attachments in environmental education, Kudryavtsev et al. (2012) recommend having programs or activities with both direct, experiential experiences, and instructional activities. Teachers learn how to engage in data collection and science inquiry through direct, experiential place-based learning. Teachers often have positive learning experiences and desire to recreate similar experiences with students. Through instructional approaches, teaching goals are predetermined and connections to place are made though discussions, text such as articles and maps, discussions, the observation and creation of art and by other means, ways, etc. A combination of these approaches help teachers establish connections to a place though developing their own meanings while learning about the meanings other people, stakeholders, and disciplines have about the same place. Thus, a teacher can see a place as a valuable resource for science teaching and learning while also learning about the historical or aesthetic significance of that place.

Gateway National Recreation Area: Gateway to STEM Learning

Gateway National Recreation Area (Gateway), a unit of the National Park Service includes Jamaica Bay, an urban wildlife refuge that offers students and teachers unique opportunities to learn about the natural world. Gateway is a hybrid of national and local city park because it both preserves vital environmental resources while also emphasizing recreation (Low et al., 2005). With approximately 25,000 acres and over 45 miles of shoreline, excluding marsh islands Jamaica Bay has a vast array of natural resources and spaces for deep, place-based, informal and formal science (and social studies) learning. As place at the edge of a dense urban context, the refuge offers students and teachers a unique opportunity to interact with the natural environment. It provides vital habitats for spawning and mature fish, migrating birds, and shorebirds, including the endangered piping plover. This urban greenspace is also an important habitat for many invertebrates, including a diverse array of gastropods, crustaceans and insects. As a recreational area, the park has spaces for people in pursuit of a variety of leisure activities, including bird watching, fishing, gardening, kayaking, boating, swimming and beach combing. However, being situated in a populous urban environment, Jamaica Bay is also vulnerable to a number of human and natural stressors including, wastewater discharges, invasion of non-native species, sea level rise, severe weather events, and land use changes. For example, extensive areas of highly productive salt marsh habitat were filled in to create John F. Kennedy International Airport along the edges of Jamaica Bay. With the variety of spaces and places situated in the park and environs as well as environmental issues to grapple with, there are ample opportunities for students to engage in hands-on, real-world science studying the wildlife, ecological spaces and dynamic human-nature interactions in the Bay.

In 2014, Gateway issued an education strategic plan entitled, “Gateway National Recreation Area: A Laboratory for Learning” to guide planning and implementation of its education programs. The mission statement reads, “Gateway’s education programs encourage new generations to become informed and passionate citizens who will understand, value and promote healthy parks and environmentally resilient communities” (GNRA, 2014). This mission has become more imperative in the wake of Hurricane Sandy, which left much damage in the park and surrounding communities, and with a specter of weather events of increasing frequency and intensity (Rosenzweig & Solecki, 2015). Goals to meet this aim include targeting underserved schools with diverse populations, empowering teachers through professional development and the production of high-quality education materials and developing a community of teachers interested in enacting place-based, service learning projects in the park. Developing a sense of place attachment for the park, both for teachers and students is an important part of achieving these goals. This means developing opportunities for teachers and their students to experience the place-attachment processes that will allow them to become intimately familiar with the park and see it as a place of maintaining identity and achieving personal and professional goals. The Gateway enactment of the national “A Park in Every Classroom” (PEC) initiative was one of the initial means of developing a community of teachers who have a strong place-identity with the park and to develop those activities and curricula that would serve as boundary objects between the park and classroom.

A Park in Every Classroom

Jamaica Bay has a history of providing professional development activities for teachers around using the resources of the park. These activities are led by Rangers and guest educators and have largely been day-long workshops that include guest lecturers, site-based investigations and discussions about curricular connections. In spite of these efforts, the Gateway staff felt that Jamaica Bay and environs are underutilized in STEM teaching and learning. The NPS developed a nation-wide initiative called "A Park for Every Classroom" (PEC) to connect teachers to the cultural, historical and scientific resources of the National Parks. Rangers were partnered with teachers to develop activities and curricula around the unique resources of the different parks involved. In Gateway, the overarching goal of the "A Park for Every Classroom" (PEC) is to encourage collaboration and the creation of a learning community amongst scientists, teachers, and students in the gathering, analyzing and using data to raise awareness about environmental change. The initiative started with a series of day-long professional development workshops or "Seminars in Science" on topics of scientific relevance to Jamaica Bay, such as:

- Supporting the Horseshoe Crab and Bringing Back Oysters to NYC
- Evidence of Environmental Change: Plant Phenology and Invasive Species
- Climate Change and Bird Migration Patterns

These workshops were co-facilitated by Rangers, master teachers, and field scientists actively engaged in park-related research with the goal of empowering teachers to use the park's resources to conduct STEM research and engage in civic actions with their students. During these workshops, teachers were introduced to science content through experiential activities and resources to bring back to the classroom. The activities allowed them to explore different areas of the park, including beaches, marsh areas and nature trails while experiencing different activities they could adapt and use with their students. Workshop facilitators had discussions with teachers around connecting the Jamaica Bay explorations to the Next Generation Science Standards and Common Core, a requirement for NYC teachers. For a number of teachers, these workshops were their first visit to Jamaica Bay. One teacher noted on her/his survey, "First time visitor—blown away by the view." Others commented on how much they liked being in the park and that the workshops provided "a chance to experience the different [eco]systems at Gateway." Many teachers who attended the workshops did so because either the topic was of interest or they wanted the opportunity to visit Jamaica Bay. Thus, the workshops provided not only an opportunity for teachers to begin to learn about the culture of the park as a STEM learning space, but also the occasion to experience the aesthetics of this urban greenspace and view this as a valuable space for both STEM education and enjoying outdoors activities.

An important goal of Gateway is to co-develop high-quality lesson plans and activities with teachers. Teachers who participated in these workshops were invited to join a cohort of Master Teachers who would work closely with NPS staff and faculty to create and pilot lesson plans and units focused on the ecological resources of Jamaica Bay. These classroom documents would be grade-appropriate, based on current research in Jamaica Bay, and enable teachers to use real scientific data in their classrooms. These documents would be available and accessible to all teachers on the Park's website (http://www.nps.gov/gate/index.htm). During the initial year, teachers did projects on invasive species, marine debris and water quality. The teachers chose topics that were of interest to them and their students and of scientific relevance to the park. What follows are a couple of examples of teachers' projects and the influence of their projects on student learning and motivation. All of the teachers described teach in public high-needs schools with large numbers of African American, Latina/o, immigrant and lower income students—students in "racialized communities that our society continues to systematically exclude and marginalize" from meaningful and relevant learning opportunities (M. Dumas, personal communication, June 13, 2015).

Art Transformation: Recycled Artworks in Jamaica Bay!

Water is spiritually significant in a number of religions and, as Low et al. (2005) notes, in urban contexts, seashore parks play a key role in the continuity of cultural practices for particular communities. As such, several religious and cultural groups actively use the Bay for water-based rituals. Hindu devotees are one of these groups as they view Jamaica Bay as a manifestation of the sacred Ganges in India (Kornblum & Van Hooreweghe, 2010). They perform pujas or special offering by placing offerings in the water. The North Channel Bridge is a public beach and commonly used for these pujas. Statues, fabrics, candles, fruits, flowers and other items are included in pujas, through dialogues between Jamaica Bay and the local Hindu community mostly biodegradable items are now used for pujas. However, because of the water circulation patterns many of these offerings—coconut shells, candles, clay pots used as candle holders, flags—end up on some of the beaches.

During a professional development field excursion to the North Channel Bridge, eighth-grade teacher Karen noted the clay candleholders and became interested in thinking about how she could use these artifacts with her students. Hence, when she joined the Master Teachers group she wanted to do an art/science based project that would incorporate these clay pots. She developed "Students Will Be Able To's" (SWBAT) as follows:

- Develop an ethic of personal responsibility and stewardship towards all aspects of the environment.
- Conduct a short "field" research project to determine the level of human impact on the environment.

She presented information to her students about the potential impacts of the pujas and other marine debris on Jamaica Bay including decreased water quality, impacts on bird life and potential hazards to humans (i.e. broken ceramics and glass). She also had a discussion with her students about the significance of the Bay to the Hindu community. She noted that students in her class who belonged to the Hindu community enjoyed sharing their culture and traditions with their classmates. Her students conducted a marine debris survey and water quality testing to make inferences about the water quality of the Bay. They categorized, counted and sketched the marine debris they encountered and brainstormed the ways that some of the items could be recycled. In addition to the (unfortunately) usual plastics and other household waste, students encountered a number of objects that originated with pujas. The park service removed the debris from the beach but through coordination they were able to save the candleholders and coconut shells for Karen's classroom. The students painted them and used them as planters for goldenrod seeds.

The seaside goldenrod (*Solidago sempervirens*) is a native perennial in the park and plays an important ecological role in sand dunes and salt marshes. As a part of restoration of sand dunes that were lost during Hurricane Sandy, there is a planting and replanting effort of native plants in existing sand dunes. Karen and her students painted the found artifacts, filled them with compost soil and goldenrod seeds and nursed the seedlings in the classroom until they were mature enough to be planted in the park. They took a field trip to Fort Tilden in Jamaica Bay to plant the goldenrods and help restore the dunes. Karen described the impact of this activity on her students in her evaluation,

> My students lived through the devastation of [Hurricane] Sandy, they truly have a sense of pride restoring their environment and community. Gateway is in their backyard; Fort Tilden is next to Riis Park, where my students frequent during the summer. The fact that they were supposed to restore the dunes that Sandy stripped away hit home for them and they were looking forward to the culminating activity. I plan on taking those students back this year for restoration as well as the new class coming up.

Karen and her students learned a number of valuable things about the park during their active engagement. They experienced place realization towards the park as a valuable resource for science learning, the significance of this place in cultural continuity for the Hindu community and the importance of caring for this place that is both sacred and vulnerable in respect to community activity and natural events. Karen's students played a key role in the place creation through the dune restoration project. Adding these layers of knowledge allowed Karen and her students to develop an attachment with the park and expanded their school sense of place to include Jamaica Bay. As the park has become integral to Karen's teaching, she now plans on returning to the site each year so that her students can see the results of their planting and their younger peers could continue the place creation begun by their predecessors. This process will allow the dunes to become an extension of the school.

Place Release and Non-human Living Things

Alyssa, a high school joined the Master Teachers group after attending one of the Seminars in Science workshops. During the workshop they learned about the ecology of the tidal zone and salt marsh, including the invasive species found there. One of the Rangers engaged participants in a quadrat study of shore crabs, first with a classroom based activity that used cut-outs to emulate the different species of crabs, both endemic and invasive, and then with the actual activity at the shore. Alyssa teaches a zoology elective class and was immediately engaged and remarked that this was something that her students would enjoy, since middle and high school students are motivated by studying living things (Defelice, Adams, Branco, & Pieroni, 2014). She focused her project on developing lesson plans and activities around shore crab monitoring.

Alyssa wanted to first familiarize her students with important concepts about invasive species so she framed her investigation around invasive species in New York City. Using plants as the focus, she planned and facilitated field trips to the Brooklyn Botanic Garden, Wave Hill Garden in the Bronx and The Highline in Manhattan for her students to gather information through observations and visual documentation. This enabled her to begin the discussion around invasive species and the ethical question of eradicating invasive species, which is a key management issue of the local National Park. She is in a school that encourages field trips and extended units, so she had the support of her administration to conduct multiple field trips. She was able to use a variety of places in the city as resources for science learning and these opportunities allowed her students to make deeper connections with places that were beyond their community and yet still a part of their city. These observational field trips also helped her students to understand the concepts of native, non-native species and importance of biodiversity. This background knowledge was then applied to the shore crab exploration in Jamaica Bay.

Alyssa and her class first did a trial run of the shore crab data collection at East River State Park, located within walking distance of her school. There, students repeated the quadrat studies that Alyssa did in the professional development, and collected, identified and counted the different shore crabs they encountered, specifically looking for the invasive Asian Shore Crab (*Hemigrapsus sanguineus*). She then took an extended field trip to Big Egg Marsh in Jamaica Bay where students did on-site data collection. She found that her students were not only enthusiastic about engaging in the research, but were very focused, detail oriented in their data collection of the crabs, comfortable in handling the crabs and were able to make inferences about crab where the crabs reside on shore (see Table 18.2). In this place release, students encountered a variety of crabs and a number of other living things that they associated with the crabs, as noted in Table 18.2. As an important part of the overarching project was learning about how students could contribute to the management of Jamaica Bay through data collection, she also noted challenges in the data collection process such as failure to follow protocols carefully and missing preliminary data (i.e. weather, location). She noted that it was helpful that students were able to practice data collection skills in the local park, as it made a difference when the students were in Jamaica Bay. However she lamented, “before this [East River Park trip], I should have done a lesson in the classroom on measurement, as well as an activity that shows the importance of random sampling.” The students who were absent for the “practice” sessions were not as productive in the field. Although they were engaged, they were unable to meaningfully contribute to the data collection process.

Reflecting on her experience with students learning in Jamaica Bay, Alyssa felt that the experience provided her students with what she described as “a living vocabulary,” which she described on her evaluation,

> My students are bombarded with hundreds of vocabulary words that they have to learn over the course of the year, but only so many include hands-on labs. But time and time again, I am reminded of how important it is for the kids to be able to apply these words to real life situations. Project-based assessments are the most memorable, and as a result, students can use their prior knowledge to relate to other questions about the world.

Alyssa wants to do more of these types of projects with her students and wants to be “more involved with other projects available to teachers around the city that are giving such great opportunities for student involvement.” Through this project, Alyssa not only saw Jamaica Bay as a valuable resource for her teaching, but through the experience of a different type of engagement with her students, she will most likely choose professional development opportunities that allow both her and her students to experience more place-based authentic science learning, she noted “The level of engagement and connectedness they felt to this research was really important to my learning as well as theirs.”

It has been noted in prior research that students who are disconnected from science in school often become engaged when the science learning occurs outside of the classroom in meaningful ways (Adams & Gupta, 2013; Basu & Calabrese-Barton, 2007). Because Alyssa’s course was an elective, the attendance rates were not high, however she noted that her attendance increased during the field trips,

> Students in my elective class tend to be quite transient, so there are only a few that experience each lesson every week. Many come in without the background knowledge of prior classes. When we began our focus on invasive species and Asian Shore Crabs, the students that were there wanted the others to participate and convinced many students to come to our final collection at Jamaica Bay. While they were there, they enjoyed the project, got their hands dirty and tried to execute the collection as best they could (with limited prior knowledge). Many expressed their interest in doing the project again, or staying longer to finish.

Her students shared their enthusiasm with their friends and even “those that didn’t normally participate wanted to be a part of what was happening.” To her, this was “music to my ears” and strengthened her commitment to seeking professional development for herself in order to facilitate more of these kinds of learning experiences with her students. Similarly, Karen stated that her 7th grade students “created a quite a buzz” about the field experiences causing all of her other grades

Table 18.2 Asian Shore Crab student observations

Group A's observations	Group B's observations
Females dominated the quadrats	More males found under small rocks
Mostly Asian Shore Crabs found	Less crabs were found in dry sand
Only one green crab collected	Only 1 female found
Most like to hide under larger rocks in big numbers	Crabs in their quadrats also usually contained worms, snails, and other worm-like organisms
Prefer damp sand conditions	That squirted water
Native species seem to be located farther from the shoreline	1 or 2 mud crabs found
Usually found near mussels	Mainly Asian Shore Crabs found
Plant cover varies	

to want to participate. The field experience has now become something for her lower grades to look forward to and the school has an emerging identity connected with the park.

Sentinels of Shoreline Change

From the PEC work, we learned that teachers are eager to engage their classes in authentic science research in the field, especially if it has a connection to the greater mission of the park. Alyssa remarked that her students were excited to be a part of research that helped scientists to know more about invasive species in the park. However, there is a lack of access to structured activities, scientific protocols, or scientists that can facilitate meaningful data collection. With these challenges in mind, and with a grant from SENCER-ISE, we developed the Sentinels of Shoreline Change, a project that connects schools with scientific monitoring and stewardship of the Bay. We would work with the PEC teachers to identify, pilot test, and revise a protocol that would be user-friendly for a range of grade levels, supply meaningful data to the scientific community and provide teachers and students the opportunity to use data to lead to civic action. The PEC Master Teachers were eager to participate as they felt that having a unified data collection process would not only with their process of planning and facilitating field experiences, but also allow students participate in a larger project around the monitoring and stewardship of Jamaica Bay.

The project began with a field trip to Plumb Beach in Jamaica Bay were teachers learned about the ecology of the salt marsh and engaged in data collection field methods to model what they might do with their students. After the field trip, teachers, college scientists and park staff debriefed the experience and decided what would be the most meaningful and feasible to do with students. Teachers discussed issues of access, materials and student motivation in the decision process about what activities they would like to field test in the classroom. We collectively decided to focus on marine debris for the first year because it did not require a lot of materials and equipment and there was an existing protocol from NOAA that had been used in the park by different community groups. Additionally, we agreed that it would be an easier and immediate connection to civic engagement. Teachers participated in professional development on the importance and use of scientific protocols and were introduced to the NOAA protocol and supporting materials.

Each teacher took her class to a different site where they used the NOAA protocol to document the different kinds of debris they found on the shore. Overall, the teachers were excited to have a well-defined protocol and found that their students were very motivated and engaged in the activity. One teacher wrote,

> I thought that the students overall were excited to get outside, but when they would be asked to take more detailed notes and follow protocol, they might not be as enthusiastic. Instead, they were engaged, and invested in getting it right. I teamed up with two boys that frequently missed class, and we established a way to collect debris and they were very thorough going through each step of the processes.

Although the marine debris activity was not focused on living things, this was still a key motivator for student participation, “They simply loved being outdoors and touching and seeing and learning about all the organisms we encountered.” This place interaction and place release allowed both the teachers and students to increase their familiarization of the park and enjoy their interactions with organisms that inhabit the place. Alyssa, who studied invasive specie with her class last year noted, “although they were disappointed that they couldn’t play with crabs, the students enjoyed themselves, they learned about some organisms they have never seen before.” While these encounters were not a planned part of the marine debris activity, they were important in allowing the teachers and students to form attachments with the place. The teachers requested information about the common marine/estuary organisms to share with their students on field trips.

Seeing the value of the park to their science teaching and learning, the Master Teachers were eager to create and share resources with other teachers. They suggested,

> we should develop pre and post-activity lessons that have clear relationships to Living Environment and Earth Science standards so Regents[1] teachers will feel confident, not ambivalent, about incorporating these activities

and “a series of CCLS and Regents aligned lessons that can be used in conjunction with these activities.” Through the process of place intensification, the lessons formalized the role of the park in teaching and learning and made it accessible to a larger circle of educators.

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[1] Regents or Regents Examinations are New York State-wide assessments in high school core subject areas required for a Regents diploma indicating college readiness. The science exams include Biology/Living Environment, Earth Science, Chemistry and Physics. http://www.nysedregents.org/regents_sci.html.

Engaging Teachers and Students in Place-Based STEM Learning

As the National Park Service begins its second century, it presents a strategic plan with Educational Leadership as one of the key outcomes. This outcome includes the following goals:

- Establish the National Park Service as an educational institution and strengthen parks as places of learning that teach about our American heritage and develop civic engagement, scientific and historical literacy, and citizen stewardship.
- Collaborate with partners and other educational institutions to expand NPS educational programs and the use of parks as places of learning.
- Develop and nurture lifelong connections between the public and parks—especially for young people—through a continuum of engaging recreational, educational, volunteer, service, and work experience (NPS, 2014).

With the emphasis on "places of learning" throughout these goals, it is the vision of the NPS is to be viewed as a valuable place to educators and those involved in teaching and learning through both formal and informal means. This means strengthening the attachment these stakeholder groups feel towards the park through deliberate programing and experiences. The teachers who engaged in the professional experiences described in this chapter learned that there are many different ways and opportunities to engage in science that not only connects to the classroom curriculum, but also connect students to a place of importance to their urban environment, as Alyssa noted, "allows students to experience their city in a new way." Dianne, a middle school Master Teacher wrote, "the most stimulating resource at Gateway is the site itself," it is that interaction with place and developing place identity that the park wants to foster so that there will be generations of stewards to follow. Through teachers' deliberate actions, students learned about places in their city that they did not know existed and teachers were able to develop new teaching identities that connected them not only to Jamaica Bay, but also to new ways of teaching science. Karen describes,

> PEC provided a unique opportunity to relate classroom science with the natural world. As an educator my focused has shifted to fostering my students long-term relationship with their environment. They need to realize what is offered in their backyards and understand the science behind it.

Place Attachment and Stewardship

People will not work to protect a place unless they feel a sense of attachment with a place, furthermore as people have different attachments to places, they may have different notions of stewardship. Increased understandings of place through direct experiences, including activities and processes that influence the quality of a place empowers people to know what actions to take in order to protect a place. Even if the teachers' projects did not include a direct civic action, it seemed that their students' sense of care towards the park increased with their scientific engagement. Dianne, a high school Master Teacher who did a project on marine debris with her students described,

> After our trip the students were asked to write a reflection about their experiences at Floyd Bennett Field. Almost all of the students commented on the amount of pollution they found on the beach and the adverse effect it could have on the ecology of the Bay. During lunch the students took care to police the area making sure they did not leave any trash behind. In addition, the school has started a recycling program. After or trip I noticed that the students were more conscious of using the proper bins to dispose of the garbage.

During discussions, teachers mentioned that their students were able to make connections with the debris they found on the beach to things that they often encounter in their daily lives like soda bottles, plastic bags and toy parts. This created an awareness about and connection to the trash they generate and what they found on the beach. This also allowed them to begin to develop their own sense of care and stewardship and not one that was being imposed on them.

In much environmental science literature, recycling is perceived as a pro-environmental behavior, without attention to the social, political and economic influences on access and choice. Interestingly, one teacher noted that her students had a negative perception about recycling, seeing as an activity for only poor people (with the bottle buy-back program in NY, many lower income people take to collecting bottles on the street as a way of supplementing income). Engaging in marine debris studies in the park and developing a recycling program at school helped to dispel this myth and allowed students to develop their own notions about what it means to care for the park and their local environment. This is an important aspect of place creation—a teacher affording her students a sense of agency in creating the kind of environment that they want for themselves and their community.

Preparing Teachers and Students for Place-Based Informal Science Learning

Through our engagement with teachers in this school-park collaboration, we learned important lessons both about integrating a resource, like Jamaica Bay, in the classroom. The initial motivating factor for most teachers was the day-long professional development. It allowed them to experience the place through direct activities with scientists and rangers involved in park management and research, and textual information, through lectures, printed and web-based materials about the Park. The activities modeled how teachers could explore the park through a scientific lens and using the same tools as scientists and the schedule allowed time for the teachers to reflect on the experience and discuss classroom practice with the scientists, park rangers and others who are familiar with the park. As the park is quite large, maps provided important spatial orientations for the teachers in respect to the location of their schools and transportation. Accessibility is one of the challenges to teachers actively using the park with their students so the identification of easily accessible sites was an important part of learning about the park.

The PEC and SENCER-ISE projects provided the necessary space to begin to build a learning community around using Jamaica Bay in the classroom. This provided a dialogic space where teachers deepened their practice and attachment to the park, but also where the park and scientists learned about applicability of different activities and research into the classroom. This was a space for developing and sharing curriculum, reviewing local and national curricula and standards in relation to park-based activities, reading and discussing relevant literature around place-based learning and civic action. The learning community afforded a space to “complet[e] the project with a team of teachers to make me feel more comfortable replicating it with my class.” This was also a place where teacher and parks staff discussed the challenges of doing science investigations in the park such as transportation (the park is a large space so there are many sites that are not easily accessible by public transportation), safety with students, especially near water, and having the right equipment to do accurate data collection. One teacher noted,

> The best way to deal with the challenges is pre-planning and preparing the students. In order for the trip to be successful the students must know their assignments and what is expected of them. It is important that they know the ground rules and how to properly handle the equipment.

While the PEC teachers were greatly influenced by working with the park, the park was also influenced by working with teachers. First, the park saw that it had to empower teachers to lead investigation with students while adhering to management and safety policy. The park has limited human resources so it is not feasible for a Ranger or other park staff to accompany each field trip, especially in the case of scaling up the number of teachers who actively use the park for teaching and learning. There have been ongoing discussions about policy around the enactment of science research field trips. In addition, certain activities require permits so it is necessary to create policy on issuing permits to schools and classrooms. In terms of pedagogy, the traditional Ranger-led field trip was done through the framework of interpretation in the traditional sense where a Ranger would lead students on a walk through the park and while pointing out particular information. There is a move more towards inquiry, where a Ranger would be a facilitator of learning; designing and learning activities that allow people to make meaning and develop a more personal interaction with and attachment to the park. The NPS strategic plan describes a more towards a more inquiry-based approach to interpretation: We foster transformative experiences that help people find meaning and make sense of issues that reflect the breadth of the country’s natural and cultural resources and its peoples (NPS, 2014, p. 6). The document then discusses activities that point to developing place attachment like promoting “active engagement and memorable experiences" and "exceed audience expectations for learning." It also speaks to a more interdisciplinary and polysemic approach, "design interpretive programs that tell all American's stories…present multiple points of view and encourage inquiry and civic dialogue" (p. 8). This is a move towards the notion of natural objects and landscapes carrying multiple meanings—ecological, scientific, indigenous, aesthetic, historical and recreational—and that these all changes with time (Van Eijck & Roth, 2010).

For the NPS to achieve these goals, it will be important to foster more collaborative relationships the formal educational institutions and create learning communities where boundaries are obliterated, resources and pedagogies are shared, and there are seamless exchanges of culture and information between the park and schools.

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Chapter 19
Preparing Informal Science Educators in a Formal Science Teacher Education Program: An Oxymoron?

Catherine E. Matthews, Susannah Thompson and Sadie Camfield Payne

I have spent many years of my life preparing formal science educators in a teacher education program. Formal science educators are easily identified—they teach in K-12 (ages 5–18) schools and universities, in programs where students must attend and complete specific classes and master a certain level of understanding of science to pass. Typically, K-12 formal science educators (i.e. teachers) have themselves come from formal science education preparation programs; although, with recent teacher shortages, some individuals have taken alternative routes to K-12 science teaching (e.g. some school districts allow unlicensed individuals to teach and then recommend them for licensure after a year of successful teaching) and some universities have hired science educators who have had no formal preparation for or experience in K-12 science teaching themselves (the normal practice is, I believe, still to require university methods professors to have had several years of successful K-12 teaching experience). While I am an advocate for formal schooling and formal science education, I believe that many of the practices, more characteristic of informal science education (ISE) or informal science learning (such as free choice learning and exploration of and in the out-of-doors), are desirable and should be incorporated into formal science education experiences.

The purpose of this chapter is to describe a university teacher education program and a science teacher educator (me) and two students, Susannah and Sadie, who graduated at different times and secured initial teaching positions (one in an informal science setting and one in a formal science education setting). Then, after several years in their initial career positions, each of these former students switched tracks. Susannah, who was first an informal educator as a Wildlife Resources Commission Education Specialist, is now a middle school media specialist/librarian

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while Sadie, who initially was a formal middle school science teacher, is now teaching in an informal science education setting at a 4-H STEM (Science, Technology, Education and Mathematics) program.

This chapter describes how a formal education program can appropriately prepare students to be successful as informal science/environmental educators. This chapter is co-authored and students' statements are italicized (Susannah) or underlined (Sadie) while the writing of the professor (my writing) is neither italicized nor underlined. We discuss the strengths and weaknesses of a formal educational preparation for positions in informal science education.

Autobiographical statements by the three of us and reflections by each of us on our experiences in the same teacher education program (although during different time periods) indicate that formal education programs might well prepare students to succeed in informal science education settings. The strengths of a formal educational preparation and the challenges of working in ISE settings, given preparation for teaching in formal settings, will be discussed.

In university settings, Teacher Education departments typically offer formal elementary (ages 5–11), middle school (ages 11–15), secondary school (ages 14–18), and higher education programs, each with the primary purpose of preparing pre-service teachers to become in-service teachers at specific grade levels. In addition to a clear focus on teacher education at a particular age/experience level, these programs often have a secondary purpose, such as rural, suburban, or urban education; general or special education; or subject specific education (science, mathematics, language arts, or social studies). The subject area specializations are typically offered at the middle school and secondary school levels as well as in post-K-12 programs. Our focus on science education and environmental education (EE) in the elementary school was possible because of the nature of our program, as described below. Most Teacher Education programs target preparation for positions in public schools and university classrooms.

Both of the former students highlighted in this chapter, Susannah and Sadie, were students in an elementary education program at a U.S. southeastern suburban university with a long history of excellent teacher preparation, including a strong professional development schools (PDS) program. The teacher preparation program is intensive. It is a 2-year program, and students move through the program as a cohort or team. For three semesters, the students take two methods classes, a seminar, and spend 10 h a week in an assigned classroom in a public elementary school (called a PDS). All of these activities occur on Mondays, Wednesdays and Fridays throughout the semester from 7:15 AM to 2:15 PM each day. The fourth semester of the program is 15 weeks of fulltime student teaching and a seminar, which meets every other week.

During the period of time that Susannah and Sadie attended the university, each cohort (there were two to six cohorts each year of juniors at this university and another two to six cohorts of seniors) was focused on a theme. Team themes included a Mathematics Team, an Integrated Arts Team, a Literacy Team, a Social Studies Team, a Technology Team and a Paideia Team, as well as a Science and EE Team. The theme for the cohorts that both Susannah and Sadie were members of was science education and EE. This program has been described previously in detail (Antonek, Matthews, & Levin, 2005).

Susannah and Sadie completed the Elementary Education Degree 8 years apart; Susannah completed the program in May 2000, and Sadie completed the program in May 2008. Their experiences were different, but they shared a number of common elements in their programs, including the fact that I was their PDS team leader. I worked with them each over a period of 2 years during their studies and then also maintained fairly regular contact with each of them after graduation. I continued to maintain contact with them as they each pursued further education and earned masters degrees. Now, they have, after beginning their careers in one profession, moved to a second career track.

In this chapter we share the stories of these two former students/current educators and my story as well, as their professor and as a professor of formal science education. Even though their undergraduate education focused on preparation for careers in formal educational environments, both students have worked in formal and informal science education environments.

There is a fair amount of literature suggesting that ISE should and indeed does have a significant role in the formal science education experiences of teachers (e.g. Stocklmayer, Rennie, & Gilbert, 2010; Fallik, Rosenfeld, & Eylon, 2013; and McKinnon & Lamberts, 2014) These authors and others (Avraamidou, 2014) suggest that ISE increases the appropriateness, meaningfulness, and relevance of the formal science curriculum; improves the engagement of students with formal school science curriculum, especially through inquiry learning and cross-disciplinary contexts; and contributes to teacher professional development. ISE can also address existing problems in K-12 as well as university science education, such as students' low interest in and engagement with science.

Avraamidou (2014) provides a synthesis of findings from studies that examined out-of-school programs for teacher preparation. In her synthesis of findings, she found that ISE environments have the potential to improve teachers' attitudes towards science, motivation, interest and engagement (Jung & Tonso, 2006; Katz et al. 2011; Kisiel, 2013; Luehmann & Markowitz, 2011; and Wallace, 2013). Avraamidou argues that integrating ISE programs and activities into elementary teacher preparation programs can more adequately and appropriately address science teaching reform recommendations.

Researchers could examine the kinds of informal science experiences teachers have throughout their lives. Avraamidou argues that those experiences impact the development of science teacher identities, suggesting that teacher educators could examine these particular experiences and then use the high impact practices in teacher education programs. In many ways, this book chapter has accomplished exactly that purpose because it examines two former university students' science experiences and how these experiences affected their science teaching identities.

A 1996 study found that ISE institutions worked intensively with teachers throughout the United States and that as much as one-fourth of professional development offerings in science for elementary teachers occurred in informal, science-rich institutions (Inverness Research Study, 1996). Certainly, our program relied heavily on ISE experiences and ISE educators who worked closely with our faculty and students to offer a number of experiences and opportunities over the 2 years of our program. These experiences will be described in more detail later in the chapter.

Recent funding policies by the National Science Foundation, the National Aeronautics and Space Administration, and the National Oceanic and Atmospheric Association have forged partnerships between institutions primarily devoted to informal science and those devoted to teacher preparation. Among some of these, the *Teacher Renewal for Urban Science Teachers* initiative in New York City brought the resources of the American Museum of Natural History and two City University of New York campuses, Lehman and Brooklyn Colleges, who serve some of the most needy communities in the city, into a collaborative to prepare Earth Science teachers (Silvernail, 2009). Most of these teachers went to work in high-need schools that had not been able to offer Earth Science and whose students were not able to take the high-stakes Regents exam (statewide standardized tests in core high school subjects) in Earth Science which decreased their opportunities to graduate from high school because a certain number of Regents exams are required for graduation. Another example of a collaboration resulting from funding policies, *Teachers for a New Era*, (2001), funded by Carnegie Corporation, Annenberg Foundation, and Ford Foundation, forged partnerships among the arts and sciences in teacher education programs and included discussions of integrating ISE into the partnership.

The Center for Advancement of Informal Science Education (CAISE) Inquiry Group report, *Making Science Matter: Collaborations Between Informal Science Education Organizations and Schools* (Bevan et al., 2010), argues that ISE connects to formal education systems in a number of ways, and some of the best connections blur the lines between formal and informal education. The report suggests that ISE can be an important part of science learning for students, cultivating experiences that involve both formal and informal science, such as a class field trip to a science museum, a hands-on science investigation conducted after-school and taught jointly by a certified science teacher and a youth development worker, or a service-learning project to study the quality of nearby bodies of water. Additionally, institutions primarily devoted to ISE may play important and formal roles in science education, offering science learning to students or preparing their teachers. This report provides other examples and further discussion of the types of collaborations between formal and informal science education that would increase science learning:

> The *National Science Teachers Association Position Statement: Learning Science in Informal Environments* (2012) has made a powerful argument for the important role of learning science in informal environments and suggested that there is clear evidence that these experiences can promote science learning and strengthen and enrich school science (Bevan et al., 2010; National Research Council, 2009). The position statement clearly and broadly defined ISE: to encompass a wide range of contexts and settings, including everyday experiences; experiences in designed settings, such as museums, zoos, nature and environmental programs, and other science-rich cultural institutions; experiences in structured out-of-school-time programs, such as after-school youth programs, clubs, and citizen science; and experiences through science media, such as gaming, television, radio, and the internet (National Science Teachers Association, 2012).

These diverse opportunities can help learners understand the relevance of science to their lives, the depth and breadth of science as a field of inquiry, and what it might be like to choose to do science in the world, either as a professional or as a hobbyist. These experiences may also provide important and unique opportunities to engage students who come from communities historically underrepresented in the sciences (National Research Council, 2009).

NSTA advocates for stronger links between formal and informal learning and recommends expansion of the role of informal science institutions in the design and delivery of professional supports for teachers in both pre-service and in-service contexts. Informal contexts provide resources for expanding the curriculum, reinforcing key concepts, and providing links to real-world situations and scientists, as well as scientific data, instruments, and laboratories.

The state of North Carolina offers an EE Certification program for both informal and formal educators. Once the North Carolina Office of EE (now the North Carolina Department of Environment & Natural Resources (DENR) Office of EE and Public Affairs) was established (1993) and an EE Certification program adopted (1995), our university students who elected to earn NC EE Certification were required, like all other individuals pursuing EE Certification, to complete approximately 200 h of training. These hours were allocated in different categories including 70 h of required workshops (e.g. *Project Wild*, *Project Wild Aquatics*, and *Wonders of Wetlands*), 50 h of outdoor experiences, 30 h of resource visits to ISE institutions (e.g. museums and state parks), and, finally, at least 20 h devoted to a community partnership project, which requires students to assume a leadership role in a partnership and complete a project which increases environmental awareness and understanding for a specific community of people. While Susannah, who began her career as an informal science educator has earned her EE Certification and completed the recertification process, Sadie, who began her career as a middle school teacher, is still working on hers. Positions in ISE are much stronger motivators for acquiring EE Certification, at least in NC, where certification is not tied to teacher licensure. Neither student completed the EE certification program while they were enrolled at the university. Their certification-seeking stories are a part of the tales they tell below.

The following stories are told first from the view of the former undergraduate students and then from the view of the university instructor. Transitions between Susannah's words (italicized), Sadie's stories (underlined), and the instructor's reflections (neither italicized nor underlined) are bolded and distinguished from surrounding text by being either underlined or not underlined. This formatting should clarify point of view.

Susannah's Story—August 1995

In the summer of 1995, I began studies at the University of North Carolina at Greensboro. My original intent was to study biology, though I was not certain where this degree would take me after graduation (a lab?). In the following years as I completed the core curriculum and explored some of the other programs at UNCG, I found that I had a greater interest in other fields, namely anthropology and education.

Susannah—Fall 1998

When given the choices for teams in the elementary education program (literacy; mathematics; social studies; and science and EE), I did not hesitate to sign up for the science and EE team. With an innate attraction to the natural world and experience working with children, EE seemed a good fit. Over the next 2 years, my team was exposed to a variety of educational projects, hands-on experiences, internships, and opportunities for networking with professionals in the field. As part of this program, I completed four internships at four different schools: one in a high wealth area with active parent involvement, one at a magnet school with a focus on science, one with a highly diverse and international student population, and one located in Aravaca, Spain, just outside Madrid.

Each semester, we would find ourselves exploring new topics, subjects, and methodologies, always with a connection back to EE, which, in my mind, became synonymous with science education. Most often we followed a constructivist approach, which helped us as individuals to develop an understanding of the learning process for ourselves and for our students. Through investigation, reflection, and trial and error, we learned how to locate the resources we needed to solve problems and answer questions about the world around us: a practice universal to both formal and informal education. Whether attempting to answer questions about objectives in the curriculum or about the alien-looking worm you found in the stream and its place in the local ecosystem, the instructional methods we used helped us to make sense of the real world.

The program stressed the importance of understanding the curriculum for each grade level. The Standard Course of Study had to be incorporated into everything we taught, and we were evaluated on how well our lessons and activities covered these objectives.

Whether teaching second grade students in a classroom or teaching traveling retirees in an outdoor classroom, knowing what you want to accomplish and what you want your learners to accomplish is essential to good instruction. You always need to understand your audience: what they care about, why they come to you, what they know, and what they want to learn. Success in informal programming requires knowing your goals and knowing your audience.

Catherine's Reflections on Susannah—August 1995

Tall, thin and serious, Susannah Thompson walked into my life determined to make a mark on the world. She had a second major in Anthropology and a mother who was an art teacher. Susannah was a vegetarian, and she was already a committed environmental enthusiast. I knew this was a good match for the EE team right away.

Susannah had my colleague, Ann Somers, in the Biology Department for Biology 105, Conservation Biology, and this course had clearly influenced Susannah's thinking. One late (very late) afternoon, just as I was readying to leave my office for the day, the phone rang. It was Susannah Thompson. She was on campus and had found a young bird that appeared to be injured. She was calling me to see what suggestions I had for what she should do. We exchanged several phone calls over the next 40 min or so and, as I remember, finally, the bird flew away.

Susannah's deep concern for our natural world remained, and as she moved semester by semester through our program, her deep appreciation of our natural world only deepened, much to my delight.

Because Susannah was such an unusual, or at least atypical, elementary education major, I kept copies of the emails that we've exchanged over the years, so it is fairly easy to recount several specific instances where Susannah and I were clearly connected.

Susannah—August 1998

As part of our time with the EE team, we were immersed in a variety of activities and interacted with individuals from different state EE organizations. Wildlife Education Specialists came to our UNCG classroom to share lesson ideas from Project WILD *and* Project WILD Aquatic*, national programs that provide educators and youth leaders with activities and games that guide youth towards environmental stewardship. The programs focus primarily on wildlife, habitats, and natural systems to engage students and to teach concepts from the required curriculum.*

The wildlife education specialists helped us investigate water quality at Piney Lake, and allowed me to try out a Secchi disk for the first time. We made copies of animal tracks using rubber molds and Bondo® then practiced identifying each track by creating our own taxonomical classification keys. Our time in the formal science education lab helped us to realize that we could use existing resources, like Project WILD *and* Project Learning Tree*, to foster hands-on experiences, to throw students into real places and situations instead of just talking about them, to create inexpensive learning materials, to make connections from concepts to the real world, to introduce new ideas, and to reflect on how these concepts relate to students' lives and their experiences.*

Susannah—Fall 1998

As a child, I had pets, both dogs and cats, and access to larger domesticated animals at my grandparents' farm. I'd been fishing with my great-aunt and my father and seen some of the diversity found around ponds. Thus, one of my favorite projects in the teacher education program was the animal project; a project initiated to teach us about the ethics of using animals in the classroom and to demonstrate how even the smallest creatures can evoke reactions in young students. As part of this assignment, a group of us cared for a particular animal, conducted research to gather background and maintenance information, made observations, and created a book of lesson plans and activities about the animals. My group selected sea monkeys (brine shrimp), small enough to avoid attracting my cat's interest (since I kept both at my apartment—sea monkeys and cat), but unusual enough to attract ours.

Over the next 6 months, I had a breeding population, started from a kit ordered online, kept in a quart-sized mason jar. They were fascinating, until a class of first graders knocked over the jar. This assignment, however, served as my first experience with keeping and sustaining aquatic organisms. Years later during my time as an informal educator, this basic introduction to animal care made me feel confident that I could learn how to maintain other aquatic species, leading to part-

time care of three large aquariums of marine species: trout, long nose gar, and bowfin.

After the completion of our animal study, we prepared to present what we had learned at the North Carolina Science Teachers Association's conference. We shared the book we had created and printed with science teachers and others attending the convention. Even though it was a short presentation, the practice speaking in front of our peers and experts in the field was immensely useful. Since that initial presentation, I've given presentations at numerous conferences as an informal educator. Informal education often requires marketing your programs to key constituents, and one of the best means for reaching potential audiences has been through conference sessions. The opportunities for finding partners for new and exciting projects also increases by networking at these kinds of events, which is useful to those involved in both formal and informal education.

Susannah—Spring 1999

During one of the final internships, our professors and the EE team constructed a mini-pond on the school grounds at one of our PDS school sites to use for habitat studies with students. This small pond provided wildlife with a habitat resource and increased the opportunities for students to explore outdoors. It was also another lesson in how to get your hands dirty. This would prove to be the first of many opportunities to get my hands dirty; I later helped to pull fields full of Microstegium species also known as Japanese Stilt Grass (an invasive plant) from an outdoor classroom, waded through frigid streams looking for giant salamanders, squeezed trout to collect eggs and milt at the fish hatchery, and documented the process of pulling otoliths (fish ear bones) and tissue samples for Chronic Wasting Disease testing. Good stuff.

One semester, the EE team took a trip to the coast for a workshop with a coastal educator. This one was called Sound Ideas *and focused on coastal waterways and activities. We were fortunate enough to have access to a boat, which took us to Carrot Island and the Rachel Carson Reserve near Beaufort, NC. The primary interest of many of my teammates was the wild ponies that inhabited the area, but my strongest memory was of a crab I found on the shore. Growing up in southeastern North Carolina, I'd been to the beach many times as a child and teen. I'd followed bubbles in the sand, digging for sand fiddlers and periwinkles, watched the waves for dolphins, chased gulls, and followed pelicans, but I'd never seen a crab like this before. It looked like two crabs, one with a splotchy brown color and one slightly faded. I asked and discovered that it was a calico crab that had just molted. That same trip, I found what looked like a piece of petrified driftwood on the beach. Later, I learned that it was actually a piece of petrified whalebone, which became more obvious when you looked from the side. It still sits on my shelf with my field guides, reminding me to always look closer and keep asking questions.*

Catherine

One of my fond recollections of Susannah's involvement in our Science/EE PDS program was her engagement with a visiting herpetologist, Dr. Margaret (Meg) Stewart, author of numerous scientific publications and the book, *Amphibians* *of Malawi*. Dr. Stewart was an alumna of our university, and I was aware of her work on frogs and thought that it would be a great professional development experience to have her come to one of our PDS schools and speak to a specific grade level and, of course, all of my PDS team members. When I extended an invitation to Dr. Stewart to do this, she replied with a bit of hesitation. She was used to working with and talking to college students, not third graders. No one had ever asked her to do anything like this before. I assured her that she would have all of our support and that the third graders would be well prepared to learn more about her and her work with amphibians, specifically frogs, because our university students were interning in third grade classes and the science lab. Susannah was instrumental in making this daylong event a huge success. Several of us took Dr. Meg Stewart to lunch, and we invited a couple of very interested students, one of whom was Susannah.

As a result of this event, the science specialist, Dr. Helen Cook and I wrote an article, "Herpetologist transports Third-Graders to Frogland", published in *Science Activities* (2004). Below are a few relevant paragraphs from this article.

When Dr. Stewart arrived, she was greeted at the door by a banner, balloons and three costumed third-graders, who 'hopped' right up and extended their greetings and an invitation to the school.

In addition to the 100 third-graders at General Greene, their teachers, their teacher assistants, some parents and the principal, Dr. Matthews' team of pre-service teachers (32 juniors majoring in elementary education) was also on hand to participate in the day's events. The two schools have had a professional development school partnership for 6 years, and this is just one example of the events that the two schools plan and share.

Near the end of the program, several of the university students donned white lab coats and humbly asked Dr. Stewart to autograph them. This signing launched the Lab Coat Project at General Greene, another collaborative undertaking and another way to introduce students to scientists. [The science specialist and I purchased a number of lab coats and then asked local university scientists as well other scientists to sign these coats. Some coats were 'biologists' coats'; some coats were 'chemists' coats' some coats had signatures of only women scientists and some coats had signatures of renowned scientists, signed by relatives if they were no longer living. The idea behind this project was that when teaching science we would wear one of these coats and teach our students a little about the scientists behind the work of science.]

The role of the university students did not end there. Following the presentation, half of the cohort helped their elementary counterparts in the lab while the other half sat down with Dr. Stewart to discuss the day from an educator's perspective. They critiqued the pedagogical usefulness of the event and highlighted effective strategies that they felt they could include in their own teaching repertoires. Amid the talk of pedagogy and strategies arose one prevailing observation: those elementary students really knew their stuff. They really understood many facets of amphibian biology.

This captivated audience was just as prepared for its guest speaker as she was for them. Dr. Stewart's reaction to her first-ever presentation to elementary school students was one of both surprise and gratification. 'It was nice to be in a room with so many little people who knew so much about amphibians. I aimed my remarks higher than I intended because I realized I was talking to an educated group' (pp. 31–33).

Susannah—Fall 1999

Another required project for the EE team was to plan and coordinate an excursion to Lucent Technology's outdoor education site on the outskirts of Greensboro along Little Alamance Creek. Each student was responsible for a specific task (e.g. creating and collecting permission slips, organizing buses, assigning student groups and creating a rotation schedule for student groups, and many more tasks) and for running a station once all the students arrived. This proved to be perfect training for planning, prepping, and facilitating field instruction and informal programming as well as introducing us to the process of organizing field trips for a classroom. We used activities from the state wildlife agency's Wild Education Sites *book. Being one of the less squeamish individuals on the team, I chose the activity on scent stations. A scent station is a small spot covered in lime or sand with a scent applied to the area. In this situation, I attached a cotton ball covered in fox urine to a stick and then placed the stick into the middle of the scent station. The idea is that animals will be attracted to the odor, come up to sniff, and leave their tracks in the lime or sand for students to identify. This way, they can see what lives in the area.*

In order for this to work, I had to set up the station the day before the field trip. I wandered into the woods by myself, not thinking much about anything except the plan for the next day. I startled a group of wood ducks that had been swimming in the stream and they startled me! I guess we both thought we were out there on our own. Lesson one: there's always someone else out there: you just have to be quiet enough and observant enough not to disturb each other (a lesson better reinforced years later when I encountered feral swine in Pisgah Forest). I set up my station, making sure to use several squirts of urine from the spray bottle, packed up and left. Lesson two: always, ALWAYS triple bag your fox urine before you put it in your car. If it leaks, the smell in the car lasts for weeks.

The next day, before the students arrived, the EE team went into the woods to set up the other stations. The people up ahead of me kept complaining about the smell and when I finally caught a whiff, I was ecstatic. I had made contact! The entire trail through the woods had been marked by a living and breathing fox that had found my scent station. I couldn't tell you what tracks were in the lime that day, but the overwhelming scent of fox urine is pretty much burned into my memory. Needless to say, it's probably burned into the memory of many other people who were out there that day, too, students and teachers alike. It's pretty potent stuff. Lesson three: it doesn't take much more than pee in the woods to create a memorable educational experience.

Catherine—Fall 1999

Always believing that we should do what we say teachers should do, along with the help of a Department of Natural Resources Wildlife Educator, we decided to use our large group of university students to provide EE for the entire fifth grade at one of our cooperating/collaborating PDS schools. For 2 days, pairs of university students designed and set up stations in the woods along a creek and taught EE lessons to small groups of fifth graders and their teachers who rotated through a number of the stations. My recollection of this event is that it was a huge success (but also a mighty undertaking) and one clear memory I have is of one young man who questioned us in front of the class. "Now, you said we don't get to go to all of the stations, right?" To which I replied, "That is correct. You'll be going to 5 of 8 possible stations because other small student groups will be at the other stations." He replied, "Well, I love this kind of thing and my Mom can bring me out on Saturday so that I can do the stations that I can't do today." For just a minute, really less than a minute, I couldn't fathom what he was really saying. And then, it dawned on me. He must think we're out here all the time. For me, a deeper comment could not have been offered.

It took most of our semester to plan this event, and we talked about it for many years following the event. The university students prepared outstanding stations, the teachers, parents, and their students loved every minute of being in the out-of-doors (there were no indoor facilities—and only one porta potty rented for the occasion) and learning about the natural history of the Piedmont. While fox pee may have been Susannah's highlight, stream explorations, building bird feeders, making leaf prints, and identifying spiders were just a few of the students and teachers other favorites.

The disappointing end to the activity was that we had hoped that this event would serve as our collective action partnership but our state office of EE denied students' requests to count this as their action partnerships, claiming that the students had not fulfilled the intent of the EE guidelines for Action Partnerships. In my opinion, this action alone resulted in the loss of 25 or so potential certified EE instructors for our state, but several students including Susannah were resilient and eventually received their EE certification.

Susannah—January 2000

Later in the program, we learned of opportunities to complete our student teaching abroad. I signed up, ready to pack my bags and go. In November of 1999, I bought my tickets and left for Spain. I had a basic knowledge of Spanish and only so much room in my bags for classroom materials. I knew that this would be an opportunity to learn how to adapt and a real test to determine my abilities as a teacher. If I could handle a new classroom in another country without all the resources that I had available in Greensboro, then I could feel confident in handling a classroom of my own. I hoped that there would be a wealth of resources available to me once I arrived. But, keep in mind that email and Internet access were still relatively new at that time and pulling lesson plans from the Internet was not as easy as it is today. There was the concern over Y2K, the year 2000, when people were unsure of what would happen to all this new technology once clocks hit 12:01 AM on January 1st. Also at this time, the Basque separatist group, ETA, ended a cease-fire with the government of Spain. There were several attacks in Madrid while I was there.

Madrid was a completely different place from Greensboro, NC. There were subways (metro) and huge crowds of people who did not behave like the Southerners I'd known all my life. Cultural traditions were so different from what I was accustomed to: Three Kings' day parade after Christmas, the Roscón de Reyes shared at a holiday party, minimal eye contact on the sidewalks, the manner of dress, hanging clothes on clotheslines at the top of multistory buildings. Certain forms of conservation in the city were not optional. In my apartment building, the radiators were shut off from about 2:30 AM to 6:00 AM to save energy. You'd best have a thick blanket or two. People in the city recycled, but not just glass and aluminum, but "bricks" or what we call juice boxes or milk cartons. Attempting to develop fluency with the language, determining what was what at the groceries and markets (a fascinating mystery), and navigating the city were all welcome adventures.

School was two metro rides and a bus trip away from my apartment in northwest Madrid. The school where I completed my student teaching experience served students from privileged backgrounds. Some of their parents were diplomats, some ex-patriots; others just wanted their children to be familiar with English and to attend American universities. Even with their advantages, students here experienced the same problems as students in the States: struggles with learning new languages, difficulties reading, behavioral problems, and discipline issues.

My placement was a second grade class at the American School of Madrid, located just outside the city in Aravaca. My mentor, Señora Brown, focused on science and math and co-taught classes with another instructor who covered reading and language arts. I student taught both second grade classes, but with my primary focus on science. The school had a garden in which students investigated the growth of plants and factors impacting growth rates. Due to its location and school security, the outdoor space was limited. Even the "farm" where we took the students on a field trip was less than 3 acres and most of that space was used for buildings. This exposure to metropolitan landscaping was useful because it helped me to plan for future EE projects when I would be teaching wildlife education from the indoors, polluted creeks, and/or sidewalks. At the end of the program, I returned home for graduation, with a backpack full of photos and memories of my time in Spain.

Susannah—May 2000

By the end of our 2-year program with the Science Education/EE Team, we had participated in many workshops, visited many EE sites and centers, attempted to complete an Action Partnership project, and were able to count all of these experiences towards the North Carolina EE Certification program (except the Action Partnership). The point of the certification is to prepare educators from all over the state, both formal and informal, to transfer concepts learned from the certification process and the many resources we learned about to their students, improving overall understandings of the natural world and hopefully, inspiring stewardship in future generations. One benefit of this program was that it led me to explore more of the resources around Greensboro: the greenway system, the parks, the Piedmont Environmental Center, and the Greensboro Natural Science Center, *some of which I began to visit on a regular basis. The second benefit was that it helped me to connect with others in both informal and formal education fields. I met naturalists, youth leaders, biologists, ecologists, and program managers. The conversations that I had during that time often sparked new ideas for approaching content, for disseminating content, and for looking critically at and enjoying the natural world.*

Catherine

Susannah's desire to teach did not come as a surprise to me, nor did her success in the field. Her emails over the 2 years were always targeted, helpful, and insightful. They were also questioning. In her first semester of internship, Susannah worked in a classroom where a student was catheterized. During one of her first days in this placement, she was asked to accompany this young girl to the restroom. Susannah dealt with this request as best she could but clearly was surprised that classroom teachers had such responsibilities. I was not much help myself, having never assisted with restroom procedures for catheterized students but Susannah figured out the procedures and the process and was comforting to the young girl as well as comfortable with the situation. This was Susannah—steady, thoughtful, unshakeable, and inquiring.

Susannah—May 2000

During my education studies at UNCG, I questioned whether I wanted to teach in a traditional setting. I remember speaking with my team leader and the wildlife education specialist who had led workshops and activities with the team about other kinds of teaching positions—informal education positions. My student teaching, though an incredible experience, made me feel more certain that I wanted to try something different and take a different path.

After graduation, I searched for jobs in the western part of the state and found one with the NC Wildlife Resources Commission (WRC). When I drove into Pisgah National Forest for my interview, I knew that this was where I wanted to be. Davidson River runs through mountain cove forests, full of hemlocks (before the wooly adelgids), white pines, and tulip poplars. Creeping around their roots you could find lady slippers, wild ginger, rhododendrons, and laurel. And then there was the wildlife.

As the interview questions about my education and experience continued, it became clear that they (WRC) needed someone interested in science, familiar with educational theory and practice, eager to earn certification as an environmental educator, and who understood the needs of teachers and their students and brought enthusiasm and excitement to their instruction. My experiences with the formal science education program provided the means to get my foot in the door with a prominent conservation organization. I was hired that summer and began teaching right away.

The programs at this particular center were well established. The main programs could be adapted for groups of varying size and focused on the assets located in the forest, river, and streams surrounding the education center: Habitats, *a program about regional habitat diversity and the habitat resources that each provides for wild animals;* Raising Fish, *a program examining the role of fish* *hatcheries in the state, the life cycle of a fish, and the process of raising and stocking fish in public waterways;* Stream Investigation, *a program investigating bio-indicators, stream health, and local threats to aquatic wildlife;* Nature Nuts, *a program series focusing on a different animal or topic each month for very young students; and* EcoExplorers, *a similar series, but for slightly older audiences. All of these core programs were designed by individuals with education backgrounds and used elements and activities from* Project Wild, *an activity guide created by wildlife agencies across the United States. This was the same education guide that I had used during internships with Guilford County Schools.*

This first informal education job gave me practice developing program materials for students of all ages and exposed me to two cultures: the culture of the state EE community and the culture of a wildlife management organization. Though aware of the EE community through my time on the EE Team, I spent more time developing relationships with individuals also committed to teaching students about the environment. Forest resources, land resources, water, and air—there were so many people with whom I could share ideas and plan new projects.

The culture of a wildlife management agency was something new. This agency was composed of several subgroups, each with a specific task: wildlife and fisheries biologists; enforcement officers; engineers; administrative staff; and conservation education specialists. Within each group, you could find different interpretations of the agency mission and, while the concept of conservation might mean preserving hunting and fishing as a tradition to one person, it could mean preserving species diversity and habitat to another, and both to someone else. Sometimes these differing interpretations caused friction between staff members but only because of their passion for their work.

As a wildlife education specialist, I learned about new tools and developed new skills. There was radio telemetry equipment to find marked creatures; geographic positioning systems (GPS) to find caches, mark boundaries and specific locations; geographic information systems (GIS) to create maps describing land use, highlight range and distribution, and show movement of wild creatures. My species, tracking, and scat identification skills improved. My knowledge of the natural world expanded, and my confidence as an instructor also increased.

Other staff members were hired and sometimes these individuals had backgrounds in science and field studies, but not education. One person in particular experienced some difficulties in translating his extensive knowledge of fisheries science into programs that excited students. He had the content but struggled with the method. We would often talk after programs, sharing our expertise. My studies and experience with child development and learning gave me the insights needed to effectively engage audiences. His understanding of ichthyology gave him a tremendous understanding of anatomy and fisheries management methods. We partnered together over the next few months; I shared ideas to connect with students and he shared details and diagrams. We both improved as educators and came to realize that even though the content or message to be conveyed is important, it can be missed, ignored, or overlooked if you do not consider the process for conveying the message.

I completed my EE certification in 2002, while I was working with Wildlife. I wanted to finish my certification because I believe in the importance of the work. I also enjoyed attending workshops. Many were held outdoors and exposed me to new information and skills. These sessions had a positive impact on my work as an informal educator. After the UNCG EE Team's second action-partnership was denied (the installation of a mini-pond at Lindley Elementary School), I set up composting stations and taught programs about earthworms and decomposition to young students. I continue to believe in the value of the certification program, and, in 2014, I completed the recertification process.

Susannah—August 2003–July 2012

After a few years, I was offered a promotion and moved back to the city (Raleigh) to teach students using a variety of technologies and tools. I traded the beauty and mystery of the national forest for an indoor classroom equipped with cameras, microphones, and monitors. I taught students from polluted streams and degraded habitats infested with invasive species. It was a major change, but it offered increased exposure to other agency staff, who could share their knowledge and expertise, and new opportunities to learn about exhibit design, marketing, and the inner-workings of the agency. This position also introduced me to audiences who had never ventured far from buildings and sidewalks, similar to many from my internships with Greensboro City Schools and the American School of Madrid—those who might most benefit from these programs.

Though this new position presented opportunities for networking and growth (and resume development), I missed the ability to build personal relationships with audiences from my previous position. Making connections with students, who were miles away and only partially visible on a videoconferencing monitor, was not as easy. Finding ways to bring the outdoors inside or to encourage students to explore on their own was another challenge. Occasionally, I was able to travel to the schools and visit in person, at which times I felt like a celebrity. "Didn't I see you on TV?" "I know you—you're the wildlife lady!" More often, I couldn't see the fruits of my labor. I couldn't always tell that these sessions made a difference for these kids. Sometimes, the classroom instructor or the technology facilitator would share stories with me about students' responses or reactions to the activities we did together, but it wasn't quite the same. In addition, I was experiencing frustration over delays to new projects and political shifts within the agency. I cared (and still care) about the overall mission and purpose of the agency but felt like momentum for growth with new audiences and improved outreach was being lost.

Catherine

In 2011, our National Science Foundation grant was funded and The HERP (Herpetology Education in Rural Places and Spaces) Project materialized. We were searching for someone who could work with us on web design and develop some specific herpetology education activities for web visitors. After some deep thinking, lots of suggestions, and two personal interviews, we invited Susannah to join us to design The HERP Project's Creature Feature web segment. At that time, we rekindled our relationship, and I saw Susannah off and on for a year or so. Her work as usual was excellent, and our project benefitted from her involvement.

Susannah—August 2012 to Present

Still determined to make a difference, and to make my way back to the western part of the state, I took a job as media coordinator at a small public school. The community is small, unemployment is high, and even though these students are surrounded by an abundance of forests, rivers, and mountains, many seem to know little about the value of these places. The potential for teaching and learning is great, and the small population makes it easy to forge relationships with my students. In my short time here, I have already witnessed positive changes in observation, awareness, and action amongst my students.

The lessons learned from my time at UNCG have continued to impact my work in the education field. I look for teachable moments. When digital photography students come to me looking for inspiration, we take the tools outdoors to capture bumblebees in flight. I try to make my conversations and instruction meaningful and relevant. I try to find partners from whom both the students and I can learn something new and, when trying to reach my students, I consider the moments that stuck with me from my own school experiences.

So, what have I learned? I've learned how to tell one frog call from another. I've learned how to age a turtle, a fish, a deer, and a dove (well, hatch year or post-hatch year). I've learned that there is always a great deal to be learned on the job, whether you accept a formal or informal education position. Learning about politics, communication, management styles, and adapting to changing expectations and evaluation can be challenging. I've learned that for me, it's essential that I love my work and that I feel I am making a difference (if even a small one) in this world. And many of these things I learned through the formal science education program.

Catherine

Susannah's journey has been fascinating. Always self-motivated and determined to pursue her dreams, she took advantage of every opportunity our university program offered. Six years after Susannah graduated from our program, Sadie started the program. Sadie's journey has been equally as interesting.

Sadie's Story—2004

During my first year in college I took a Conservation Biology class taught by Ann Somers in the most passionate way. I had come to college with an innate appreciation for the wilds of the outdoors and an excitement to take my basic knowledge up to a university level. While I never considered Biology as a career, I hoped that this class would allow me to speak more knowledgably about environmental issues and that I could translate that into my career in education. I knew that some children learned better when they were allowed to explore the outdoors and to touch, smell, and ponder all that it holds because I was that child. I chose environmental studies as my minor before I even committed to a major in education.

Sadie—August 2006

There I was, sitting in an auditorium full of education majors waiting to be divided into our teams. These would be the subject matter focus groups we had chosen to guide us through our last 2 years of college and most of our education experience. The room was huge and full of chatter and, somehow, I knew so few people and none who had chosen the same team as I had. I had initially decided, along with the few people I knew who were also pursuing an elementary education degree, to be on the Language Arts team and use literature as our foundation to build bright, passionate youth. We would have tons of fun reading and writing and doing all of the wonderful things elementary teachers do to bring books to life for their children. But, somehow, last year, when I was handed the piece of paper and those four check boxes sat there looking so informal, I didn't choose Language Arts. I had not faltered, questioned, or spent one second of thought on it, and I had happily checked the Science box. This was definitely not something I had considered, but my quick decision did not faze me at all; I was going to be a scientist! The choice was made so instinctually; I couldn't even recall it then.

Thinking back now, I am sure that the time I spent outside as a young person influenced this decision. I know that the times I was allowed to explore the woods on my own and the moments I was lucky enough to spend with educated adults in the outdoors had a huge impact on how I viewed the world. You learn lessons in the outdoors that you might never learn in a classroom. I realize now that I chose the science team because I wanted to be able to be the one to walk with young people and open their eyes to the excitement and magic of the natural world, because it might just be the spark that instilled in them the life-long love of learning that I have felt.

I was on the right track. My choice did come as a shock to the friends I had met in the short internship we were allowed to do in our sophomore year before being admitted into the School of Education. It also came as a shock to my mother, with whom I was very close and had talked to many times about the excitement of reading and teaching my students though story. Everyone was shocked but me. But even though I was just as surprised that I hadn't chosen Language Arts, I was content and knew, somehow, that I had chosen correctly.

I was confident in my decision to be on the Science Team until I was sitting in the auditorium and happened to glance to the back of the room and see the professors waiting to take their teams to their classrooms as they were called. I tried to decide who would lead the science team and scanned the professors hopefully. I've always loved the excitement of the first day of school. I love the smell of new pencils and notebooks and that first meeting with your teacher. Though, since my second grade teacher had called me a sunflower on the first day of school, I had also been wary of those teachers who tried too hard and never quite made that connection with their students.

I could detect pretense and was prone to being quickly unenthusiastic if I thought the teacher did not know their stuff. So, during a lull in the program when we were allowed to chat for a minute, I scanned the professors, analyzing them and trying to see who looked scientific. Suddenly a laugh bubbled up in me so quickly I couldn't help it and burst forth completely unexpectedly. A professor in the back of the room, standing just like the others, quietly waiting for their turn to take their students for the next 2 years of their education, was wearing a hat with big bug eyes and a wide-open mouth—a frog hat! As soon as the laugh escaped me, I wished I could put it back in; this was not a funny moment. This was surely the leader of the science team, my leader. The leader I knew would treat us as children, and play silly games, and from whom I was sure to learn nothing.

This did turn out to be our teacher. However, something unexpected happened when we got back to the room that would serve as our main meeting place for the next 2 years. After a short introduction of herself and the doctoral student who would be co-leading the science team, she let us talk. We wrote facts about ourselves and had snowball fights with the wadded up paper. We laughed and learned names and strange facts about each other and the nearly thirty of us became quickly just as comfortable with each other as if we had all decided to join the science team together. She had removed her frog hat after a quick laugh and was teaching us how to work with children through example. Her class had turned into what we all hoped we could develop in our own classrooms 1 day: trust and collaboration and excitement for what came next. This was a big lesson—first impressions are not to be trusted.

Over the next 2 years, we learned how to be confident, hands-on teachers who led their students to great discoveries through a wonderful variety of methods. We became experts in higher order thinking and creating an atmosphere of inquiry-based learning in our classrooms. This knowledge came through formal observations of our lessons as well as activities led by our instructors that were designed to teach us how to facilitate an active learning environment. We became comfortable teaching in our classrooms but also taught in outdoor classrooms, on nature walks, and through games and a variety of other venues.

Catherine's Reflections on Sadie—August 2006

Long, bright, red hair everywhere and an environmental studies major! Sadie, like Susannah, had had my colleague, Ann Somers, for a freshman class in Conservation Biology, Biology 105, and this redhead was in love with the environment, a perfect match for our elementary education professional development school. Though not shy, Sadie was not too assertive, especially with children. She enjoyed their antics way too much, especially at the beginning of our 2-year program and especially given our expectations of young children in public schools.

An environmental studies major (maybe our first) and someone with a deep interest in EE is always a welcome addition to our team of elementary educators. While many (well, most, we hope) of our students come to appreciate our work over our 2-year program, many students don't necessarily arrive with a deep appreciation of EE, environmental science or environmental studies.

Sadie—January 2007

While I was in the School of Education, I was also pursuing my minor in Environmental Studies. This concentration paired perfectly with being on the science team because, through the minor, we explored past and present issues and legislation in the environmental world, while on the science team we were working towards our EE certification that focused on how to be effective educators about these issues. Environmental studies and the issues with them had always been close to my heart, and I realized that by combining my love of the natural world with education, I came away with a social understanding of what was happening in the environmental world as well as a clear foundation for how to educate others about it. This connection also proved rewarding by introducing me to people and experiences that I never would have had without it.

I was introduced to conservation biology during a class, which focused on all matters conservation related, my freshman year and I fell in love with the subject. This led me to contact the professor and learn about a conservation class that was only offered every 2 years called *The Biology and Conservation of Sea Turtles*. This was a class with a specific application process that required you to write a letter of interest and include three letters of reference. It was a high requirements class and most students were Biology majors. Forty-five percent of the grade was determined by classwork; you were expected to learn the history and biology of the seven species of sea turtles and evaluate their current status on the endangered species list. The final 55% of the grade came from field studies in a local North Carolina Sea Turtle Rehabilitation Hospital and a trip to the Caribbean Conservation Corporation Research Station in Costa Rica to collect data on nesting sea turtles including egg counts, body dimensions, and species identification and to install a small identification tag for researchers to use the next time they nested. Sign me up!

It was a defining moment in my life and truly changed how I saw myself. In my application, I passionately wrote about how I could use this experience as a way to reach youth on a much deeper level in a non-traditional way. I had just begun my time in the School of Education but I knew how powerful this experience could be for a teacher. Ms. Somers accepted my application and 12 others that year, including a middle school educator, many biology majors, and a nursing major. I was not a biology major but she realized that education is the most powerful tool in any environmental issue and that I was in a position to educate others about how great an environmental threat sea turtles faced. This was exactly the case.

While we were asked to memorize the scientific names of the turtles, specific behaviors of each, and trends in international species relations, we were also asked to design a service project on an environmental topic of our choice. I can still tell you the scientific name of each sea turtle, because it took much more work than the service project did because I was stepping out of my small circle of knowledge.

For the service project, we were allowed to design our projects individually but our group realized that if we came together as a team we could impact a much wider audience. My classmates and I worked together to create an Earth Day event for underserved youth in our county. The youth were urban youth from a local Boys and Girls Club. Most of these young people grew up in the city where there are very few natural areas left to safely explore on their own so they did not have a strong connection with the natural world, and, collectively, our class knew that it was good experiences in nature that would help develop an appreciation of the natural world and lead to fond memories later in life. We designed a number of hands-on activities in a number of environmental fields. We created stations for students to travel through including seining (walking through the water with a net (a seine is a fish net) to catch aquatic animals), identifying macroinvertebrates, and fishing. We invited environmental experts to provide connections and serve as role models so that these students could see that these were jobs that they could pursue after high school and college. We had tracks, pelts, snakes, and many other wildlife experiences for the students as well.

The day was a wonderful experience for the youth we hosted at this event but it truly made an impression on not only the youths' lives but on each of our lives too. Our class of twelve college students showed ourselves that we were able to coordinate an event that these kids would never forget; they were ecstatic to be outdoors and learning about their world. Later, on the science team, Dr. Matthews would tell me that sometimes it isn't about teaching the kids you work with a specific task or fact to memorize; the most important thing may be to simply give them a good experience in nature. This hit home with me and I realized that this is exactly what we had done with this group of kids. This may have been the very first experience they had with the natural world and it might have been just what they needed to spark a connection with their environment.

Catherine

Sadie is our only undergraduate to make the trip to Costa Rica in 20 years. I will never forget that red hair flying everywhere—whether it was at night as she walked in the wind to the ephemeral pool, or during the day as we boated over to Carrot Island on the North Carolina coast, and always with a smile hiding somewhere just behind the hair. And that giggle; everything is fun and everything is funny to Sadie Camfield Payne. We all reveled in her joy either together as her team leaders or privately as we remembered times in our own lives when we had had similar responses to just plain living.

Sadie was an enthusiastic participant on all of our environmental adventures—to vernal pools, streams, and the coast. Sadie's cohort was visiting a local stream when we found ourselves standing in a rainstorm beside an urban stream that suddenly deepened by a quarter of inch, a half-inch, an inch and then inches. In 30 min or so we were fighting for footholds on a very slippery slope and we were loosing the fight; so, we made a decision to call an end to this particular field trip. Once again, that red hair, drenched and plastered to her scalp, framed Sadie's giggling profile. She had no fear.

Sadie was able to link our outdoor experiences to more traditional learning. She attended all of our environmental education activities included as a part of the 2-year PDS experience, completing 10-h workshops including *Project Wild*, *Project Wild Aquatics*, *Outdoor Skills* (Salamander Workshop) and 6-h workshops on *Project Learning Tree*, *Project WET* and *Population Connection*. Many of these workshops have an outdoor component, and I spent time with Sadie in vernal pools, forests, and a cattail marsh and watched as she thoroughly enjoyed the mud, the ice, the animals, and even the briars. Her sheer joy while engaged in these activities is something I will always remember about Sadie.

Sadie—August 2007—May 2008

In my final semester in the School of Education, I completed my student teaching in a kindergarten through fifth grade science lab in a Science and Technology Magnet School. This meant that science was expected to be taught in all classrooms and also taught as an elective in the science lab. I taught 45-min lessons to each class in the school once a week, and, through this experience, I learned so much. I collaborated with each teacher and grade level to plan lessons that correlated both to the *Standard Course of Study* and the grade-level pacing guide. Lessons needed to be engaging, hands-on, and effective—the qualities of any educational program. You do not want an elective class like the science lab to be seen as just playtime. This was a truly intimidating prospect, but I will never forget what our professors told us. They said that when we were nervous or unsure of ourselves to remind ourselves that we were the teacher. No one could take that away from us and at the end of the day we had to convince ourselves of that first. "You are the teacher." Try it, just once. It helps. "I am the teacher."

During my student teaching, I learned a great deal from the teacher whose position I was now sharing. She showed me resources for materials, lessons, and hands on experiences as well as how to write grants for further resources to enhance the students' engagement with the content. I'll never forget the unit I taught with her guidance on the human body. The students made lungs out of balloons and plastic water bottles, heard the heartbeat of a mouse and an elephant, and, when my supervising teacher said we should bring in a cow heart to demonstrate the chambers and arteries, I was a little shocked but definitely excited! I picked up the heart from a local meat processing plant, and it filled an entire cake pan and was heavier than I imagined. When I brought it to school, students put on latex gloves and examined the huge heart while I passed it around the tables. These experiences made the content real to the students and ignited their excitement for learning.

The science team taught us to create hands-on learning experiences in our classrooms that would teach students the basic skills they needed to move on to more advanced science in middle and high school without intimidation. But, these experiences also ignited excitement for science and learning that stayed with them through the years to come. Inquiry is a huge part of learning, as are building connections with the world around you and processing information. Being a part of the science team taught us to build inquiry into as many experiences as possible in a way that engaged the students and allowed them to explore concepts in their own way.

Catherine

As a part of UNCG's program in teacher education, Sadie completed three internships in Guilford County Public Schools, each 10 h a week for 15 weeks. She completed internships in a Kindergarten class at Lindley Elementary School and a second grade classroom at General Greene School of Science and Technology (first and second semesters of her junior year). She completed a yearlong experience in the science lab at General Greene during her senior year, interning in the fall and student teaching in the spring. At her teaching placements, Sadie taught all subjects and offered different activities to keep students actively engaged with the instructional material. Sadie's instruction was creative, student-centered, and involved risk taking on her part. Sadie loved the science lab, although she still had to struggle to stifle the giggles of joy inspired by the not always appropriate antics of young children.

Sadie—May 2008

Blending my environmental studies minor with my love of education led me to pursue my Masters of Natural Resources at North Carolina State University. I still carried that spark and love of learning that I had when I began my undergraduate studies. However, I worried that I would be too busy to make the decision to go back to college once I began working, so I chose to go straight from undergraduate into graduate school. This decision was solidified by the state of education in North Carolina. I knew it was extremely difficult for new teachers to find jobs and, as positions were cut, it was the new teachers who were the first to go. I hoped taking 2 years to make connections and pursue my master's degree would make me more marketable even if the state of education had not recovered by the time I was ready to teach.

Becoming more marketable once I was ready to teach was also a part of the reason I decided to study Natural Resources instead of continuing with a degree in education. In fact, I believe that it was this degree that got me my first job as a middle school science teacher when I graduated. The education market had not changed, and jobs were still scarce. I applied in places 3 h apart, but the pool of applicants was large while the positions were few.

Catherine

Sadie graduated in May 2008 with a degree in Elementary Education and a concentration in Environmental Studies. Then, she completed her master's degree in Natural Resources at North Carolina State University, where she did a study of *Project Learning Tree* materials around the state for her master's project. Sadie's master's project focused on evaluating *Project Learning Tree: Tree Trunks* to determine their potential as resources for quality, accessible EE tools. I agreed to serve on her committee if she would agree to pursue publication of any relevant findings. Her findings were interesting (if expected) but she has yet to consider publication of this work. However, now that we will see 'this' piece in print that will suffice.

Sadie—August 2010

I accepted a position at a middle school teaching sixth grade science. I loved getting to know my students and the experience of teaching solely science. If I had returned to an elementary school, I would have had to teach at least two, if not four, subjects (Language Arts, Mathematics, Social Studies, and Science). It felt like going back to my student teaching days where I could teach exclusively science and make it as creative and hands-on as possible while integrating the other subjects into my lessons. When I was encouraged to pursue my middle school science certification I saw it as an opportunity for professional growth. I was happy to take the praxis exam and to add another certification to my license, especially since I enjoyed my position and wanted to secure it a little more.

Sadie—August 2012

I taught 6th grade for 2 years, and the year after I completed my middle school certification, I was moved to eighth grade science. I saw it as a challenge to grow as a teacher and exciting to be able to teach the same students I had during my first year of teaching. I would never be the educator I am today without having the experience of teaching eighth grade, but during that year I realized what I had feared going into education.

I had heard many stories of teachers leaving the profession in their first 5 years, and I always prided myself on not being a statistic. During my 3 years of teaching, I had created an afterschool wildlife club for students, served on many committees and chaired more than one, revised the county pacing guide, and I had become the county middle school science academic coach. What troubled me the most that year was the fact that I was losing sight of why I had become a teacher. It was my own love of learning and excitement for reaching students that inspired me, yet that was suddenly what I felt I had the least amount of time for. I no longer felt that I was truly giving the students what they needed and considered a move back to my roots in elementary education. There I thought I could integrate the subjects into lessons that stretched beyond a state's mandated tests and reach the students themselves rather than just raise test scores.

As I continued to teach, I realized it was the system of formal education that was making me feel burdened. Test scores and data swam in my head at night, and it began to show in my lessons. No longer were they truly experiential; there was not time for that. My students scored well on their End of Grade tests, and this seemed to be what the administration felt was most important. But I no longer felt like I could reach every student in their own learning style at the pace they needed. The moment I realized that, I decided I needed to transition to a job outside of the school system. As soon as I realized I was not going to be able to give the students what I hoped I could, I began looking for a way I thought it would be possible. That way in my mind was still through education, but it was outside the classroom.

My decision to move from formal education to a non-formal education position was the hardest of my career. Halfway through my second year of teaching eighth grade science, I was offered a position in 4-H Youth Development with North Carolina Cooperative Extension working specifically with underserved youth. My heart skipped a beat at being able to reach more young people at a deeper level; it also sank at the thought of leaving my current students I had invested so much in that year. The relationships I built with the students were why I knew I had to move on but also what made it so difficult to leave. Having more than thirty students in a class for only an hour a day did not allow me to reach the students at the level I felt they deserved. I wanted very badly for them to succeed in science, but more than that, I wanted them to realize the love of learning that so many teachers helped me discover as a student. I hoped I could instill the same love that took me into education.

Sadie—December 2014 to Present

In my new position, I do not have four classes of thirty-five to reach; I have an entire county. As a 4-H agent working with the underserved youth of our community, I am charged with giving kids of all ages a learning experience that goes beyond a 1-h session ending with a test. The 4-H goal is to expose children to experiential, hands-on learning in the areas of science, citizenship, and healthy living and to give them an experience they may never have had before in hopes that they might discover something new about themselves, what they hope to be when they grow up, or even a new perspective on their community and how they are a part of it. These experiences may lead them to the idea of college or spark the idea of a profession they may never have considered or even known about before. Attending college is not the ultimate goal though; the goal is to bring the light of learning to someone else, just like those great teachers brought it to me—To inspire students to dream, to show them what their future could hold while supporting them in all that they are going through today. These goals were the same ones I had in a classroom but I felt stifled and strained by so many other tasks that had been given priority, not by me as the teacher, but by the demands of public schools. In my new position, it is my hope that I will be able to accomplish, or at least get a great deal closer, to my original goals, and I have found that without my background in formal education, I would be grossly unprepared to do the job I am in now. However, this was not obvious to me at first.

Going into this case study of my experiences, I honestly did not know what connection I would make between my formal education in the education department at the University of North Carolina at Greensboro and my recent shift to an informal education position as a 4-H Extension Agent because I had yet to discover what this job truly entailed day-to-day. I knew my new colleagues kept spouting their excitement that I had been a teacher and would approach this job with my previous knowledge of working in a classroom and with other teachers, and I began to get nervous. So I waited. I waited for inspiration to strike, at work, maybe, or at home where I could clear my head. In the middle of my befuddlement, I had to attend a workshop to complete my EE Certification, which I had begun during my time on the science team but did not complete. It was a Friday night and full Saturday workshop that fell right in the middle of my frenetic search for deeper understanding about this new position in informal science education and enlightenment about why my new colleagues were so excited about my teaching background. It was here of all places where I cleared my head. It was laughing with these like-minded people from all across the state that showed me right where my place was and how wonderful it was to have arrived there.

There were 15 of us who had committed our precious weekend to this workshop. We had all completed the required 10-h independent study of historical ideas and legislation in EE and were ready to be taught how to actually put the theories we had read and written about into practice. We were tired from working all week and driving, some of us for over 3 h, to be there. Only four of the fifteen participants had been formal educators, and only two were still in the classroom. The other eleven participants were a mix of non-formal educators from all walks of EE. Some of these individuals were State Park educators who led groups of all age and skill levels, while others were science center program directors, students still finding their path, or those near retirement who had traveled many paths. No matter our background, we were teachers. Each of us wanted to learn how to deliver effective EE to our audience. Each place around the table held for its student a freshly sharpened pencil and a *Methods of Teaching Environmental Education* booklet. We had been told that this was to be a much different workshop than the previous hands-on workshops we had all attended to receive our certification; we were here to work.

Just as we all got settled and our yawns were getting long, our two teachers stood us up and took us outside. We laughed and played games that taught us everyone's name and helped us make connections between those who had been strangers just a minute before. We forgot we were learning. The instructors had begun the workshop in the same manner that my professor had in the school of education at UNCG. They were teaching us how important it is to build a relationship with our groups by letting us experience what a difference it made to our attitudes about the workshop. Suddenly we were talking to those around us, making connections, and exchanging business cards so we could chat some more. We were hooked, just like they knew we would be, just like I had seen before on my first day in the School of Education.

As the workshop evolved, we learned in a way that was very similar to the instruction I had received as an undergraduate in the School of Education. We addressed multiple learning styles, planned for the diverse groups we might be asked to teach, designed lessons, taught the lessons to our new peers, reflected, and, of course, assessed the lessons. To be doing all of this for something as informal as EE surprised me at first. I realized later that it only surprised me because Dr. Matthews had made these tasks second nature to us in the School of Education. To me, this was how all lessons and programs should be conducted as an educator. It allows the students to gain the most out of your program or lesson as well as allowing you, as the educator, to assess knowledge and understanding of your group in a well-organized fashion. But the real surprise was how difficult most of the group found the workshop. Except the four of us with formal education experience, everyone spoke of how they were overwhelmed by the new ideas and ways of leading their groups. They needed more time to decompress during our lunch break and asked question upon question about how goals related to objectives and how to assess them and still left feeling like they had to go home and study their booklets before their next day at work to fully grasp it. The four of us who had taught in a classroom suddenly became the group leaders, guiding the others through the process of lesson planning and evaluation. It was then that I knew the true impact of the School of Education on my life as a non-formal educator. I was miles ahead of those very competent educators who had never had a background in formal education. While they were trying their very best to decide how to write a lesson plan for their programs and incorporate higher order thinking, the few people who had come from formal education in the group were more than ready to put our knowledge into practice and move on.

When I first met my husband, well before I knew he would become my husband, he asked me a funny question. What would I be if I were not a teacher? Would I be a nurse, work with animals, be a businesswoman? I had just finished graduate school and was looking as hard as I could for a teaching position and the question struck me as strange. What would I be? "I am a teacher," I said. And that was that: I am a teacher. Educators in an informal setting need the same skills as a classroom educator. They need to know how to structure their lessons with specific goals and objectives, to manage a group, to reflect on their lessons, and to plan developmentally appropriate lessons. I know for certain that my programs, both as a formal educator and a non-formal educator, have been strengthened by the fact that I was taught in a formal education setting. No matter what your job, if you are working with children, you are an educator. It can only help to have been taught that way.

Catherine—October 2013

Ms. Sadie Payne applies for and is hired to become a 4-H Youth Development Agent with The Cooperative Extension Program at North Carolina Agricultural & Technical State University. As a part of my recommendation letter, I wrote, "Sadie is passionate about teaching and the environment. She is an excellent candidate for a 4-H Youth Development Agent. She is bright, energetic, enthusiastic, positive, easy to work with, responsible and reliable."

Sadie—Present

I conducted my first program as a 4-H Agent at a Boys and Girls Club across from UNCG. Our programs are not created based on Common Core or Essential Standards. They are guided by the principals of 4-H and the needs in the students' community. We started a gardening club for a handful of interested students, and we wanted to get the entire club involved for the garden dedication. I knew from my time on the Science Team in the School of Education how powerful a connection could be between youth and the outdoors. I believe so strongly in the power of this connection because I watched it develop in myself as a child and adult. As a teacher, I created a Wildlife Club for our middle school where we explored various aspects of wildlife, forestry, and our natural world. I watched students with severe ADD in a classroom become calm leaders and others who didn't fit in become confident in their skins. I knew this program could reach the underserved urban youth of the Boys and Girls Club in a meaningful way and help address problems of health disparities, obesity, nutrition, and even help improve their scores in school and understanding of entrepreneurship.

We decided to celebrate the beginning of the garden during National Gardening Month and National EE Week to build excitement and momentum for the garden project that would continue throughout the year. I worked with their program director to plan environmental themed stations for the 60 kids that are regulars at the Boys and Girls Club. My energy was focused on developing engaging stations, organizing volunteers, and making sure everyone had their materials and were ready for their kids. I was to be the floater to make sure no one had trouble with a station and everything moved along smoothly.

Needless to say, the best-laid plans are the ones destined to go awry. Volunteers were late and the hardware store that had donated the beds, the seeds, and the transplants for the day had canceled their lesson because they were understaffed and couldn't let anyone leave to come do a program for us. Without even thinking, I jumped up on the edge of the raised bed in the very center on the garden, my heels tickling the soft dirt behind me, and started the 45-min gardening station on my own. "If you can hear me, clap once!" "If you can hear me, clap twice." I didn't have to whisper or shout because everyone had clapped and wanted to know what I was going to do next; this made me smile and I knew I had them. "If you can hear me, wiggle your toes and touch your nose!” Giggles rang all around and we sunk into the beds and got our hands dirty and started the lesson.

I am reminded daily how valuable my background in formal education is to my current position as an educator outside the classroom. This is mostly because I continually take it for granted that everyone I work with has a similar background upon which to build. It still surprises me when this is not true. I recently attended a required training for my new position, which took place over a whirlwind 3 days. I expected the training to revolve around how best to reach my low income audience, how to recruit volunteers in limited resource areas, and how to best manage the program I was creating in my county. However, the entire first day of training was devoted to strategies that we could use with youth. This included behavior management, learning styles, experiential learning, 21st century learning, and developmentally appropriate concepts for varying ages of youth development. All of these topics, ones that I had been taught in college and applied each day as a teacher, were being busily scribbled down by my new colleagues while I answered questions on best practices as if I was following an old familiar script.

What astounded me the most was that I felt over-qualified to do a job I was not even sure how to do. I knew how to reach youth, but I did not know how to develop a program that required me to recruit volunteers, plan events, and juggle fifteen different clubs at once. Because my experiences on the science team took us to a multitude of teaching settings, I am prepared to teach in streams, fields, wetlands, and on trails and in the weather, whatever kind of weather it might be. Dr. Matthews used every opportunity as a teachable moment. If a spider web caught her right in the face on a trail she would just pull it right off and move on, letting us know that we couldn’t scream and scare our students even if we were terrified of spiders.

I’ll never forget doing the Project CATCH workshop with the science team. We were fishing all along the bank of a pond and I let my line out accidentally before I had cast. When I looked down to see it crumpled on the ground I also noticed what it was on top of—a snake! I had been fishing with this guy (or girl?) and had no idea s/he was curled up at my feet. Dr. Matthews gathered us around, showed us the proper way to handle a snake and proceeded to teach us about this one. The smell of the musk he put out when she handled him surprised me, but it was no worse than fish bait!

These teachable moments and diverse experiences taking our classes outside the walls of a classroom allow me now to have no fear of taking youth outside as well. Coming into this new job, I knew how to engage children and manage their different needs from my time in formal education. I knew when to present new ideas to keep the spark alive and when to delve deeper into a topic even when your lesson plan did not leave room for it because it was going to be the thing that the kids truly needed to connect with the lesson. To me this was basic. How could you be a youth development professional without this knowledge? I realized that our trainers knew this too. They knew that whatever else we had yet to learn about our new profession would fall into place, but if you did not have the background on how to work effectively with children by creating lessons based around proven pedagogy, then your programs would not succeed no matter how hard you recruited, juggled, or planned. It just so happened that I already had that background and had a huge head start.

While on the PDS Science Team, we completed many of the required workshops to earn our EE certification. During my student teaching at General Greene Elementary, I partnered with a fellow student teacher from our department to improve the school's existing nature trail that we used often during teaching. For this project we created stations at different areas of the trail, using mailboxes as a fun way to hold information, materials, and educational explorations for teachers who brought their students to the trail. The idea was that we could make the trail more approachable to all teachers by taking away the guesswork of what to do once they were there, hopefully leading to increased use of the trail by the entire school.

While this project was being completed, I accepted a volunteer position in Greece that began immediately after the school year ended. I worked with a conservation group that focused on educating the public on the endangered sea turtles and the huge tourist impact on the beaches. We also conducted night patrols and nest-monitoring surveys to collect data on the number of turtles that nested and their health.

After I returned from this 6-week volunteer trip I began my master's studies at North Carolina State University and my nearly completed EE certification reached the end of the 5-year time period for completion. In 2012, I restarted my certification, taking many of the same EE courses that I took on the science team, but with new eyes. I had been a teacher for a year and saw the true value that this certification would lend to my teaching and my students' learning. As of 2014, I am about halfway finished with requirements for my EE Certification, and I plan to do my community action partnership project with the local Boys and Girls Club's community garden I described earlier.

Cross Case Findings

From Susannah's and Sadie's stories, it is easy to identify common components of our formal Elementary Education program at UNCG. Both Susannah and Sadie chose to be on the Science/EE Team, and therefore their experiences were focused for 2 years on what might now be called value added components—opportunities to spend more time and focused energy on elementary school science and EE activities and experiences while earning their degrees to become generalists in elementary education. Both of these students spent three out of four semesters at a Science and Technology Magnet School, and both of these students spent at least one semester in the Science Lab at General Greene, School of Science & Technology Magnet School.

As working professionals reflecting back on their formal teacher education preparation, both students identified common elements of their programs that have clearly and positively impacted their careers as informal educators: experiences in the out-of-doors, experiences with children in the out-of-doors, inquiry-based instruction, opportunities to share their knowledge with others (children and adults), and the ability to locate resources and needed information.

Both Susannah and Sadie left our program knowing essential skills for effective instruction. These are their words: “Know what you want to accomplish and what you want your learners to accomplish; know your audience: what they care about, why they come to you, what they know, and what they want to learn; know how to effectively engage your audience; make your instruction collaborative and exciting; and use inquiry-based instruction.”

The literature is abundant with examples of informal science education in formal science education programs as described in the following paragraph. The literature is also clear about why ISE should be included as a part of a formal science education program. In the chapter, “Informal Science Education in Formal Science Teacher Preparation” in the *Second International Handbook of Science Education* (2007), McGinnis and his colleagues report what is known about the use and the potential of including informal science education in formal science teacher preparation programs; these findings are reported below.

Studies that have investigated the inclusion of informal science education events, opportunities, and activities in formal teacher preparation report a number of perceived benefits including positive attitudes, greater interest, more excitement, more confidence, improved pedagogy (specifically the use of theory in practice, collaboration, teaching for all, classroom management, and resource management), more well developed science skills, deeper knowledge, and broader perspectives on science teaching and learning—in essence a stronger science identity for these elementary school teachers.

Informal science educators argue that formal science education students should take greater advantage of the opportunities that ISE offers. Because science content is often repeated frequently in ISE settings, students have many opportunities to test different teaching methods with similar content. Additionally, spending time in ISE settings provides many opportunities to see science inquiry in action. Visitors to ISE institutions are often diverse, so students learn to address the needs of people who range in age, gender, learning needs, and interests.

However, McGinnis et al. (2012) report that there are also challenges when incorporating ISE components in formal teacher education programs. These may include a content focus that is deeper or narrower than typical school science and a lack of focus on formal assessments. Audiences may be less diverse than typical classes of school children, and the instructional time frames may differ considerably.

While the literature is abundant with calls for including more informal science education in formal science education programs, less common is the notion of how formal education might prepare informal science educators and what the advantages of such a program might be. As students’ stories demonstrate, formal science programs are relevant and provide valuable information for individuals who are interested in careers as informal science educators.

Bevan et al. (2010) suggest that informal science educators, who often work with formal audiences, need professional development that addresses the nature of work with schools and teachers, including school policies, assessment policies and trends, theories of learning, program design, and evaluation. However, informal science educators who participate in formal science education programs may find that instruction is constrained by testing, lack of creativity, or pressure to cover certain material in a specific period of time. Informal science educators may be surprised by school system policies that do not permit field trips or require schools to pay for field trips and buses to transport students to ISE settings. University teacher education programs typically do not allow future teachers to fulfill their student teaching or even internship requirements at an ISE institution.

Beyond many shared content and practice goals for science education, informal environments often value—and specifically strive to foster—capabilities and affective outcomes that are unlikely to register on school-based assessments of learning. Several reports from the National Research Council, particularly *Taking Science to School* (2007) and *Learning Science in Informal Environments* (2009), attempted to consolidate the outcomes of learning in informal science settings by synthesizing the current body of research and evaluation studies from out-of-school and in-school learning. *Learning Science in Informal Environments* (2009) categorizes the following six strands as a set of goals and practices for science learning in ISE:

Strand 1: Sparking and Developing Interest and Excitement
Strand 2: Understanding Science Knowledge
Strand 3: Engaging in Scientific Reasoning
Strand 4: Reflecting on Science
Strand 5: Engaging in Scientific Practice
Strand 6: Identifying with the Scientific Enterprise

University Science Educator Patricia Patrick (personal communication, August 2014) suggests developing a teaching rubric that addresses these six strands of ISE in order to best prepare informal science educators and in order to take charge of any sort of impending certification for the ISE profession.

Bevan et al. (2010) suggest that while there are many examples of successful collaborations, they come and go with changes in funding or leadership. Additionally, they maintain that the hybrid nature of formal-informal collaborations make them fall outside of obvious funding categories, render standard assessment tools inadequate to document their effects, and challenge priorities of both formal and informal institutions, since this work appears to fall outside of the core activities of each institutional type. That has been my experience thus far.

To best prepare science teachers and informal science educators we need to work together. Each of our respective fields, formal science education and informal science education, has much to offer and there is a potential synergy that is lacking now. Formal teacher education has a focus on theory and pedagogy, elements that Susannah and Sadie drew on in both their informal and formal science teaching experiences. Understanding how and why people learn and want to learn and what they want to learn are all important theoretical concepts that are applicable to both schooling and informal science learning. The benefits that a formal teacher education program might provide to individuals who wish to pursue careers in informal science education are many: a grounding in learning theory, an understanding of pedagogy, a broad look at science and thus science education, education about science, a feeling for scope and sequence of developing conceptual understanding, some insight into motivational factors, and connections with the school community and the broader community. Susannah and Sadie certainly benefitted from our collaboration of formal science education and informal science learning.

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Chapter 20
A Comparative Look at Informal Science Education and Environmental Education in Bengkulu Province, Indonesia and North Carolina, USA

Aceng Ruyani and Catherine E. Matthews

In this chapter, we share our personal observations as well as a review of the literature on the implementation of informal science education (ISE) in the province of Bengkulu, Sumatra, Indonesia and the state of North Carolina (NC), United States of America (USA). We compare and contrast the ISE experiences available in NC with those in Bengkulu. The purpose of this comparison is to provide context for understanding how ISE differs in developing and developed countries. Additionally, we look at how universities and schools, parks (national, state, and local), zoos, and nature centers are or are not involved in ISE in both countries in specific states and provinces. In this chapter, we focus our consideration of ISE on conservation education and environmental education (EE), but realize that ISE covers the spectrum of the sciences.

To begin this chapter, we feel it is important to share details about our partnership, which has resulted in the co-authoring of this chapter, plus many other collaborative efforts to bring best practices in ISE (with respect to conservation education and EE) to Indonesia, specifically Bengkulu Province in Sumatra, and the USA, specifically the state of NC. The first author of this chapter, Aceng Ruyani, a science educator at Bengkulu University, Bengkulu, Sumatra, Indonesia, contacted Catherine Matthews, after getting her name and the project name from a public database on NSF-funded projects, to see if she would be interested in partnering on a grant he was writing to focus on herpetology education in Bengkulu. The second author of this chapter, Matthews, a science educator at the University of North Carolina Greensboro, is Principal Investigator on the NSF-funded ISE project, *Herpetology Education in Rural Places & Spaces*. The edited email of October 3, 2011 from Ruyani follows:

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> We (my colleagues and I) are preparing a project proposal focused on improving teaching methods for secondary schools through an outdoor science education program in order to develop students' appreciation for the relevance of science and the importance of local herpetology issues in Bengkulu City, Indonesia. In Indonesia there is a funding opportunity, Partnerships for Enhanced Engagement in Research (PEER) Program (http://www.nationalacademies.org/peer), which has a deadline of November 30, 2011. The proposal from Indonesia requires the involvement of a US collaborator (http://www.nsf.gov/awardsearch/). I looked at your project entitled "ISE Full-Scale Development: Herpetology Education in Rural Places and Spaces (The HERP Project) Award Abstract#1114558" and believe it has similar intentions to the project that we are proposing in Bengkulu. In my opinion, your experiences in North Carolina might be implemented to some extent in Bengkulu.

Matthews' response was affirmative and the partnership has continued with Matthews' trip to Bengkulu University for a week in 2012, Ruyani's nearly 6 week stay at The HERP Project's residential herpetology programs in NC in 2013, regular email contact, and a quick meeting in DC in June 2014 to work on preparations for this chapter. In August 2016, Matthews and two colleagues (one from the University, a biologist, and one from the NC Zoo, curator emeritus of reptiles and amphibians) spent 10 days in Bengkulu at the invitation of USAID, funders of the PEER Project. In October 2016, Ruyani then spent 2 and a half weeks in North Carolina, South Carolina, and Wisconsin targeting work on his funded proposal, "UNIB Campus, A Safe Home for Turtles".

This chapter provides an overview of conservation education and EE in Bengkulu and NC, focusing on ISE but also providing a glimpse at formal science education as well. Additionally, environmental concerns in both locations are discussed.

Introduction to Bengkulu Province, Sumatra, Indonesia

Bengkulu was, successively, a colony of Britain (1685–1824), the Netherlands (1824–1942), and Japan (1942–1945). After the independence of Indonesia (1945), Bengkulu became, first, part of Sumatra Province (1945–1946) and, then, part of South Sumatra Province (1946–1968). In 1968, Bengkulu was declared an independent province, divided into Bengkulu City, North Bengkulu, South Bengkulu, and Rejang Lebong. In 2004, Bengkulu Province was divided into 10 district governments: (1) Bengkulu City, (2) Seluma, (3) South Bengkulu, (4) Kaur, (5) Central Bengkulu, (6) Kapahiyang, (7) Rejang Lebong, (8) Lebong, (9) North Bengkulu, and (10) Muko-Muko.

Bengkulu, Indonesia, is located between 2° 16′ S and 3° 31′ S latitude and 101° 1′ E–103° 41′ E longitude. The eastern part of Bengkulu province is a hilly area that is dominated by the Bukit Barisan Mountains. The western part of Bengkulu Province is a low-lying area, with mostly residential houses and farms. The lowlands are adjacent to the Indian Ocean, creating a 525 km coastline. Bengkulu topography includes mostly lowlands (45%), hilly areas (40%), and steep slopes (15%).

Bengkulu Province borders West Sumatra to the north, the Indian Ocean and Lampung Province in the south, the Indian Ocean in the west, and Jambi and South Sumatra to the east. Bengkulu Province is a tropical region with temperatures between 23.3–31.4 °C. The highest rainfall occurs in June (490 mm) while the lowest rainfall is in September (53 mm). The average rainfall per year is 401 cm. In Bengkulu there is no clear distinction between the dry season and the rainy season. In low-lying areas, the temperature is hot, with a relative humidity between 82–85%, and these are ideal breeding conditions for mosquitoes. The province includes an earthquake-prone area, with earthquake activity reported 114–200 times a month. Nearly 2 million (1.7 million) people live in Bengkulu (and 50 million people on Sumatra). Bengkulu contains 7,691 miles^2 of land while Sumatra has 182,812 miles^2 of land. The population density in Bengkulu Province is 220 people per square mile (Indonesia Population, 2014). Most Indonesians are Muslims (87% of the population on Sumatra is Muslim) and do not eat pork. Sumatra is not a popular tourist destination. Other areas of Indonesia, such as Bali on Bali Island, have many more tourists.

Introduction to North Carolina, USA

North Carolina, a former English colony before it declared its independence in 1776, is located on the southeast coast of the USA and is considered a mid-Atlantic state. Its latitude is 34° N–36° 21′ N and its longitude is 75° 30′ W–84° 15′ W. North Carolina is bordered on the east by the Atlantic Ocean, on the north by Virginia, to the south by South Carolina and Georgia, and to the west by Tennessee. Nearly 10 million (9.8 million) North Carolinians live on 53,821 square miles of land. The population density in NC is 182 people per square mile of land. NC has varied topography: the coastal areas in the eastern part of the state (45%), the foothills in central NC Piedmont (35%), and the Appalachian Mountains in the western part of the state (20%).

The Piedmont and coast have a humid subtropical climate, while the mountains have a subtropical highland climate. The temperature generally ranges from 32 °C in the summer to 10 °C in the winter. Annual rainfall varies between 114 and 127 cm, with most rain occurring in the summer. In most parts of NC, there are four distinct seasons. The relative humidity in NC is high, especially in the summers. North Carolina, with 100 counties, is the 28th most extensive and the 10th most populous of the 50 United States. North Carolinians are mostly Christian and the state is a part of what is often referred to as the Bible belt. Hog farming in NC is the second largest domestic livestock operation in the US. Thunderstorms occur in spring and summer, tornados in summer, and ice storms in winter. Several natural features are among the state's major attractions: the Great Smoky Mountains National Park, the Blue Ridge National Parkway, and the Cape Hatteras and Cape Lookout National Seashores.

Environmental Threats in Bengkulu and North Carolina

In the province of Bengkulu, as in other provinces in Indonesia, and in NC, and other states in the USA, there are conflicts between short-term economic interests and efforts to preserve biodiversity. Major environmental issues in Indonesia are deforestation, wildlife trade, the exploitation of marine resources, and pollution from industries and farming (The World Wildlife Fund Borneo and Sumatra, 2015). In Bengkulu, deforestation is the number one problem, because short-term economic interests are dominant and land is rapidly being converted into plantations and mining regions. Palm oil, chocolate, tea, and rubber plantations and coal, gold, and titanium-rich iron mines in the past fifteen years have had significant effects on the economic profile of the community and the local government in Bengkulu. The raw materials (palm oil, chocolate, tea, rubber, coal, gold, and titanium-rich iron ores) are all typically exported to other countries. They are not processed in Bengkulu, only harvested (Environmental Problems in Indonesia, n.d.).

The state of NC has suffered sewage discharges, storm water overflows, and coal ash pond leaks into its rivers. Threats of hydro-fracking for natural gas and ongoing water quality and air quality issues associated with large animal operations also threaten the state. Recently, North Carolina has been steeped in controversy, pitting environmentalists against economists; governmental officials have been accused of manipulating a governmental website to downplay issues such as climate change and sea level rise (Climate Progress, 2014). North Carolina's Department of Natural Resources website, http://portal.ncdenr.org/web/guest/important-issues, lists the following as important issues: storms, drought, coal ash, the Dan River spill, and oil and gas exploration programs. Nutrient inputs from cities and farms, pesticides from these same polluters, and toxic wastes from industries all threaten NC's water supplies. Acid rain, combined with damage by the invasive wooly adelgid (*Adelges tsugae*), and harsh environmental conditions in the NC mountains, have led to the decline of coniferous forests (Global Invasive Species Database, *Adelges tsugae*, n.d.). Invasive species are moving from many geographic directions into and around NC, threatening the native flora and fauna. According to ecologist Dr. Stan Faeth (Personal Communication, August 13, 2014), invasive species are NC's biggest environmental threat. For additional information on invasive species, see the Global Invasive Species Database online at http://www.issg.org/database/welcome/.

A Comparison of Bengkulu and North Carolina

Both geographical locations provide varied topography with coastal and mountainous areas. Both areas have a fair amount of forested land, 60% for NC and 46% for Bengkulu. Population densities are somewhat similar, though Bengkulu is more densely populated than NC. Twenty percent of the population of Bengkulu lives in poverty (World Bank, Population, 2015), while 17% of North Carolinians lived in poverty in 2012 (U.S. Census Bureau, North Carolina QuickFacts, 2015). Bengkulu is much smaller than NC, but Sumatra is about three times larger than NC. Agriculture and wood products are mainstays of both economies. Both areas have fragile environments that are threatened by increasing populations of humans who tend to fragment the land and exploit the natural resources. Air, soil, and water quality are threatened in both areas.

Formal and Informal Science Education in K-12 Schools and Universities in North Carolina and Bengkulu

Typically, NC students score in the midrange on international tests in mathematics, science, social studies, and literacy. Indonesian students score near the bottom. The USA is above the TIMMS Scale Centerpoint at all grade levels in mathematics and science, while Indonesia is below the TIMMS Scale Centerpoint at all grade levels in mathematics and science (Mullis, Martin, Foy, & Arora, 2012). The literacy rate of North Carolinians is about 86% (National Center for Education Statistics, 2003), while in Bengkulu the literacy rate was reported as 95% in 2011 (World Data Atlas, 2015). According to the 2000 Census, 22% of North Carolinians over the age of 25 did not have either a high school diploma or a GED (NC Literacy Organization, 2002). From 2009 to 2013, the percentage of all North Carolinians over 25 years old with at least a bachelor's degree was 27.3% (IndexMundi, 2016).

Although the Indonesian government has tried to improve living standards by requiring all Indonesian citizens, 7–15 years old, to complete elementary and junior high school, the reality in Bengkulu in 2012 was that 4% of children had never attended school. Higher education is still quite expensive in Bengkulu, so in 2012 only 6% of the population were university graduates.

Education in general is nationalized in Indonesia but not in the USA. The central government in Jakarta, Indonesia determines the curriculum, procures teaching materials, and conducts national examinations for certain subjects. Therefore, most provinces in Indonesia offer a similar formal science education program. While the curriculum, teaching materials, and examinations are determined by the national government, the management of school buildings, laboratories, and the hiring and training of teachers is conducted by local governments. This division of authority between the national and local governments is typical for all Indonesian provinces.

In the USA, K-12 schools are generally under local and state control, but are also subject to national legislation (e.g. The No Child Left Behind Act of 2001 [US Department of Education, 2010]). As such, there are large differences in formal science education practices not just from state to state, but from one school district to another, and probably the greatest differences in science instruction are actually within school districts between schools in the same district.

As for ISE, there is little in Bengkulu. North Carolina however is replete with options for ISE focusing on conservation education and EE. There is a NC Office of Environmental Education and Public Affairs (2014), more than 200 EE Centers (2014), and numerous federal, state, and local agencies that offer both EE and conservation education. NC Environmental Education, EE Centers (2014) are facilities that provide quality EE for the public, including outdoor experiences, exhibits, and programs. They are also a valuable resource for classroom teachers, parents, and non-formal educators and serve as vital partners in the NC Environmental Education Certification Program (2014). The more than 200 EE Centers in NC consist of federal, state, and local governmental facilities, as well as non-profit, corporate-sponsored, and university-operated centers. North Carolina's Environmental Education Centers are committed to professionalism and cooperation with other EE facilities and programs through the NC Association of Environmental Education Centers (NC Environmental Education, Association of EE Centers, 2014).

Forty-nine schools are designated as EE Schools (NC Environmental Education, EE Schools, 2014). If schools have programming or features that support EE, such as a school garden, a nature trail, composting bins, a recycling program, an energy or water conservation plan, or a green building design or if they take field trips to EE centers, have an environmental club, or host special events such as Earth Day or Walk to School Day, then they are considered an EE school.

The NC Green Schools Program (2014) recognizes NC P-12 (ages 4–18) public and private schools that encourage a culture of sustainability in five designated areas: (1) school philosophy and culture embraces sustainability, encourages professional development, and sparks the creativity and engagement of all of its members; (2) school practices conserving energy and water, reducing solid waste, and increasing transportation options, with strong student engagement; (3) school grounds enhance learning environments and promote a healthy and fit lifestyle; (4) curriculum helps students experience and understand the natural environment and their place in it; and (5) innovations and new initiatives demonstrate that the school is trying to go above and beyond in becoming a Green School. Seven NC Schools have been recognized as Green Schools (NC Green Schools Program, 2014). In addition to state designations as green schools, there is also a national USA organization that supports green schools—The Center for Green Schools (http://www.centerforgreenschools.org).

Indonesia also has a Green School. In 2012, an international school (started by a Canadian and an American) received the "2012 Greenest School on Earth" award from the U.S. Green Building Council's Center for Green Schools (Green School, Bali, Indonesia, 2015). This seems to be the only Green School in Indonesia. It is in Bali on Bali Island. It has an enrollment, K-12 (ages 5–18), of about 300 students. As stated on the school's website (http://www.greenschool.org), the school's vision is to offer a natural, holistic, student-centered learning environment that empowers and inspires students to be creative, innovative, green leaders (Green School, Bali, Indonesia, 2015).

The NC Environmental Education Certification Program (2014) recognizes professional development in EE and acknowledges educators committed to environmental stewardship. This program establishes standards for professional excellence in EE for formal and non-formal educators. The goals of the EE Certification Program are to increase environmental literacy, provide practice in EE teaching methods, and foster community leadership. The program aims to increase the number of leaders and organizations that provide quality EE across the state as outlined in NC's state plan for EE. The certification program is designed to recognize individuals who elect to take EE courses or workshops and who demonstrate a desire to develop a sense of stewardship for NC's natural resources and to instill that sense of stewardship in children and adults. All NC Park Rangers are required to complete EE certification. In NC, Park Rangers perform tasks related to resource protection as well as education (NC Division of Parks and Recreation, 2014).

Another EE opportunity in NC are the Natural Play and Learning Areas (Natural Learning Initiative, 2014), which are designated, managed locations in an existing or modified outdoor environment where children of all ages and abilities play and learn by engaging with and manipulating diverse natural elements, materials, organisms, and habitats through sensory, fine motor, and gross motor experiences. North Carolina has several of these areas, which have often been installed with the collaborative support of museums and zoos throughout the state. Many EE opportunities occur where forested land is prevalent and the following section of this chapter discusses forested lands in both locales. Opportunities for EE activities are examined, as are threats (present and historical) to forests in Bengkulu and NC.

Forests in Bengkulu and North Carolina

The government of Indonesia classifies forests into three types: conservation, protected, and production forests. Bengkulu forests, which now cover 46% of the land surface in Bengkulu Province, are comprised of 50% conservation forests, 27% protected forests, and 23% production forests. According to Indonesian law, the goals of conservation forests are to preserve biodiversity and ecosystems, while the protected forests are managed with the goal of soil and water conservation (based on the Decree of the Minister of Forestry, RI, No. 643, November, 10, 2011). Production forests are managed to meet the needs of Indonesians as well as people in other countries who wish to purchase Indonesian wood. Land cover conditions in Bengkulu Province based on the interpretation of Landsat 7 ETM images in 2009/2010 are 21% primary forest, 18% secondary forest, 0.5% plantations, 59% non-forest, and 1.5% other land. Forest use permits in Bengkulu Province have been granted for mining, cell tower construction, and hydroelectricity (Profil Hutan Bengkulu, 2013).

North Carolina is rich in forest resources with almost 60%, or 18.3 million acres, of the state covered in forests (NC Department of Agriculture and Consumer Services, 2014). However, NC has little primary forest left. Generally, only swamplands, the steepest mountain slopes, and small remnants of primary forests remain. Essentially, all of the present woodland in NC was farmed and abandoned in the past (NC Department of Agriculture and Consumer Services, 2014). The equivalent of what are called ‘production forests’ in Indonesia are called ‘working forests’ in NC. North Carolina’s forest products industry typically ranks as one of the top two industries in the state’s manufacturing economy (NC Forestry, 2015). North Carolina has four national forests—two in the mountains (Nantahala and Pisgah), one in the Piedmont (Uwharrie), and one on the coast (Croatan). North Carolina also has a group of nine protected areas known as State Forests, which are managed by the NC Forest Service, an agency of the NC Department of Agriculture and Consumer Services.

Seven of the state forests are *State Educational Forests*, and they are primarily used to educate the public, especially school children, about the forest environment, forestry, and forest management (NC Educational State Forests, 2014). Each educational forest features self-guided trails that include exhibits, tree identification signs, a forest education center, and a talking tree trail (audio information is relayed to the public through an artificial tree which speaks). The main website, http://www.ncesf.org, is organized so that there are links to each of the state forests. When a user clicks on one of the state educational forests, like Clemson, you are taken to a webpage, http://www.ncesf.org/CESF/home.htm, where there is educational information. The forest offices offer programs for schools and other youth groups. All of the state forests provide recreational facilities for hiking and picnicking (NC Educational State Forests, 2014). North Carolina also has a Museum of Forestry (NC Museum of Forestry, 2014) as well as the Forest History Society. The Forest History Society, located in Durham, NC, is a nonprofit library and archive dedicated to collecting, preserving, and disseminating forest and conservation history (NC Museum of Forestry, 2014). In contrast, Bengkulu does not have any educational forests; yet, well-managed educational forests could be a resource for teaching and learning about tropical forests. Tropical forest conservation is a global responsibility, and educational forests could provide important information about tropical forest conservation to the people of Bengkulu and Indonesia, as well as the people of the world.

Recently, many acres of protected areas in Bengkulu have been converted into mining and plantation areas. These lands are unlikely to revert to their former protected status. Illegal land conversion problems are complex issues in Bengkulu, and throughout Indonesia, and they have increased over the past 15 years. In Lebong, 5–10% of the protected forested areas have been damaged. Deforestation in other districts in Bengkulu is also significantly increasing (Santoso, 2012). Deforestation and forest degradation of protected areas occurred rapidly due to various factors including forest fires, expansion of plantations, land clearing for mining and logging, and customs clearing of agricultural land by burning. Furthermore, as Indonesia transitions to a democracy, the move toward regional autonomy has resulted in a lack of law enforcement to protect forests to ensure environmental sustainability in Bengkulu. Currently, public opinion in Bengkulu seems to be that economic interests are not compatible with environmental conservation, and most people believe that economic interests are more critical than environmental conservation (Wiryono, 2002).

While there seems to be little research on the attitudes and beliefs that North Carolinians hold about their forests, there has been an outcry over NC State University's recent decision to sell its largest forest, Hofmann Forest, which occupies nearly 80,000 acres. What follows is an excerpt of several paragraphs from an article entitled "N.C. State wants to sell its largest forest and invest the proceeds in Wall Street" that provide insight into the attitudes and beliefs that some North Carolinians hold about their forests.

> N.C. State's largest forest, the Hofmann, as it is often called, is intensively harvested by logging companies. However, Hofmann established a nonprofit that controls the forest, the N.C. State Natural Resources Foundation. It donates all of its profits—about $2 million annually—to the N.C. State College of Natural Resources, and dictates that for every acre cut, an acre must be planted.
>
> Mary Watzin, dean of the College of Natural Resources, says the Hofmann—which dwarfs the size of the college's other woodlands, the largest of which is less than 6,000 acres—is now worth more to the college as cash. She hopes to sell the property for $117 million and put the money into a stock portfolio, which she claims will double the current yearly net. It will also pay for more research and scholarships, she says.
>
> But many college students and faculty strongly oppose the plan.
>
> "The decision to sell the Hofmann is a tragedy, which must be stopped," wrote Fred Cubbage, a N.C. State forestry professor. The sale with no due process, no faculty, student, or community consideration for ephemeral gains perceptible only to a secret foundation and selected university administrators, would be the most hypocritical example of stewardship imaginable (Huntsberry, 2013).

Natural Areas, State Parks, and National Parks in Bengkulu and North Carolina

Bengkulu Province has 26 protected areas including 16 nature reserves, three natural parks, one forest park, two hunting parks, two tourist parks, and two national parks. The two national parks on Sumatra are Kerinci Seblat National Park (KSNP) and Bukit Barisan Selatan National Park (BBSNP). KSNP is located in several districts in the Bengkulu Province, while BBSNP is located partly in Kaur (23%) and mostly in Lampung Province (77%).

North Carolina has 14 national parks (some which are national monuments or national historic sites) and 41 state parks. Some of the state's 100 counties have one or more county parks, and cities typically have one or more city parks. Often these parks have educational programs. For example, each state park in NC has a written curriculum called an Environmental Education Learning Experience (EELE), designed for teachers and students at specific grade level ranges and focused on lessons that highlight the natural resources in the state park (NC Division of Parks and Recreation, 2014). For example, Hammocks Beach State Park, which is on an uninhabited barrier island on the NC coast and accessible only by boat, has an

EELE (NC Division of Parks and Recreation: Education—EELEs. Hammocks Beach State Park, 2001), focusing on loggerhead sea turtles and designed specifically for middle school students.

A Comparison of Educational Programs in the National Parks and Zoos

The mutual benefits of cooperation between schools and park managers in some developed countries, such as the USA has been well documented (National Park Service, 2014). Giving students opportunities to have direct experiences in nature provides a basis for young people to construct a deeper understanding of ecosystems, a stronger sense of place, and a deeper connection to nature (Placed Based Education, 2014). However, forests remain under-utilized as an educational tool.

Despite the fact that Bengkulu Province has 26 protected areas, these areas are not yet viewed by educators as potential sources of conservation education or EE. Although some schools are located near the protected areas, science teachers in Bengkulu rarely associate a particular subject with conserving protected areas. Schools almost never include field trips to even the protected areas close to their schools. Teachers and principals seem to agree that the learning process is best accomplished in the classroom or laboratory. In accordance with the policies of the national education curriculum, schools are strongly oriented towards formal education with primary goals of high achievement, high national test scores, and high graduation rates. These numerous protected areas in Bengkulu Province offer an untapped resource for both formal as well as ISE. Developing cooperative projects between the Resources Conservation Agency in Bengkulu and local school communities would enhance both formal and ISE and could lead to stronger feelings for continuing to protect these valuable areas.

Utilizing protected areas as a learning resource in Indonesia is very limited. However, West Java's Bodogol Conservation Education Center located in the National Park of Mount Gede Pangrango (Indonesia Tourism, 2013) is a good example of what might be implemented in Bengkulu. The mission of the Conservation Education Center is to sustain high biodiversity in this tropical rainforest which includes several types of flowering plants, medicinal plants, and ornamental plants as well as the Java Eagle and Java Gibbon. There are several programs for visitors including bird watching.

KSNP, which contains a tropical rain forest, offers learning opportunities for young people from Bengkulu, Indonesia, and many nations including the USA:

> In KSNP there are many potential sites for nature tourism, but only a few of these are being utilized. Where development has occurred it has at times been haphazard, leading to a degradation of the very values that should be conserved as a focus for nature-based tourism. However KSNP still offers a wide array of unspoiled attractions that, with wise management, will provide recreation to national and international visitors and economic benefits to the local people.

> …KSNP offers: clear-flowing streams and rivers, mountain panoramas, active volcanoes, waterfalls, hot springs, the potential for long treks through pristine forests, crater lakes, opportunities for sightings of rare and endemic Sumatran birds and other unique animals and plants, traditional villages inaccessible by motorized transport, highland swamps and marshes, and much more (Kerinci Seblat National Park, 2014).

The USA national parks offer a variety of ISE opportunities, including a Junior Ranger program where more than 800,000 young people became Junior Rangers in 2013 (National Park Service, Junior Ranger, 2014).

Though there are zoos in many cities in the US, there is only one National Zoological Park (the National Zoo), which the authors visited together in June 2014 while preparing this chapter, spending most of their time at the reptile and amphibian exhibits. The National Zoo is one of the oldest zoos in the US and is part of the Smithsonian Institution. The mission statement of the zoo is to provide leadership in conservation science and education and inspire diverse communities so they become part of the Zoo’s commitment to celebrate, study, and protect animals and their habitats.

North Carolina has one state zoological park, which offers teachers ways to integrate the natural world into their classrooms. Zoo staff members visit schools, and teachers bring students to the zoo in Asheboro for unique field study projects. Teachers can help their students become involved with conservation projects in far corners of the world, while Zoo lesson plans and activities help them meet NC curriculum objectives (NC Zoo, Education, 2014).

Zoo Camps (NC Zoo, Education—Zoo Camps, 2014) for kids offer a way to learn about animals and the natural world in an outdoor setting. The Education Section of the NC Zoo facilitates a wide variety of experiences and activities within the park and beyond to help people understand the natural world. Educators promote awareness and concern for nature, placing value upon conservation of plants and animals.

The NC Zoo cooperates with Asheboro City Schools to offer 150 selected students in the 10th, 11th, and 12th grades (ages 14–18) opportunities to use all of the Zoo’s resources by attending ZooSchool (NC ZooSchool, 2014). Teachers work with Zoo staff to plan and incorporate their lessons with the Zoo. Students who attend the ZooSchool attend one to two classes at the Asheboro High School main campus then travel to a classroom and lab facility at the Zoo for the remainder of their classes in science, English, mathematics, and social studies. Students are actively involved in their learning through problem-solving methods, group-based projects, technology-based projects, and the use of the 1,500-acre zoo as their classroom.

The presence of a zoo in the city has been widely recognized as a good learning resource for conservation education (National Zoo, Education at the National Zoo, 2014). In Bengkulu, there is a mini-zoo, Taman Remaja. Taman Remaja was established in 1984 by the provincial government for the purposes of tourism and education, but it has fallen into disrepair and is not suitable as a learning resource for conservation education (Taman Remaja, 2014).

Taman Safari Indonesia (TSI) in West Java is well managed and has an international reputation as a good zoo (Taman Safari Indonesia, 2014). Furthermore, the Indonesian government awarded TSI an Indonesia Green Award and a Best Indonesia Travel and Tourism Award. TSI is well known as an animal conservation center as well as a modern zoological garden with various collections of flora and fauna. In this park, visitors can enjoy the beauty of nature and also watch as the animals wander freely. Visitors can travel in this conservation area using their private car or a bus, exploring wild habitats. TSI's collection includes animals from nearly all over the world and local animals such as komodos, rhinoceros, bison, sun bears, white tigers, elephants, and anoa. There are more than 2,500 animals with hundreds of species currently being maintained. While TSI is an excellent zoo, it is also well known as one of the leading amusement parks in Indonesia. TSI's website highlights its animal conservation work but also features the amusement park, which has a USA western, "cowboys and Indians" theme. Zoos in Indonesia do not have sufficient state funds to operate and are very sensitive to visitors' preferences, which, recently, for many visitors, are entertainment services. Furthermore, because Bengkulu Province has no zoo, animals that are injured or ill, including endangered species, need to be transported to zoos in other provinces. Restoration of the Zoo in Bengklu is a potential source of conservation and EE for K-12 students.

Another potential source of learning about conservation education in Bengkulu is the Gajah Seblat Elephant Center (2009). This agency is addressing many conflicts between elephants and community members, as elephant conservation is now an international concern.

Wildlife Refuges and World Heritage Sites

There are ten National Wildlife Refuges in NC: Alligator River, Cedar Island, Currituck, Mackay Island, Mattamuskett, Pea Island, Pee Dee, Pocosin Lakes, Roanoke River, and Swanquarter National Wildlife Refuges. Nine of these refuges are located on the coast while the tenth is located in the Piedmont.

USA National Wildlife Refuges have a multipurpose agenda: clean water, clean air, unusual and abundant wildlife, and world-class recreation (National Wildlife Refuges, 2014). The National Wildlife Refuge website, http://www.fws.gov/refuges/education/natureOfLearning/framework.html, has several special sections dedicated to the education of teachers and students. The National Wildlife Refuge system has developed some unique partnerships between neighborhood schools and US Fish and Wildlife Refuges (U.S. Fish & Wildlife Service, Nature of Learning, 2013). The partners include natural resource professionals, teachers, students, parents, and administrators from selected schools and together they set goals for the program and establish timelines for projects.

The NC Alligator River National Wildlife Refuge, which the authors visited with high school students from The HERP Project in July 2014, offers EE programs for school classes. The letter excerpted below from The Coastal Wildlife Refuge

Society (2015), the non-profit support group for Alligator River, is an excellent example of the kind of ISE opportunities that are available in NC.

> Dear Teachers,
>
> Connecting children with nature is a major focus with the National Wildlife Refuges today. The U.S. Fish and Wildlife Service recognizes the importance of getting kids out-of-doors, out into the natural environment with all of its wonders. Scientific studies have shown that spending time outside produces smarter, healthier, and happier children.
>
> Alligator River and Pea Island National Wildlife Refuges have lots to offer schools in terms of environmental education, wildlife trails and drives, interpretation, and just plain memorable outdoor experiences. You are invited to bring your classes to experience these national wildlife refuges. Our hope is that they'll come back on their own and bring their families.
>
> The main objective of the program is to encourage students to learn about and appreciate wildlife, habitat, and other natural resources. We believe in experiential learning and support taking children out-of-doors. In several middle schools in Dare and Tyrrell counties, the Society has sponsored "Junior Refuge Friends" clubs. We invite your school to form a group or club that would focus on building a relationship with your local national wildlife refuges (Coastal Wildlife Refuge Society, 2015).

Unlike rehabilitation centers in NC, there are no rescue centers for endangered animals in Bengkulu. Provincial conservation agencies have a team to help the community if there are wild animals (tigers and elephants, for example) that go into gardens or settlements. The team will encourage the wild animals to re-enter the forest; if this does not work, the team will capture the animal for relocation. If a wild animal is caught in Bengkulu, there are no temporary holding facilities available. Illegal trade in endangered species (tigers and elephants) is still ongoing in Bengkulu. In Sukabumi, West Java, there is the Cikananga Animal Rescue Center (2015), which has the support of international agencies.

The World Wildlife Fund Borneo and Sumatra has listed Sumatra as a priority site for protecting endangered species. Sumatra is the world's sixth largest island and, home to 50 million people, the world's fourth most populous island. Their website states that Sumatra is

> home to some of the world's most diverse rain forests and Southeast Asia's last intact forests. …The island's tropical climate and diverse eco-regions have created habitats that house thousands of unique species and the world's last remaining Sumatran tigers, orangutans, pygmy elephants, and Sumatran rhinos. Massive rivers cut across the landscape. These are the islands' lifelines, offering transport and providing the freshwater needs for the islands' people (The World Wildlife Fund Borneo and Sumatra, 2015).

According to the UNESCO website, http://whc.unesco.org/en/statesparties/US/, there is only one World Heritage Site in NC. This site, the Great Smoky Moutains National Park, hosts over 3,500 plant species and numerous animal species; for example, the park is among the world's top places with the greatest variety of salamanders. KSNP is the only World Heritage Site in Bengkulu and it is described in detail in the next section of this chapter.

Charismatic Megafauna and Flora of Bengkulu and North Carolina

Indonesia holds the world's largest track of tropical rainforests in the world. These forests are very rich in biodiversity. Although Indonesia occupies only 1.3% of the world's land area, it possesses about 10% of the world's flowering plant species; 12% of the world's mammal species; 17% of all reptiles and amphibian species; and 17% of all birds. Because of its biological richness, Indonesia is recognized as one of seven mega diversity countries and has two of the world's 25 biodiversity hotspots, areas of high diversity as defined by Conservation International (Tropical Rainforest Heritage of Sumatra, 2015). The country also has 18 (11 terrestrial, four fresh water, and three marine) of the World Wildlife Fund's Global Eco-regions (Prakosa, 2003).

Sumatra's parks, particularly KSNP, play an important role in protecting this biodiversity. According to KSNP's website,

> The park plays an important role in the conservation of many globally threatened charismatic mammal species. One of the rarest and most endangered mammals in the world, the Sumatran rhinoceros (*Dicerorhinus sumatrensis*), is present in unknown numbers in the park in Jambi and Bengkulu provinces. The park is known to be a very important protected area for conservation of the Sumatran tiger (*Panthera tigris sumatrae*). Both of these species are threatened by poaching throughout their ranges, including in KSNP. The Sumatran hare (*Nesolagus netscheri*) is a little known Sumatran endemic that is found in several areas within the park. Populations of Sumatran elephants (*Elephas maximus sumatranus*) in Bengkulu and Jambi have ranges extending into the park, but probably are more reliant on the lowland forests outside the park boundary. KSNP is almost certainly the single most important Malayan tapir (*Tapirus indicus*) habitat in the world. Important populations of sun-bear (*Helarctos malayanus*), clouded leopard (*Neofelis nebulosa*), and Asian wild dog (*Cuon alpinus*) also occur within the park (Kerinci Seblat National Park, 2014).

Two flowers that occur in the park are of prime importance to Bengkulu City: the rafflesia flower (*Rafflesia arnoldii*), the largest flower in the world, and the kibut flower (*Amorphophallus titanum*), one of the tallest flowers in the world. A wealth of flora endemic to Bengkulu offers interesting potential for natural resource development. This flora includes vanda orchids (*Vanda hookeriana*) and pencil orchids (*Papillionanthe hookeriana*).

Several animals in Bengkulu offer interesting potential as megafauna, which can be used to develop tourist attractions and to draw the general public's attention to the plight of these animals. These animals include Sumatran tigers, sun-bears, siamang (*Symphalangus syndactylus*), tapirs, clay buffalo (*Binuang buffalo*), deer (*Cervus unicolor*), and Sumatran elephants. Komodo dragons (*Varanus komodoensis*) are found only in the lesser Sunda of the Indonesian archipelago, including the islands of Komodo, Flores, Rinca, and Padar. These animals have been successfully bred by a few major zoos in Java.

There are long lists of protected species in Bengkulu (Protected Species in Bengkulu, 2014) and of endangered or threatened flora and fauna in NC (U.S. Fish & Wildlife Service, NC Threatened & Endangered Species, 2013). While many Bengkuluans and North Carolinians are likely unaware that most of these species are at risk, certain species, termed charismatic megafauna or megaflora, are more widely known and recognized. While the pitcher plant, one of several carnivorous plant species native to NC, is of interest to many people, and poaching of carnivorous (insectivorous) plants remains an issue, the marine mammals (whales) and reptiles (sea turtles) are probably the best known endangered species.

The Karen Beasley Sea turtle Rescue and Rehabilitation Center at Topsail, NC (2014) is a world-renowned resource for the rehabilitation of injured sea turtles. In conjunction with the Rehabilitation Center, the 26 miles of coastline at Topsail are monitored daily to identify sea turtle tracks and nests. The HERP Project is involved in a somewhat similar program, The Box Turtle Connection, where Eastern Box Turtles (*Terrapene carolina*), a species of concern and NC's state reptile, are marked, measured, and monitored. Efforts at Bengkulu University focus on aquatic and terrestrial turtles, and these efforts are described in more detail later in this chapter.

Not all NC charismatic megafauna and flora are threatened, endangered, or at risk. For instance, while NC bears are not a species of concern (their population is increasing and ranges are expanding); red wolves certainly are. Red wolves are endangered and at one point all red wolves were in captivity with researchers hoping to save the species by captive breeding and releasing programs. The reintroduction of the red wolf in NC is a controversial issue, as hunters claim they decrease deer populations and farmers, who can legally eradicate foxes, are often unsure of identification features that allow them to distinguish red wolves from foxes.

Integrated Conservation Development Projects in Bengkulu: A Case Study in ISE-Conservation Education

Historically, local Indonesian communities in the vicinity of protected areas generally have had local cultural policies compatible with and respectful of natural ecosystems. Given the rapid population growth, 1.2% in 2013 (World Bank, Population Growth, 2015), and demands for a better life, short-term economic motivations seem to have replaced these traditional policies. Local governments are being corrupted by the primacy of economic gain, and now economic interests are pitted against environmental conservation.

In 2008, it was estimated that tropical rainforests in Indonesia would be logged out in a decade. A 2007 United Nations Environment Program report estimated that 73–88% of timber logged in Indonesia was illegally sourced and more recent estimates put this at 40–55% (Schmidt, J., Expert Blog, Natural Resources Defense Council, 2010). Between 1990 and 2010, 20% of the forested area in Indonesia was lost, and, by 2010, only 52% of the total land area was forested. Developed countries, including European communities and the USA, have had a long history of deforestation until they find a balance of economic development and natural conservation.

Prior to the arrival of Europeans, about one half of the USA's land area was forest—990 million acres in 1600. Yet today, forests comprise only about 740 million acres. Nearly all of this deforestation took place prior to 1910, and the forest resources of the USA have remained relatively constant throughout most of the 20th century (Tchir, Johnson, & Nkemdirim, 2009). The tropical forests in Bengkulu will not be as forgiving as the temperate forests in the USA. Therefore, it is important not to allow a long phase of deforestation in Bengkulu because it is possible that the tropical forests, once logged, will not be recoverable.

One often hears that forests are the world's lungs because trees take in carbon and produce oxygen. According to the UNESCO World Heritage Centre (2015), it is the duty of the worldwide community to participate in the preservation of tropical forests and ensure their sustainability. Tropical Rainforest Heritage of Sumatra (2015) is a member of the World Heritage, which consists of the three national parks in Sumatra: KSNP, BBSNP, and Gunung Lauser National Park in North Sumatra and Aceh. In the last 10–15 years, rapid economic development in Sumatra, together with the increasing human population and lack of community awareness regarding the importance of natural resource conservation, have placed considerable pressure on KSNP. KSNP is threatened by deforestation and encroachment, illegal tree felling, illegal forest product collection, poaching, mining, and poor land management in the catchment and park surroundings. The problems are many, and each is complex and deep-rooted. Guarding the park with strong law enforcement alone will not result in conservation of biodiversity or preservation of the ecological functions of natural areas.

A number of international projects, such as the Integrated Conservation and Development Projects (ICDP), were started in Bengkulu to assist with the preservation of protected areas (Kelman, 2013). The objectives of the ICDP are to stabilize the park boundary, maintain biodiversity and promote sustainable forest management within and around the park, and enhance the livelihoods of poor families who live around the park. ICDP offers important lessons regarding the reconciliation of tensions between conservation goals and the aspirations of people in and around protected areas (Wells, Brandon, & Hannah, 1992). Indonesia's ICDP network has been supplemented by $130 million from international donor funds, and the U.S. has contributed $20 million to the Biodiversity Conservation Network, enabling the establishment of 20 ICDPs, several of which have been implemented in Indonesia (Hughes & Flintan, 2001). Since 1996, the Government of Indonesia has employed the concept of ICDP. The project is designed to link biodiversity conservation within the park and rural development investments in the target villages on the park boundary. To date, 74 villages have participated in this project. Through this project, concern over Conservation Parks has been steadily growing at the provincial and district levels. Conservation and protection activities have been incorporated into local governmental regulations and programs (Anwar, 2013).

People working on the ICDP assume that local people rely on the natural resources of protected areas because they do not have other sources of income. Therefore, one recommendation of ICDP is to improve the welfare of local communities with development activities in the buffer zone. However, it is very difficult to determine the types of activities that can be implemented and provide adequate income for the community, and at the same time preserve biodiversity. ICDP implementation results show that the new development activities managed to increase income, but failed to reduce threats to protected areas. There was no relationship between the increased economic achievements and conservation efforts (Manullang, 1999).

The Indonesian government has found it difficult to provide the level of protection that these globally important forested areas need. International organizations have been involved, and some of their initial efforts were to involve locals in the official governance and management of protected areas. ICDPs were implemented and seem likely to continue, especially with ongoing partnerships. However, poor park law enforcement has been a key obstacle, and law enforcement problems continue to hamper biodiversity conservation throughout Indonesia (Kelman, 2013).

The Current State of Conservation Education in Bengkulu

Indonesia is one of the 44 countries that collectively contain 90% of forests in the world. In 2007, Indonesia was the country with the fastest rate of deforestation (2% annually) on our planet and had the fastest rate of deforestation during the previous period, 2000–2005. This is a rate of 1.9 million acres annually or 51 km^2/day, or the equivalent of 300 football fields every hour (Tjahyono, 2007). The concept of biodiversity conservation management, which was introduced by international conservation organizations, was adopted and has been the policy of conservation in Indonesia for more than 40 years. However, at this time, conservation management does not show encouraging results, because damage to the conservation areas continues with no guarantee of success in controlling the damage (Sjarmidi, 2014).

The implementation of international projects with their expensive foreign consultants needs to be evaluated. Indonesia is a country transitioning to democracy. Three issues are of critical concern and must be evaluated and addressed: (1) forest policy reforms in accordance with the concepts of participation and decentralization, (2) chaos as a result of drastic decentralization, and (3) rapid deforestation and degradation of the forest due to various factors such as forest fires, large-scale plantations, logging, and slash-and-burn agriculture (Inoue, 2004). Perhaps the root of the problem is that neither the local community members nor the local government understands the true meaning of conservation. It is difficult to obtain and gauge the results of international conservation education efforts.

Even though Indonesian schools and homes are in close proximity to the protected areas, there were some concerns that students and teachers either did not know about the existence of these protected areas or did not understand the function of these protected areas. However, the results of a survey about the knowledge and attitudes of teachers (Putra, Karyadi, & Ruyani, 2009) and students (Avico, Karyadi, & Ruyani, 2009) in eight primary schools in the Lebong district of Bengkulu showed that both teachers and students have adequate knowledge about and positive attitudes toward KSNP. Similar studies conducted by Putra, Karyadi, and Ruyani (2009) on 180 junior high school students at KSPN in Jambi showed that these students also had adequate knowledge of and positive attitudes toward KSNP. The results of these three studies suggest that the complex conservation issues in local communities near KSNP may be at least partially addressed through early conservation education. However, it is unclear if the schools in these studies were included in the 74 villages targeted by an ICDP project. Furthermore, it important to know whether, and, if so, how, teachers at the schools planned to use KSNP as a learning resource.

Conservation education, a part of EE, should be provided to students in elementary school through high school. Environmental education in Bengkulu, as well as other provinces in Indonesia, has been offered for the last 32 years as population and environmental education, which was to be integrated across the curriculum (Adisendjaja & Romlah, 2007). Integrated learning outcomes were not encouraging. The principles of sustainability and the implementation of environmental ethics are not yet practiced personally on a day-to-day basis and are not yet a basis for setting public policy by the local government. Conservation education activities for both community members and students in schools were not successful in increasing positive behaviors with respect to the use of natural resources, such as conserving resources through reduction, reuse, and recycling, and replanting trees that are logged and practicing population control (Chiras, 1993).

Although conservation of protected areas has been ongoing for the past 40 years and conservation education has been carried out the last 32 years in Bengkulu, there is some thought that because formal education places too much emphasis on competition, students become more egocentric and less empathetic and thus find it difficult to see themselves as a part of a natural ecosystem, which is an essential perception for solving environmental problems (Danusaputro, 1981). Environmental problems are conditions in the biophysical environment that hinder the fulfillment of human needs for health and happiness (James & Stapp, 1974). Living in harmony with nature will only be achieved if everyone understands the principles of sustainability and implements environmental ethics.

Formal, Non-formal, and Informal Conservation Education in Bengkulu

Science education policy can be developed in two different ways. The approach most familiar to planners and policy makers is from the top down and starts with the identification of national goals, which can be converted into policy for different sub-sectors (Lewin, 2000). In Bengkulu, as in other provinces in Indonesia, education policy including conservation education is top down; the central government in Jakarta determines curriculum and national examinations. While non-formal and informal education have received some attention in Indonesia, it has been in the framework of a supplement to formal education.

From 1981 to 2007, conservation education was to be integrated into the curriculum in relevant subjects from elementary school to high school (ages 5–18). In the years 2007–2013, the central government gave school districts autonomy over how to offer conservation education. Then, in 2013, given the national curriculum and a goal of reducing the number of subjects taught in schools, the government again recommended that conservation education be integrated into other subjects. During three decades of formal conservation education, only memorization of concepts and principles was stressed. Changing behaviors of students was difficult to achieve because the students heard only limited explanations of conservation in classrooms. Teachers found it difficult to offer students opportunities for observation, field practice, lab practicals, project work, internships, or adventure activities. Teacher readiness was also generally inadequate. Therefore, formal education in Bengkulu does not yet make a real contribution toward young people's appreciation and knowledge of natural resources, nor does it have much of an effect on their conservation-oriented attitudes and behaviors.

Extracurricular Activities and Learning Outside the Classroom

In Bengkulu, extracurricular activities are organized by educators. Activities are designed to help students develop their talents and interests and provide opportunities for socialization, recreation, and career preparation. Extracurricular activities must meet a number of principles and offer individual choice, active involvement, enjoyment, opportunity to develop a work ethic, and social benefits (Decree of the Director General of Mandikdasmen No. 12 of 2008). There are several different types of extracurricular activities in Indonesia, including programmed activities and non-programmed activities. Programmed activities must be planned and followed to address learners' personal needs and circumstances. Examples of extracurricular offerings include academic programs; sports, arts, and culture; religion; Scouting; leadership training; Scientific Youth; Red Cross Youth; Nature Lovers; journalism; and theater. Non-programmed activities are also implemented directly by teachers and the school for all students and include flag ceremonies, gymnastics, special worship services, and classes on personal hygiene. Schools in Indonesia also consider the following activities extracurricular: greeting behaviors, waste disposal, lining up, and resolving disagreements. Teachers try to model everyday behaviors such as dressing well, speaking with correct grammar, diligently reading, compassion, and punctuality.

Excellent schools in Bengkulu usually offer more extracurricular activities, but most schools are limited to two or three activities. Some activities related to science education, such as National Science Olympiad, Scouting, Scientific Youth, Red Cross Youth, and Nature Lovers, have the potential to strengthen the knowledge and attitudes of students concerning natural resources conservation. However, this potential is not easily realized because teaching green, green teachers, and green schools are not yet ideals or practices for most teachers and principals in Bengkulu.

Scouting Activities in Indonesia and the USA

The Scouting Movement began in Indonesia during the reign of the Dutch in 1912 and spawned youth patriotism (Indonesia Scout Movement, 2014). Scouts are offered for boys from seven to 25 years old. The Scout Movement aims to have each member develop a noble personality and a spirit of patriotism. The Scout Movement also requires that members be law-abiding, disciplined, and uphold the noble values of the nation, as well as preserve the environment.

In 2013, the Indonesian government recently established a policy that makes the Scout Movement part of the curriculum and Scouting mandatory for all students in Indonesia. Mandating that Scouting be required as an official part of the curriculum in Indonesia was shocking. Requiring Scouting runs contrary to the spirit of Scouting, as initiated by the founder Baden Powel (History of Scouting, 2015). In developed countries, including the USA, Scouting is not mandatory and young people choose whether they want to be involved.

Although the Scouting Movement in Indonesia explicitly states that preservation of the environment is an important goal, this goal has not been realized. Scouting activities have been criticized as too militaristic, with marching drills and ceremonies. However, Wanabakti Scouts provide an example of sustainability efforts. These Scouts are provided with specialized knowledge and skills in the field of forestry and are encouraged to develop a sense of love and responsibility for managing natural resources sustainably. The program includes forest management, forest conservation and natural resources, forests and the environment, and the utilization of forest products for the community (Wanabakti, 2013).

North Carolina Boy Scouts and Girl Scouts offer popular informal science education activities for children who choose to participate. Neither group of Scouts could provide specific information about North Carolina statistics on membership numbers, demographics, summer camps, etc., but NC does have very active programs in Scouting, including summer residential programs.

Nature Groups, Nature Associations, and Nature Lovers in Indonesia and North Carolina

In Indonesia, groups or associations of nature lovers attract individuals, especially members of the younger generation. These groups participate in recreational activities that often involve adventure travel, which usually occur on holidays or semester breaks, and typically desire to help in the protection and conservation of natural forests. These groups have done some good environmental work. For example, a group from Yogyakarta and Bandung preformed greening activities on the Mountains. However, some of these groups have left negative impressions on the general population in Indonesia due to their attire, personal appearance, and accusations that they have been involved with vandalism (particularly graffiti) of natural environments. While these groups could potentially contribute to conservation efforts in the country, it appears that, for now at least, some of their activities are misguided and have left negative impressions on many Indonesians (Mallolongan, 2006).

Nature lover organizations have been growing rapidly in Indonesia since the 1960s. In 2010 there were approximately 2,000 Nature Lover Groups in Indonesia (Belantara Indonesia, 2014). Natural Resources Conservation Agency and a local university, college, or school usually sponsors the group. In Bengkulu, there are 19 nature lover groups consisting of eight university associations, nine non-governmental groups, and two high school associations (Daftar Alamat Pencinta Alam Bengkulu, 2013).

There are many nature groups and nature associations in North Carolina. The website Eco-USA (www.eco-usa.net) lists 67 different environmental organizations in North Carolina. These organizations include The Sierra Club and the Audubon Society, as well as groups that focus on butterflies, birds, clean air, clean water, specific creeks, rivers and sounds, and specific geographic regions of the state.

The term “nature lover” has negative connotations in North Carolina and the Urban Dictionary defines a nature lover as a “useless human being, who probably has made more friends with trees than humans”. This Dictionary also defines nature lover as a hippie and/or environmentalist. Much like the term “tree hugger”, the term “nature lover” is not used much in the United States.

However, the term nature camp is used frequently and nature camps are offered by many nature centers in North Carolina. Additionally, there are garden clubs, nature photography associations, birding clubs, herpetological associations, wildlife clubs, and fishing groups, all of which might be considered broadly as nature groups and associations of nature lovers.

Science Tutoring (An Out-of-School Activity) in Indonesia and North Carolina

Science tutoring outside of school is an interesting phenomenon in the context of ISE in Indonesia. In 1970, science tutoring began to appear in major cities such as

Jakarta, Bandung, Yogyakarta, and Surabaya to provide additional lessons for prospective university students. Tutoring activities are usually conducted by seniors from local state universities. The goal of science tutoring for individual tutees is to be accepted as a new student at the state university. Now, science tutoring services have spread to almost all districts/cities in Indonesia, including Bengkulu. Science tutoring is oriented toward increasing students' scores on national examinations, civil service examinations, and university admission examinations. Science tutoring, as an example of ISE, does not offer much hope for addressing issues of natural resource conservation education. Science tutoring in NC has a similar focus on achievement and includes tutoring in only formal coursework.

In School and After School Competitions (Science Olympiad and Envirothon)

Each year, the Indonesian government holds Olimpiade Sains Nasional (OSN, The National Science Olympiad, Indonesia, 2015) for elementary through higher education. OSN is held at district, provincial, and national levels. OSN national champions qualify for the regional and international Olympics. Bengkulu participants have not been strong competitors at the national level. In addition to the annual science competitions there are several organizatons for young people who are interested in science: Kelompok Ilmiah Remaja, pendidikan/kir-remaja and OSN Pertamina.

The mission of the U.S. Science Olympiad is to improve the quality of K-12 science education, increasing male, female and minority interest in science, creating a technologically literate workforce, and providing recognition for outstanding achievement by both students and teachers. These goals are achieved by participating in Science Olympiad tournaments and non-competitive events, incorporating Science Olympiad into classroom curriculum, and attending teacher-training institutes.

Science Olympiad tournament goals include bringing science to life, showing how science works, problem solving, and understanding science concepts, using teamwork and cooperative learning. Every year, tournaments are hosted on university, community college, and public school campuses across the state. These tournaments are rigorous academic interscholastic competitions that consist of a series of hands-on, interactive, challenging, and inquiry-based events that are well balanced between the various disciplines of biology, earth science, environmental science, chemistry, physics, engineering, and technology. In 2014, more than 800 K-12 (ages 5–18) teams, representing over 14,000 students and 70 counties in NC, participated in Science Olympiad activities. Thousands of volunteers donate their time each year to making these activities a success.

In NC, students have opportunities to participate in a variety of events that specifically focus on conservation education and environmental education. While the Science Olympiad might include some tasks focused on the environment, the Envirothon is all about EE. The Envirothon is an annual competition where middle school (ages 11–15) and high school (ages 14–18) teams compete for recognition and scholarships by demonstrating their knowledge of environmental science and natural resource management. The teams, each consisting of five students from participating schools, home study groups and environmental clubs, exercise their training and problem-solving skills in a competition centered on five testing categories: soil/land use, aquatic ecology, forestry, wildlife, and current environmental issues. High school teams have the added component of an oral presentation that requires the students to assemble their knowledge of all the tested subjects and use critical thought to solve a complex environmental problem and present their solution to a panel of judges (Envirothon, n.d.).

Envirothon succeeds in its mission to develop knowledgeable, skilled, and dedicated citizens who are willing and prepared to work toward achieving a balance between the quality of life and the quality of the environment. The Envirothon program is an effective educational tool, capable of supplementing environmental education both inside and outside the classroom. Led by a volunteer advisor, teams usually meet from late autumn until spring. Teams work collaboratively to develop their knowledge of ecology and natural resource management and to practice their environmental problem-solving skills in preparation for Envirothon competitions. The primary coordination and leadership for the program is provided by the NC Association of Soil and Water Conservation Districts. But, private and corporate sponsorships provide the majority of the funds needed to hold the Envirothon.

The goals of the Envirothon include learning more about the natural environment, natural resources and promoting stewardship of these natural resources. It is important to realize that teachers or parents are the main contacts for these special activities, so students have varying opportunities to participate based on their parents' suggestions and teachers' willingness to participate.

Summer Programs (4-H, Universities, and Museums)

In North Carolina, both after school and summer programs are sponsored by the state 4-H Extension Service, with some 4-H camps focusing specifically on the environment and resource conservation. Private organizations and universities offer marine science camps as well as many other science specialty summer camps. Universities and museums offer many different programs, too numerous to list, many of which focus on education about the environment.

In Bengkulu, 4-H is not popular. 4-H is relatively new to Indonesia (http://4-h.or.id/about/) but it has possibilities to enhance environmental education. Few summer programs are offered by universities or museums in Bengkulu at this time.

Current Status of Herpetology Education in North Carolina and Bengkulu

Given that our collaboration started with a request to partner on herpetology education programs in Bengkulu Province and the state of NC, it seems fitting to conclude our chapter with a report about the current status of these projects in our respective countries. The NSF-funded *Herpetology Education in Rural Places and Spaces* (The HERP Project) grant has completed its fourth year of summer programming, with over 200 high school students who have attended summer programs, and is gearing up for its final summer of programs. During the summer programs, The HERP Project participants focus on six research studies on semi-aquatic turtles, box turtles, salamanders in ephemeral pools, salamanders in streams, snakes, and lizards. Follow-up days during the academic years were offered the past four years, with as many as six follow-up days offered each year, including weekend events focusing on herpetological field experiences, herpetological society meetings, and public celebrations including Reptile and Amphibian Days at the NC Museum of Natural Sciences. The HERP Project has also hosted and attended a number of special public events called Celebrations.

Bengkulu University (UNIB) has expanded its captive breeding program of turtles and is using aquatic turtle traps to assist with the capture of these animals from streams that are threatened by sedimentation due to population increases and residential and business development. Public programs have been expanded and include efforts to reach children in Bengkulu with UNIB's message for the future: "Better conservation education for a better future." A revised proposal for the Partnerships for Enhanced Engagement in Research (PEER) Proposal was submitted, reviewed, and funded. This program, titled Developing Science and Learning Research Capacity of Bengkulu University in Ex Situ Conservation of Sumatran Freshwater and Terrestrial Turtles, will run through November 2018 (http://sites.nationalacademies.org/PGA/PEER/PEERscience/PGA_168049).

The UNIB campus has a protected forested area of 18.53 ha (Wiryono Hidayat, Hidarto, & Ruyani, 2009). This Campus Forest is the most extensive conservation area in the Bengkulu community. Members of the UNIB Forestry Department have identified the types of vegetation in the Campus Forest area. However, fauna, including herpetofauna, at the Campus Forest is not yet well documented. Those who glance at the Campus Forest commonly find frogs, snakes, turtles, and lizards (including geckos), but these have not been identified.

The Department of Biological Education, the Faculty of Teacher Training and Education (FTTE), and UNIB received the Program Hibah Kompetisi A-2 grant from the Indonesian government for developing a Biological Garden during the years 2006–2008. The grant was aimed at improving the quality of undergraduate student research using live biological material collections, which were established in an area adjoining the side of the FTTE Building on the UNIB campus. The Biological Garden supports academic activities including teaching and learning and also serves as a resource for biological research. The installation is used by undergraduate and graduate students as well as elementary, middle, and high school students from areas around Bengkulu City. A group of students can request that the Coordinator of the Biological Garden arrange a visit and an outdoor science education program.

The Turtle Survival Alliance (TSA) supported research that worked to develop a Science Teaching Plan (STP) to increase students' knowledge and appreciation of Indonesian turtles in the Garden. The STP model focused on fifth graders, was 80 min long, used eight live turtle specimens (*D. subplana*, *A. Cartilaginea*, *M. emys*, *H. spinosa*, *N. platynota*, *C. odhamii*, *S. crassiocollis*, and *C. amboinensis*), and printed materials. Post-tests and attitude measurements were performed separately one week after completing the STP. Fifteen science teachers participated, learned the STP in a workshop and then implemented it in their classes, reaching a total of 515 students. The STP lead to increased students' knowledge of and interest in the turtles studied (Ruyani, 2009).

In September 2009, UNIB received permission from the Ministry of Education and Culture, the Republic of Indonesia, to start the Magister Program (S2) in Science Education to increase the competence of science teachers in Bengkulu Province and surrounding areas. This is a 2-year program with the motto "Natural Conservation Education for A Better Life." Green teachers, teaching green, and green schools are important concepts in the graduate program. Initial candidates for the program have a diploma with a degree in science (Biology, Physics, or Chemistry). The S2 offers a combination of basic science research and learning research, based on a local issue (Ruyani, 2009). This focus on local issues contextualizes the learning experiences, making them more meaningful (Winarni, 2009). These graduate student science teachers have been involved extensively with studies in the Biological Gardens and with the turtle work at Bengkulu.

An increasing number of events are held in the UNIB Biological Garden. In June 2011, the Hall of Science (Pendopo) was constructed as a part of the Biological Garden, and it can accommodate 20 students. The Biological Garden as a learning resource is gradually being developed with the support of internal resources. The study of general botany and zoology in the Garden is routinely performed by S1 and S2 students. As of September 2012, terrestrial and freshwater turtles are housed at the Biological Garden. The live specimens are a pioneering effort to initiate captive breeding of turtles at UNIB. Many Indonesian freshwater turtles are threatened with extinction. The following email, June 2014, from Ruyani to Matthews summarizes the issues:

Fig. 20.1 Students at UNIB participating in the turtle program

> The program, "UNIB Campus, A Safe Home for Turtles" (see attached pictures) will soon enter its second stage. This year we will focus on *Coura amboinensis*, and as many as 48 students will be involved in these activities. Our students regularly use the aquatic turtle trap from The HERP Project to monitor the presence of aquatic turtles. We also have a number of large tortoises, *Manouria emys*, as next target of the program; this species would require different monitoring tools in the field. What would you say about using radiotelemetry?
>
> We (Hery Suhartoyo and I) have two students, Donna and Efran, they are interested in investigating the presence of turtles at the border of Kerinci Seblat National Park and Bukit Barisan Selatan National Park. Donna plans to implement her results of the study of turtles to develop a teaching-learning activity at the school, which you visited in Lebong, September 2012. It should be noted the Parks in Bengkulu are not yet used optimally as learning resources for improving the quality of conservation education so we look forward to this next phase of our project.

At this time, the program "UNIB Campus, A Safe Home for Turtles" has received positive feedback from students, faculty, and the leadership of UNIB. In November 2013, the Rector of UNIB inaugurated the first year of the program by releasing a number of *C. odhamii* on a pond, Taman Pintar, in the park, which will be used as a place for outdoor teaching and learning. The leadership of UNIB has provided land for the second year (November 2014) of the program, which will focus more on *C. amboinensis*. A number of S2 graduate students have been and will be involved in these activities (Fig. 20.1). The program uses the aquatic turtle traps (Fig. 20.2) as well as procedures and techniques that have been developed by The HERP Project in NC. Every year another species of turtle will have a safe place on the UNIB campus.

Fig. 20.2 Capturing turtles

Conclusion

Clearly, NC has more numerous and more well developed opportunities for individuals interested in conservation education and EE than Bengkulu. While NC has many opportunities, a lot of these are not well funded or well attended and often participation is low (for example, the NC EE certification program has certified less than 1% of NC K-12 [ages 5–18] teachers).

In contrast, Bengkulu has just as much, if not more, land set aside as natural areas for the purpose of conservation, but few opportunities for ISE exist. It is unlikely that integrating conservation education and EE across the curriculum in formal science settings will result in more environmental awareness and more environmentally-friendly activity. More ISE opportunities must be developed and implemented and made widely available to residents of Bengkulu.

The natural resources in Bengkulu Province are threatened primarily by the expansion of mining and plantations. Currently, 46% of the land in the province is forested, but Bengkulu's natural resources are under attack. NC also has many environmental issues that must be addressed now and in the future. In order to conserve Bengkulu's natural resources, we suggest a two-pronged approach: (1) conservation education, and (2) more ecologically informed law enforcement personnel. NC's policy of requiring park rangers to obtain their EE certification is a policy that is consistent with our recommendation for law enforcement officers in Bengkulu's parks. The principle of sustainable economy is in line with the ideals of natural resources conservation as well as science education that produces innovators. A culturally appropriate effort for increasing young peoples' knowledge, appreciation, attitudes, environmental awareness, and involvement in the conservation forest areas are necessary as a part of holistic conservation efforts in Bengkulu.

It is critical that NC and Indonesian wild lands be preserved and conserved. Renewed efforts are needed to attract the general public, especially young people to the fields of EE and conservation education, to both locales.

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Chapter 21
Explorers of Nature in Natural History Museums—An Approach to Integrating Children with Refugee or Migration Status

Alexandra Moormann

Introduction

In 2015, 250 million people worldwide migrated (Helfrich, 2016) and their reasons for doing so are diverse. According to the United Nations High Commission for Refugees (2015) 59.5 million people were fleeing from war, persecution, poverty, or criminal violence in 2014. Today, these enduring migration situations are a humanitarian crisis and a social, economic, and development policy challenge (Helfrich, 2016).

Approximately 1.1 million people arrived in Germany in 2015 and were registered by EASY (**E**rstverteilung für **Asy**lbewerber, which means first distribution for persons applying for asylum). This number includes all refugees who passed the German border. Even though some of the refugees moved to Northern Europe and did not stay in Germany, 500,000 people took shelter and filed an application for asylum (Federal Office for Migration and Refugees, 2016). In order to integrate the immigrants into society, Germany provides various forms of aid. The successful integration of migrants and refugees, from an economic, social, and cultural point of view is one of the main challenges, but also an opportunity for German society. A Culture Report published by the European United National Institutes for Culture (EUNIC, 2014/2015) in collaboration with the European Cultural Foundation (ECF) states that "Be it religion, language, education, or media—culture is clearly the key to successful integration" (EUNIC, 2014/2015). For children, this cultural integration may begin at school.

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Education for Nonnative Students

After arriving in Germany, refugees are housed in emergency accommodations, where they live with their families or with other refugees in crowded conditions. According to the Education Act in Berlin, compulsory education applies to everyone from age 6 to 16 (Schulgesetz für das Land Berlin §42, 2010) and for refugees and asylum seekers up to the age of 18 (United Nations High Commission for Refugees [UNHCR], 1951). After their arrival, children are expected to begin school as quickly as possible.

But how could nonnative students with no knowledge of the German language be educated? In Berlin, during the 2011/2012 school year, the Senate Department for Education, Adolescence and Research (Senatsverwaltung für Bildung, Jugend, & Wissenschaft, 2016) established Welcome Classes. Welcome Classes are learning support groups for immigrant children who have no knowledge of the German language. These special classes are established at regular schools—primary schools and secondary schools—with a reduced number of students (maximum 12 students per class) who come from different countries, speak different languages, and are different ages. According to the *Guideline for Integration of Nonnative Children and Teenagers into Kindergarten and Schools* (Senatsverwaltung für Bildung et al., 2016), the immigrant students must assimilate into the regular class after 6–12 months and attend classes with German students.

The focus in Welcome Classes is learning the German language. Language is the most important medium for interpersonal communication. Shared language not only accounts for social integration and participation, but is a central competency for gaining knowledge in school (Senatsverwaltung für Bildung et al., 2016). In the case of science education, Carlsen (2010) emphasized the role of language in science and science teaching as the achievement of shared understanding. Learning and language are social accomplishments; therefore, he postulates that language is a tool for participation in communities of practice.

Access to Cultural Education and Science Education

At school and during language courses, refugees learn the German language and obtain a basic insight into German culture. Learning in school contributes greatly to a child's integration into the new society. But based on the fact that culture is a key to successful integration (EUNIC, 2014/2015), all immigrants should have access to cultural institutions such as museums. Because Germany is hallmarked by a high level of immigration, museums in Germany must take into account the cultural diversity that leads to new perspectives and new directions in museum work (Network of European Museum Organisations [NEMO], 2016). In response to the call for understanding the influence of immigrants in museum work, NEMO (2016) stated that "Engaging with the issue of migration runs in parallel to the efforts that many museums are making to become more open and to develop new ways of working with and for the public" (NEMO, 2016, p. 4). These engagements with immigrants are an important aspect of the museum because (1) science museum exhibitions promote emotional reactions, reframe ideas, introduce new concepts, communicate the social and personal value of science, encourage deep experiences of natural phenomena, and showcase cutting-edge scientific developments (National Research Council [NRC], 2009, p. 41) and (2) "museums offer a personal, cultural approach to new communities; they support dialogue between cultures and help with understanding one's place in the world" (NEMO, 2016, p. 3).

Since their inception, science museums have developed from research and collection oriented institutions to places for public education and learning (Falk & Dierking, 1992; Shaby, Assaraf, & Tishler, 2016). The learning that occurs outside of school has been bequeathed with many names (e.g. informal education, non-formal learning or learning in out-of-school contexts) (Rennie, 2010). For the purpose of this chapter, informal science learning occurs in outside of school activities which are not part of the school curricula (Crane, Nicholson, Chen, & Bitgood, 1994; Patrick, 2016). In the case of the Museum für Naturkunde Berlin, cultural education and science education are seen as merging to inform all about science. In the museum, all visitors are provided the chance to learn, no matter their age, educational background, gender, race, ethnicity, or ancestry. More than 75,000 people, from 5 years old to adult, take part in Museum für Naturkunde education programs each year. Our main focus is to open the museum to visitor groups, such as adults, elderly, families, students, and tourists, as well as, migrants and refugees. Museum für Naturkunde educators are instructed to consider that learning "is influenced by the context (personal and social as well as physical) in which it takes place, that it is primarily a social activity, that it is underpinned by its cultural significance, that it requires an understanding for multiple perspectives and that it is increasingly collaborative" (Black, 2012, p. 81). Based on the assumptions that learning is cultural and based on social activity, the museum educators began to contemplate the possibility of developing a special science program for Welcome Classes in the Education Department of the Museum für Naturkunde.

Explorers of Nature

Due to support from the F.C. Flick Stiftung gegen Fremdenfeindlichkeit, Rassismus und Intoleranz (Foundation Against Xenophobia, Racism and Intolerance), in the summer of 2015, the museum educators began the *Explorers of Nature* program. In order to provide access to culture and nature from different perspectives and in the context of diversity, the program had to be interdisciplinary and include the participation of museum educators (biologists) and artists. Because the project was new and innovative, the educators ran a pilot project with two Welcome Classes of 9–11 students (ages 6–12). Two classes were chosen in the beginning so that the educators had an opportunity to learn from the process. The idea was to establish a team that would contribute various competencies and experiences to the project. The resulting team consisted of: (1) two museum educators with backgrounds in science and experiences in teaching science, (2) two artists, who developed and conducted many art projects for children, and (3) an Arabic speaking college student.

In preparation for the project, the team met with the social worker of the residential home for refugees and the two classroom educators who taught the Welcome Classes. The team discussed important points concerning the project and developed the content and the sequence of the program together. When the program began, some of the children had just arrived in Germany and had a long and difficult escape from their home countries, sometimes with traumatic experiences. The social worker of the residential home and the two Welcome Class teachers provided us with important information, such as, the background of the children, behavior, language abilities, nationalities, and needs. Additionally, the social worker clarified organizational procedures, e.g. the needs of the children to be picked up at the residential home and accompanied to the museum or excursions, because they did not know the city or how to use public transportation. (*Note*: Based on the initial success of the Explorers of Nature program, the team decided that understanding the needs of children was essential for the success of the project.) Developing a team with various perspectives and working directly with the classroom educators and social worker, provided expertise the museum educators did not have. Before the project started, all involved persons visited the Welcome Classes and introduced themselves, so that the children knew all the team members.

The aims of the Explorers of Nature project was (1) for children to explore the urban nature of Berlin scientifically, especially biologically, artistically with drawings and photographs, geographically with the focus on orientation and in a social and cultural manner that supported and embedded German language learning and (2) to build a relationship between migrant families and the museum. These goals were supported by field trips that were considered "inspiration" tours (Sørensen & Kofod, 2003), in which the children could explore nature and the exhibitions of the museum accompanied by the team and on their own. During the project, the children were encouraged to use their senses, such as observing, touching, hearing, and smelling. Additionally, the parents were invited to participate in a similar field trip with their children and attend a feast at the museum.

Description of the Program

The program lasted one school week for each Welcome Class and included a family weekend completed a few weeks later. Table 21.1 describes the daily activities in which students were involved.

Day 1. The first day of Explorers of Nature focused on students and museum staff getting to know each other. The students explored the museum by participating in a guided tour through the exhibitions of the museum and behind the scenes into

Table 21.1 Sequence of the project Explorers of Nature

Day	Place	(Learning) topic
1	Museum für Naturkunde	• Getting to know the museum with its exhibits, scientific collection and research projects • Identifying professions in natural history museums • Learning about the museum as an educational, cultural and scientific place that brings people together
2	Karow Ponds located in nature reserve Barnim Nature Reserve	• Observing the protected area • Collecting microorganisms in a stream • Bird-watching • Getting in touch with nature in Berlin Student assignments: photographs and drawings
3	River Spree canoe trip	• Learning about canoeing • Developing team building skills • Observing the natural area • Collecting microorganism and benthos, like bivalves • Bird-watching • Developing orientation skills Student assignments: photographs and drawings
4	River Spree canoe trip	• Learning about canoeing • Developing team building skills • Observing the natural area • Collecting microorganism and benthos, like bivalves • Bird-watching • Developing orientation skills Student assignments: photographs and drawings
5	Museum für Naturkunde	• Investigated the collected microorganisms Final product: a presentation of the week's findings, including photographs and drawings to invited family members and museum staff

the scientific collections. At the end of the first day, the students discussed various museum professions, such as collection assistant, taxidermist, exhibit designer, photographer, security staff, cashier, etc.

Day 2. During the second day the students visited the Karow Ponds located in Barnim Nature Park, a nature reserve where they explored the local nature. Students participated in bird-watching (Fig. 21.1) and collected water samples (Fig. 21.2) with microorganisms, which they analyzed in the microscopy center at the museum. The microscopy center is a teaching and learning laboratory for museum visitors such as citizen scientists, students, teachers, and other interested visitors (for more information see Moormann & Faber, 2015).

In order to introduce the students to domestic bird life, the students were given laminated photographs of cuckoos, cormorants, egrets, wild ducks, brants, and swans. Equipped with field glasses students walked around the nature reserve and

Fig. 21.1 Bird-watching in the Karow Ponds located in Barnim Nature Reserve, Berlin

used the laminated photographs to identify local birds. During their visits to the outdoor areas, students were asked to take photographs of their activities to share with family and friends. In addition to taking photographs of the nature reserve, each student had a logbook for the project week, in which they documented their findings and experiences in the form of drawings and notes. Their drawings often prompted discussions which allowed them to develop their communication skills and promoted learning (Ainsworth, Prain, & Tytler, 2011). For example, while reflecting on their drawings, students named the animals, plants, or objects they drew and learned the specific names in German (Fig. 21.3). During the drawing discussions, the museum educators relied heavily on the Arabic speaking student assistant. The Arabic speaking students assistant proved to play a key role in the project as she attended both weeks of the project and assisted when language was a barrier.

Days 3 and 4. As reflected by a student drawing in Fig. 21.4 and a student photograph in Fig. 21.5, the next 2 days focused on canoe trips to the river Spree, which is located in the middle of Berlin. During the canoe trip, the students collected benthos, like bivalves and microorganisms, insects, and crustaceans, and stopped for a picnic at Treptower Park. The project team artists were responsible for the canoe trips, because they often organized canoe trips for people who were interested in exploring the urban nature of Berlin. Additionally, each canoe trip included a certified life-guard. We found that the children were very interested in the life-guard and he became an important part of the project.

Fig. 21.2 The students collected water samples, which they subsequently investigated in the microscopy center at the museum

Fig. 21.3 Student's drawing of a red-breasted merganser (*Mergus serrator)*, in German called "Mittelsäger"

In addition to experiencing nature, one group, during their first canoe trip, was checked by the water police. Even though the museum educators did not plan this experience, they found that the experience with the water police was a teaching moment about local culture and became ingrained in the adults' and students' ideas

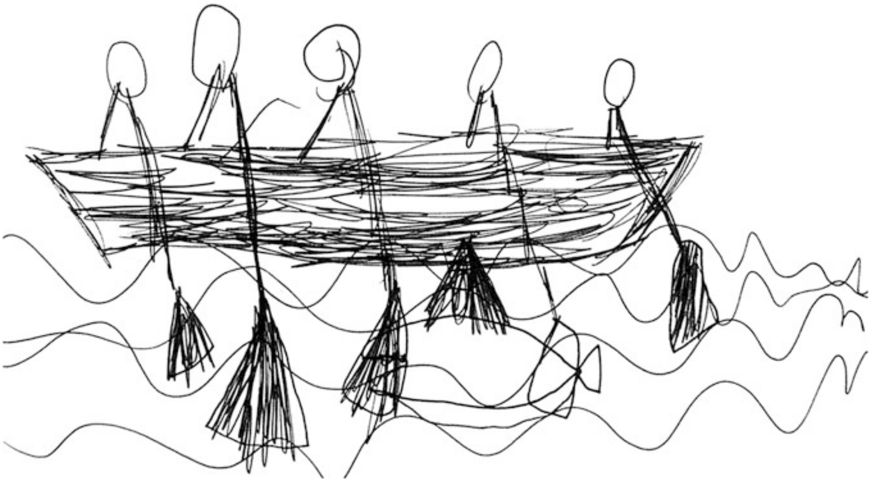

Fig. 21.4 Student's drawing of the canoe trip on river Spree

Fig. 21.5 The children with their attendants during their canoe trip on river Spree

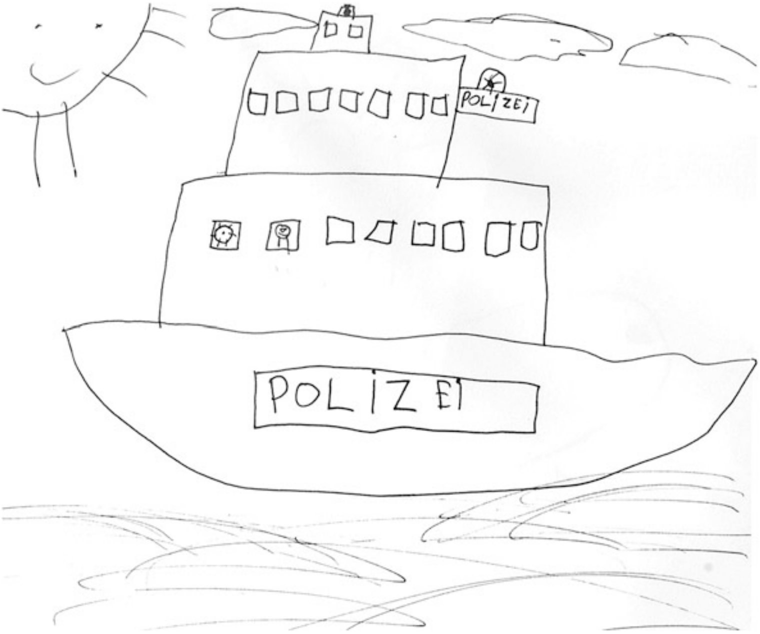

Fig. 21.6 Student's drawing of the experience with the water police

about the experience. In fact, when asked to reflect on the day through drawings, a student drew the water police, which was an impressive experience for the children, as shown in Fig. 21.6 (The next section includes vignettes from the artists, who mention the water police experience.).

Day 5. On the last day of the event, the students gathered to discuss the organisms and water samples, along with their drawings, photographs, and impressions of their experiences. After they had an opportunity to review the experiences they had during the week, they met with the artists and the museum educators. The artists and educators worked with the children to analyze their data and prepare their findings about the organisms and water samples. Students used high quality stereo microscopes to view the world inside a water drop. They shared their drawings and photographs and reflected on the experiences they had during the project. The goal of the last day was for students to prepare a presentation in which they would share their Explorers of Nature experiences with their families and museum staff. At the end of the project the children received Explorers of Nature certificates, which stated they were certified explorers.

Including Family

Two weeks later. The premise for Explorers of Nature was to provide immigrant children with outdoor experiences that would promote German language learning and forster science learning. However, the desire of the Explorers of Nature team was to additionally include the families of the children. Therefore, a few weeks later the families were invited to the museum to participate in a 2-day canoe trip on the River Spree that included activities for the entire family. The families explored the city, observed the open space on the River Spree, and had a picnic on the shore of the river. The family weekend proved to bring the experiences of the children in sync with their parents' experiences and they were able to share science experiences. Even though the weekend focused on exploring nature, the families had an entertaining and exciting day.

Weeks later. A few weeks after the completion of the project, the team invited all stakeholders in the Explorers of Nature project (children, their families, Welcome Class teachers, residential home social worker, education team, student assistant language interpreter, general director of the museum, representative of the granting foundation) to a large feast at the museum. All attendees were encouraged to bring their families. During the party, the students' findings, drawings, and photographs that resulted from their participation at the Karow Ponds and River Spree were presented in a slide show. In addition, all attendees were invited to do hands-on experiments and to tinker in the microscopy centre. Moreover, students were museum experts and guides and shared the museum exhibitions with their parents. At the end of the party, each migrant family received a free annual museum pass in order to encourage them to stay involved in the museum.

One Project: Many Perspectives

After the project was completed, a classroom educator, the artists, and the Arabic speaking student assistant were asked to write about their experiences during the Explorers of Nature project. Their vignettes are included below, because the vignettes provide the reader with the perspective of those involved in the project. The following vignettes have been translated from German to English.

One of the Welcome Class educators described her experience as an adventure. She stated that

> We all felt excited like pioneers which in fact we became. Walking to a small stream we would never have thought of catching little water organisms in. Coming to a museum we would have never thought of doing our own research, with microscopes. In rooms that were behind doors behind the exhibition space, unknown to most visitors. We never knew we would observe so much detail, sketching all those birds and fish that got valued by our guides and hence became visible everywhere around us. We became actors and respected partners in an adventure, (re)discovering our own unknown curiosities and new skills. We loved the excursions into nature on foot and by boat, that reminded us of our very own personal nature experience back home. And back in the museum we could finally show all

> the photos and treasures to our families so they'd appreciate and understand what we learned and created with the museum guides, the artists and that much beloved Arabic college student translator. They had become friends and we discoverers to go on (Heike/Teacher).

While the Welcome Class educator focused on being an explorer or discoverer, the artists were most interested in the interactions that took place during the canoe trip. They stated that

> After a prolonged start in the canoes (the water police were taking ages to check our permission to paddle there) on the inner city river Spree we finally took to the waters. Moments later it started to rain and everyone dressed up in rain gear. It meant our trip in the canoe was reduced to 30 min paddling. For the adults it was slightly tiring and disappointing, yet the kids didn't mind to go back to the shore and wait it out. After a while it stopped raining and we were able to sit outside on the terrace at the river shore named "Doppelkaianlage am May-Ayim-Ufer" in Berlin Kreuzberg. We were drying in the sun and some children started by themselves to draw from memory things we have seen during this super short canoe trip. We exchanged the log books gifting drawings to each other. It was a concentrated 30 min session without much explanation or guidance necessary. It really made everyone's day. Water police encounters, rain on the river and the occasional water bird turned into solid memories: drawings (Caspar & Birgit/Artists).

The translator focused on the cultural and social burdens the students carried with them as they left one country and became migrants to another country.

> This was my 2nd project with the Museum für Naturkunde and I never felt so much in love before. It was amazing to see all those kids, from all over the world, playing together, respecting each other and forgetting about the past. Some of them lived in fear and going out to learn about the love and glory of nature have never been so important. Sitting in a canoe and listening to some of their stories about fleeing in a military boat was quite scary. Those lovely little kids are so brave and I am happy to get to meet even more of them in the future, to learn from them and become friends. On my opinion it's a tragedy to know that some of them are not allowed to stay here. But they know we just have to live for the small things and make them bigger. No matter if we're eating sandwiches on a picnic, talking about birds while sitting in a canoe or waiting for the bus which drives us to our next adventure. We never know what the future holds and when we're going to see each other again. So let's sit down and draw, learn and love (Isra/Arabic speaking student assistant).

When asked about her perspectives of the Explorers of Nature project, the Welcome Class educator stated that the project allowed "the museum [to] reactivates [reactivate] its role as an active agent in society." She described the museum as a place that has potential to present everyone with an awareness of global connectedness. In collaboration with this Welcome Class educator, I created a visual to depict the various perspectives and diversity of the Explorers of Nature project. Figure 21.7 presents a triangle in which the center represents the student's discovery of a new self-concept. This self-concept is influenced in various ways by each of the project participants. The educator stated that the "refugees are typically reduced to language learners or people who need help. Their unique perspective and their own multiplicator [ability to teach or share information] function are often not taken into account."

Fig. 21.7 Triangle of interactions between the different participants of the project Explorers of Nature

In the project Explorers of Nature the Welcome Class students took on the role of discoverer and knowledge broker. As students developed their internationally informed narratives they became active in the science learning progress. Their status as a refugee was not relevant during these interactions, instead their curiosity, interactions, and developing narratives were crucial. In this context, the children and their families interacted with and shared experiences with the various project participants. During their interactions with the artists the children and the artists investigated within and developed their narratives and established new perspectives for each other. The children better understood the perspectives from an artistic point of view and the artists gained insight into the personal views and biographies of the children. Even though the individuals in the project had differing dimensions of appreciation for the experiences and the modes of teaching and learning were different, their interactions with each other contributed to enriching the experiences of everyone involved. In other words, the experiences were different, but complemented each other and led to opportunities to share cultural and personal narratives. The museum educators introduced scientific methods like observations, microscoping, drawing, collecting and identification of species; the artists provided a cultural and social perspective through art; and the students became active learners through their experiences during the field experiences. Thereby, all involved fostered curiosity and aroused interest—not only in natural sciences, but also in individual stories and perceptions on varying layers.

From the point of view of the Welcome Class educator, the museum and the community needed the Nature of Explorers project because "it places the museum in the role of an active, up-to-date agent of society. It presents natural science in a position of relevance for the well-being, education and meaningful progress of humankind. It introduces interdisciplinary work fields with multifold [multiple] points of approach. It clearly positions natural sciences as actively going beyond racist, colonial and abusive historical shadows. Explorers of Nature promotes the museum to these children (important multiplicators!) as an accessible and fun place to go."

Discussion

As previously stated, the desire of the team was for children to explore the urban nature of Berlin, be exposed to the German language, and build a relationship between migrant families and the museum. Overall, the goals of the project were met. The team members perceived the project as a fruitful and intensive experience with a sustainable effect (see Anyimadu, 2016, p. 9). The student participants became familiar with science skills, such as collecting samples, drawing, observing, photographing, and using a microscope. Moreover, through the conversations that occurred with the team and others, the students were exposed to the German language and the team learned about the experiences and life of the migrant children and their families. The information learned on both sides of the experiences was invaluable. The team found that the project was successful in promoting interactions among families and encouraging the families to interact in science focus experiences. This supports the supposition that Explorers of Nature facilitated family science experiences, in the context of the museum and nature (National Science Teachers Association, 2009; Perera, 2014). The families were exposed to the natural side of Berlin, the River Spree, wild animals, and the exhibits in the museum (e.g. dinosaurs, pterosaurs, archaeopteryx).

Museum educators realize that the first goal of science museums is making science accessible to the public through learning experiences instead of through educational content (Shaby et al., 2016). This project supports this notion by involving refugee students and families in science learning experiences. Based on the idea that experiences instead of content are important, this project could be a model for other cultural institutions. For those who might be considering a similar project, I make the following suggestions:

- The success of the project is closely related to the careful preparation and close collaboration between the museum and classroom educators, social worker, and artists.
- The team must be multi-disciplinary and include various perspectives.
- The project must take into consideration the needs of the refugee population. For example, in this project student travel to the museum was a major barrier.

- The previous knowledge and experiences of each student is crucial to their individual learning.
- Shift the project focus from what is being learned to how the learning is experienced (Shaby et al., 2016).
- Prior to the project, define your refugee population and find someone who works closely with the population.

In summary, museums should develop projects for refugees that are based on the a clear identification of refugee needs and experiences. In order to integrate children and their families into society, the activities must focus on the refugees and their experiences. In other words, the program and activities must be focused on the migrant children and their families and making them feel like a vital part of the interactions. As a matter of course, more projects should be tested and discussed in the museum community that focus on migrant families. Moreover, an important aspect of program development is the exchange between all stakeholders to achieve a quality program.

Note: The presented pilot project Explorers of Nature was an experiment and all participants had the same goal: to implement annual projects for Welcome Classes and refugees to explore Berlin's nature in form of diverse approaches and perspectives for a better integration in our community. This project conforms to the demand pronounced by NEMO (2016), that cooperation projects needs to be developed that enables a concrete form of collaboration, to enable people to participate in the everyday cultural life of a city or community.

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Part V
Science Communication

Chapter 22
Preparing Scientists to Be Science Communicators

Ayelet Baram-Tsabari and Bruce V. Lewenstein

Science communication is a professional skill increasingly expected of scientists by their own organizations (Kuehne et al., 2014a; Leshner, 2003, 2007; National Research Council, 2014). Several studies have described motivations and challenges for scientists who wish to engage with the public, as well as the abundance of such interactions (Bauer & Jensen, 2011; Besley & Nisbet, 2013; Besley, Oh, & Nisbet, 2013; Dunwoody, Brossard, & Dudo, 2009; Dunwoody & Ryan, 1985; Dunwoody & Scott, 1982; Jensen, 2011; Jensen, Rouquier, Kreimer, & Croissant, 2008; Kreimer, Levin, & Jensen, 2011; Peters et al., 2008; Poliakoff & Webb, 2007; Torres-Albero, Fernández-Esquinas, Rey-Rocha, & Martín-Sempere, 2011). However, few studies have systematically examined scientists' ability to communicate with the public. Nonetheless, many organizations and institutions have created training opportunities to help scientists become better at public communication. Universities and professional organizations offer a wide range of training programs for scientists. According to the US Directory of Science Communication Courses and Programs, as of 2007 there were 51 university-based programs in the United States (excluding commercial or nonprofit training options) (Atkinson, Deith, Masterson, & Dunwoody, 2007). According to the European Guide to Science Journalism Training, as of 2010 there were some 80 such programs throughout Europe (Directorate General Research, 2010). Similar programs also exist throughout Asia and Australia (Gascoigne et al., 2010).

Although much effort is being invested in science communication training, a conceptually-based list of specific learning goals has not yet been developed, and the existing training efforts are rarely accompanied by systematic evaluation of learning outcomes. Few programs do sufficient and appropriate evaluation to

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demonstrate the effectiveness of their approach (Silva & Bultitude, 2009a). This chapter begins with reviewing the motivation behind communication training for scientists, and demonstrating the heterogeneity of current approaches to such training. Then it identifies a list of core competencies for effective science communication by scientists in terms of skills, knowledge, and attitudes and specifies assessment practices to measure the attainment of these goals. It demonstrates and points to effective pedagogies to achieve the relevant learning goals in the context of a science communication course aimed at STEM graduates in a Technological University.

Motivation for Communication Training for Scientists

In recent years, leaders of the scientific community have called for public engagement in science (Leshner, 2003, 2007; Royal Society, 2006). Modern science communication is part of the contextual approach that "sees the generation of new public knowledge about science much more [as] a dialogue in which, while scientists may have the scientific facts at their disposal, the members of the public concerned have local knowledge of, and interest in, the problems to be solved" (Miller, 2001). Scientists and publics need better communication because of the wide array of social issues that have a scientific component: public health, climate change, energy choices, sustainability, food security, etc. Yet to address these issues requires both better public knowledge of technical issues and better scientific understanding of the social and political dimensions of science-related social issues (Fischhoff & Scheufele, 2013, 2014). However, communicating with non-technical audiences is not part of the training that most scientists receive.

Alan Leshner, then-CEO of the AAAS, called on universities to initiate activities that engage the public and create platforms for scientists' involvement in these activities. He made two recommendations: to change the benefits system for scientists so that it would include public involvement, and second, to have university science departments start programs to train their graduates in communication with the public, by adding communication training to their scientific training (Leshner, 2007). More such calls for integrating science communication training as an essential part of educating graduate science students have also been expressed (Kuehne et al., 2014b).

The need for better training in media skills for graduate students in STEM fields (Science, Technology, Engineering, and Mathematics) was also discussed at the GradSciCom conference (COMPASSonline, 2013). Participants drafted a common vision, explaining how the successful integration of media training for university graduates in the sciences can become a catalyst for changes in various areas. On the societal level, an improvement in scientists' communication skills can foster scientific literacy among the public, and in the scientific community training can facilitate the development of more effective interdisciplinary science. On the individual level, training can help recipients meet the requirements of funding foundations and provide them with additional routes for professional development. The participants defined a number of specific objectives, including making media training an integral part of academic training, just like ethics and statistics, and helping teachers acquire a shared understanding of best pedagogical practices. The delegates concluded that evaluation is also needed because few programs actually assess the efficacy of their training, thus making it hard to evaluate whether they provide a proper return on investment (COMPASSonline, 2013).

Members of the public, as well, expect scientists to communicate more. Nearly 60% of Europeans think scientists should put more effort into communicating about their work (Eurobarometer, 2010). Focus groups conducted in European countries thought scientists should appear as main actors when science is presented in TV programmes (Lehmkuhl et al., 2011).

Most scientists do not have any training in media or public engagement (The Royal Society, 2006). In general, the training of communication competencies does not seem to be a systematic part of research management. Rather it is viewed as the result of inborn personality traits, and one of the many things that future scientists have to learn somehow along the way (Horst, 2013). However, social norms, a sense of self-efficacy, and a desire to contribute to the public debate were found to be correlated with scientists' online engagement with the public (Besley, 2014). Therefore, motivating and enabling scientists to participate in civic life may involve efforts to improve internal efficacy through training (Besley, Oh, & Nisbet, 2012). Tsarfati, Cohen, and Gunther (2010) found that shyness plays a role in reducing scientists' motivation and effort to disseminate their work beyond the scientific community. They also suggested that training to increase comfort and confidence is important, in addition to raising awareness of the importance of science communication.

Scientists seem to agree with this conclusion. Poliakoff and Webb (2007) found scientists' belief that they lacked appropriate communication skills to be one of the main causes of their non-participation in public activity. Unsurprisingly, science scholars, many of whom are deeply involved in providing such training, are largely in agreement that bench scientists and engineers as well as science and health regulators would benefit from both media training and training in communicating with the public (Besley & Tanner, 2011).

Approaches to Science Communication Training

So far we have used "media training" and "communication training" almost interchangeably, although the first is focused on speaking with journalists, dealing with unpleasant questions in live broadcast TV shows, etc., and the latter helps scientists to communicate with the public, focusing on abilities such as creating trust and appearing involved and empathic. This aggregation of very different audiences and goals is typical of this under-conceptualized field.

The richness of science communication initiatives is characterized by heterogeneity of pedagogy and perspectives used in training programs established around the world. Science communication is being taught in a great variety of ways; it may vary with regard to duration and location, science background requirements, emphasizing skills or theory, and stressing different agenda (e.g. Burns, O'Connor, & Stocklmayer, 2003; Gold, 2001; Ham, 2008; Miller, Fahy, & The ESConet Team, 2009; Mulder, Longnecker, & Davis, 2008; Silva & Bultitude, 2009b).

Programs operate within a variety of frameworks. Some courses are designed to prepare students for careers in public organizations, foundations, research institutes, museums, and science journalism. The academic programs address audiences that can include undergraduate, graduate, or doctoral students. Some programs focus on science in the media and others integrate other disciplines such as general media studies, education and STS. The programs vary in length from a few days to a full degree program several years long (Bettencourt-Dias, 2007; Mulder et al., 2008). Trench and Miller (2012) found that the emphasis across the main groups of actors supporting scientists' public communication training—governments, higher education institutions, research councils, and the European Commission—is stronger on dissemination than on dialogue and significantly stronger on capacity-building among scientists than on professionalization of science communicators.

Turney (1994) classified science communication training programs into (1) Media skills training, (2) Training combining skills and theory, and (3) Complex training, combining skill teaching with content from broad scientific disciplines, which may include elements of science education. Mulder et al. (2008) reviewed the common factors in media training at 19 universities and defined four frameworks for science communication studies: scientific content, science education (didactics), science and technology studies, and media studies (theory and skills). Nearly all the programs surveyed included assignments such as conducting an interview, preparing a poster for a scientific conference, and writing a press release. About half of the programs required writing a news item, writing a children's story, creating a display for a museum, and producing a radio or television item.

Bray, France, and Gilbert (2012) sought to define the core components for the effective teaching of science communication, based on the opinions of science communication experts, using the Delphi methodology. The experts concurred that training needed to focus on the audience and its needs. They believed courses in science communication should foster a broad understanding of the nature of science and the political, social, and cultural components which affect the environment in which scientists operate, rather than focus on developing technical skills. Similarly, a survey of science communication scholars revealed that the most common focus of training by these scholars was basic communication theories and models, rather than practical media training. Some training programs were oriented toward public engagement, and news value was relatively common for bench scientists and engineers and science and health regulators (Besley & Tanner, 2011). AAAS members, the beneficiaries of this training, value training that makes their message more understandable to a range of audiences, but they also value training which will help them frame their message to resonate with an audience's values or predispositions and help them appear credible and caring (Besley, Dudo, & Storksdieck, 2015), all of which are very practical goals. Indeed, the demands of the public engagement approach are great. Reddy (2011) claims that scientists have to do a better job of communicating not just what they know, but also what they do not know, and what is uncertain. Nisbet and Scheufele (2009) suggest that scientists and their organizations must learn to focus on framing their messages in ways that activate participation from wider, more diverse and otherwise inattentive publics. They also suggest that scientists explore new media platforms for reaching non-traditional audiences.

In addition, in the past 10 years, many books have been published with practical advice for public communication of science and technology (e.g. Baron, 2010; Bowater & Yeoman, 2012; Christensen, 2007; Dean, 2009; Hayes & Grossman, 2006; Johnsen, 2010; Meredith, 2010; Olson, 2009; Van den Brul, 2013; Walters & Walters, 2010). These books contain many excellent suggestions of what scientists need to know or be able to do. However, the advice in these books and the courses described earlier is based almost entirely on practical experience, not on systematic learning theory. As researchers concerned with the issue of science communication, and frequently involved in working with scientists who wish to improve their communication with nonscientific audiences, we believe there is a need to establish a more coherent framework for measuring scientists' communication competencies and, through that framework, measuring the success of science communication education programs. We start this attempt by thinking about potential learning goals for scientists who are learning to communicate with non-technical audiences.

Potential Learning Goals

We used the theoretical framework of situated knowledge and enculturation (Brown, Collins, & Duguid, 1989), which sees "learning science" as learning to communicate in the language of science with its special vocabulary and norms. From this perspective, learning science means learning to talk science, with its own semantic patterns and specific ways of making meaning. "It means learning to communicate in the language of science and act as a member of the community of people who do so" (Lemke, 1990, p. 1). For scientists, who only learned how to speak of science in the language of science, communicating with the wide public demands yet more learning. It is by no means a trivial or natural task.

Following the educational triad of skills, attitudes and content, we have identified learning goals in three key areas: communication skills, views about science communication, and knowledge of the context in which science communication takes place. This is by no means a comprehensive list of learning goals. For example, an important long-term learning goal that we do not address is a behavioral change—such as an actual increase in participation in science communication events. We also do not address issues such as creating a sense of trustworthiness or empathy, which are increasingly being recognized as central to the process of public engagement with science. This list represents a conceptually and practically based attempt at addressing potential learning goals for science communication with an emphasis on media training and written science communication (such as writing for the traditional or new media).

(1) *Communication skills*.[1]

We developed a framework of learning goals for public communication of science (Table 22.1). This framework builds on work that looks at different contexts and types of public communication (Miller et al., 2009); on theoretically-informed analyses of pedagogical presentations by scientists and science students (Kapon, Ganiel, & Eylon, 2009a, b; Sevian & Gonsalves, 2008); and on our own reading from the wide range of practical advice books for scientists described above.

Learning goals must be tied to the specific context for which the learning is intended. The most explicit set of categories we found came from the EU-funded ESConet training program, which divides its study modules into "basic" and "advanced" (Miller et al., 2009). The advanced modules, in particular, deal extensively with "dialogue-based" science communication in which scientists and publics interact with regard to issues that have high policy relevance or social controversy associated with them. We divided the ESConet "basic" category into "basic" and "intermediate" categories, to better align with the material we drew from the pedagogical literature.

The pedagogical literature looks at issues, such as the presentation techniques of leading physicists, who are also highly successful popular physics public lecturers (Kapon et al., 2009a, b) and the practices used by science graduate students to explain their research to nonscientists (Sevian & Gonsalves, 2008). We found the clusters of goals identified by Kapon et al. to be especially useful:

(1) *Content features*: includes elements that reflect a judicious choice of content: What to include, what to omit, and means to achieve this goal (e.g., selection of topic or level).

(2) *Knowledge organization features*: includes elements that manage knowledge (e.g., structure, repetition).

(3) *Analogical approaches*: includes elements that explain the novel in terms of the known (e.g., analogy, metaphor).

(4) *Stories*: includes elements that construct scientific ideas through means that are common in fiction (e.g., narrative).

To these clusters, we added "dialogic," to provide space for goals associated with the dialogue model of science communication. We made adjustments based on our reading of other materials. We conceptualize analogy, narrative, and dialogue as forms of organization, rather than as a desired outcome, such as persuasion or curiosity (Kinneavy, 1971; Rowan, 2003).

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[1] This section on "communication skills" is closely based on Baram-Tsabari and Lewenstein (2013).

Table 22.1 A framework for learning goals in written science communication (Baram-Tsabari & Lewenstein, 2013)

Level	Learning goals	Clusters	Kapon et al. (2009a, b)	Sevian and Gonsalves (2008)	Practical advice books
Basic	Use appropriate language, address readability, use basic explanations as appropriate, avoid jargon, acknowledge prior knowledge (or lack of specific necessary knowledge)	Clarity	[includes clarity within "knowledge organization," includes language within "story"]	Pedagogical content knowledge	Content, language
	Select appropriate content: engaging, interesting, relevant to particular audience. Include scientific information, as well as nature of science, scientific method, implications	Content	Content	Content knowledge	Preparation, content
	Organize presentation well, using good pedagogical and communication techniques: main theme, framing, scaffolding, repetition	Knowledge organization	Knowledge organization	Pedagogical knowledge	Content
Intermediate	Use aspects of style creatively: humor, emotions, anecdotes, local references	Style	[includes aspects of style within "story"]	Pedagogical knowledge	Style
	Develop analogic strategies for explaining complex topics	Analogy	Analogical thinking	–	Style
	Use complex narrative tools as appropriate, such as character development, conflict and resolution	Narrative	Story	–	Style
Advanced	Acknowledge and show respect to multiple world views	Dialogue	–	–	–

Finally, we considered the many detailed suggestions provided by the practical science advice books. This advice, we found, fell into four clusters: preparation, content, language, and style (Table 22.2). We found that these categories could easily be aligned with the clusters derived from the other works (Table 22.1).

In the process of developing these learning goals, we examined a wide range of other sources, such as the guidelines provided by the British Council for participants and judges of the international science communication competition "Famelab" (British Council, 2011) and the judging criteria provided by the "Intel International Science and Engineering Fair" (Society for Science and the Public, 2011). These guidelines can easily be incorporated within the clusters, suggesting that the clusters listed in Table 22.1 are both sufficiently broad and sufficiently differentiated to capture the range of possible learning goals.

Because of the "basic, intermediate, advanced" structure, the learning goals appear to be hierarchical, with each additional goal building on the previous one. While we do not wish to be dogmatic regarding the ordering of the goals, we do call attention to the inherent dependency of higher learning goals on earlier ones.

(2) *Views.*

We know from our own experience and conversations with others that many trainings address issues beyond straightforward communication skills. This is especially true for those trainings developed by researchers in the field of science communication who also bring background from the field of science and technology studies or other "meta-science" areas. These trainings address issues such as the responsibility of individual scientists for public communication; the benefits and impediments to scientists of speaking with the media; individual and institutional norms about interacting with the media; and attitudes towards using new media for public engagement. To more systematically identify these issues, we drew on several existing surveys and studies (Besley, 2014; DOTIK Project, 2007; Gascoigne & Metcalfe, 1997; Ham, 2008; Hartz & Chappell, 1997; Lewenstein, 1987; Martin-Sempere, Garzon-Garcia, & Rey-Rocha, 2008; Peters, 2013; Peters et al., 2008, 2009; Ruth, Lundy, Telg, & Irani, 2005; Schneider, 2009; Tai, 2010; Treise & Weigold, 2002). The learning goals are detailed on Table 22.3 in the left column of the attitudes section, emphasizing media related goals.

We also attempted to address the mental models scientists hold regarding science communication. Many studies in the field use the "deficit model" and a "public engagement model" as reference points for a "traditional" and "progressive" views held by scientists about the public and the role and process of science communication.

Brossard and Lewenstein (2009) reviewed four main theoretical models of science communication, which take different stances on (1) what information ought to be delivered to audiences and how, and (2) how organizations should engage citizens with science. The first of these, the deficit model, rests on the assumption that the more scientific information the public has, its decisions will resonate with the scientific consensus, and/or the more sympathy it would have toward science. This narrow assumption drives efforts to bring scientists and other groups in society closer together by disseminating information and reforming science education,

Table 22.2 Summary of advice for scientists interacting with the media[a]

Title	A scientist's guide to talking with the media	Am I making myself clear?	Sharing knowledge	The hands-on guide for science communicators	Explaining research	Escape from the ivory tower	Goals and design of public physics lectures
Author (year)	Hayes and Grossman (2006)	Dean (2009)	Hartomo and Cribb (2002)	Christensen (2007)	Meredith (2010)	Baron (2010)	Kapon et al. (2009a, b)
Preparation							
Know the basics of journalism	✓	✓	✓	✓	✓	✓	n/a
Get media training	✓	✓	✓	✓	✓	✓	n/a
Know your interviewer	✓		✓	✓	✓	✓	n/a
Build relationship with the journalist	Keep reporters up to date, become on-call expert	✓	✓	Be proactive	✓	Reach out instead of waiting	n/a
Know your audience and shape your message accordingly	✓	✓	✓	✓	✓	✓	✓
Assume minimal prior knowledge	✓	✓	✓	✓	✓	✓	✓
Practice	✓	✓	✓	✓	✓	✓	✓
The message: content							
Focus on a few main points	3–4	1–3	2–3	1–3	✓	3–4	✓
Repeat your main points (in different ways)	✓	✓	✓	✓	✓	✓	✓

(continued)

Table 22.2 (continued)

Title	A scientist's guide to talking with the media	Am I making myself clear?	Sharing knowledge	The hands-on guide for science communicators	Explaining research	Escape from the ivory tower	Goals and design of public physics lectures
Create clear and concise messages	✓	✓	✓	✓	✓	✓	✓
Include methodology/processes	✓	✓	✓	✓	✓	✓	✓
Avoid too much information	✓	✓	✓	✓	✓	✓	✓
Qualify when necessary	✓	✓	✓	✓	✓	✓	✓
Put message into perspective (the "so what?" question)	connection with day-to-day life	✓	connection to current issues	✓	✓	✓	✓
The message: style							
Use examples, analogies, metaphors, give meaning to numbers	✓	✓	✓	✓	✓	✓	✓
Use/avoid clichés	Use	–	–	Avoid	Avoid	Avoid	–
Visualize: use pictures, graphics, tables, animations and movies	✓	✓	Bring the journalist to your lab	✓	✓	✓	✓
Talk from the heart, show passion and enthusiasm	✓	✓	✓	✓	✓	✓	✓
Use humor	✓	–	–	–	✓	✓	✓

(continued)

Table 22.2 (continued)

Title	A scientist’s guide to talking with the media	Am I making myself clear?	Sharing knowledge	The hands-on guide for science communicators	Explaining research	Escape from the ivory tower	Goals and design of public physics lectures
The message: language							
Use simple and short words and sentences	✓	✓	✓	✓	✓	✓	✓
Avoid jargon, acronyms, and abbreviations	✓	✓	✓	✓	✓	✓	✓
Use sound bites	✓	✓	Eye-catching headlines, lively quotations	✓	Artful quotes	✓	–

[a] Additional advice concerns the actual delivery of an interview. These include: stay on message; don’t get angry with the interviewer; never guess answers; offer to check the final draft (but don’t expect the journalist to agree); suggest other scientists who could comment on your work; and offer a written summary so the interviewer will have all the details

Table 22.3 Selected learning objectives for science communication education (focusing on media training) and potential items for their assessment

Learning objectives[a]	Suggested item for assessment
Skills	Short essays, multiple-choice questions
Identify jargon, recognize the level of public prior knowledge	In your opinion, which of the following science concepts should be defined when writing to a non-technical audience? Mitochondria, Angle, Pulsar, quantum, Meiosis, Dark matter, Polymer, Epigenetic, Isotope, Kinetic energy, Density, DNA, Cell, The standard model
Describe your own research clearly and concisely	Please describe your research, its context and implications for a general audience in 150–200 words (you can pick a specific project in progress or research that has already been completed)
Use science to explain everyday phenomena	Imagine you are talking to members of your family, who do not have a science background. Knowing that you have general science knowledge, they ask you one of the following questions about science in their lives. Choose one question and answer in 75–150 words. (1) "Why doesn't the doctor prescribe antibiotics for flu?" (2) "If there is no oxygen in space, how does the sun burn?" (3) "Why can't I use metal in a microwave?" (4) "How do the police identify people based on their DNA?" (5) "How come grandfather, who smoked a pack a day for 72 years, is alive and well at the age of 91, while his vegetarian nonsmoking doctor died of cancer?"
Address questions about science's role in society with respect to different worldviews	Happy with your answer, they now ask one of the following questions, about science's interaction with society. Choose one question and answer in 100–200 words. (1) "How can you believe that humans developed from monkeys, when the Bible says God made us?" (2) "How can you believe that the universe is 13 billion years old, when the Bible says God created it less than 6000 years ago?" (3) "Are humans responsible for the Earth getting warmer or not? Why can't scientists agree on that?" (4) "Is genetically modified food safe? How come the Europeans don't use it but people in America do?" (5) "Why do we spend all this money on giant particle accelerators and journeys to Mars, when there are hungry people in the world?"

(continued)

Table 22.3 (continued)

Learning objectives[a]	Suggested item for assessment
Attitudes	Statements accompanied by an agree-disagree six point Likert type scale, multiple choice questions
Feel well equipped and comfortable working with the media	I feel: • Well equipped to engage with the media about my research • Comfortable working with the media
Recognize the importance of the media for public understanding of science	It is important that the media covers science related issues
Decrease negative attitudes to science in the media	In your experience, mainstream media coverage of scientific topics in general is: accurate, based on credible sources, comprehensive, hostile, manipulative, trustworthy, biased
Recognize the responsibility of individual scientists to communicate with the public	Communicating with the public should ideally be: (1) Not at all part of a scientist's work; (2) An optional activity for a scientist, not a basic part of a scientist's work; (3) An integral part of a scientist's work if he or she receives grants from public funds; (4) An integral part of a scientist's work; (5) other: ____ (choose one answer)
Value the contribution of scientists, from diverse backgrounds, who speak in the media	What are your thoughts about scientists who speak in the media? • Only senior researchers should speak to the media • Good scientists don't have time to speak to journalists because they are busy doing research • Scientists who allow themselves to be interviewed for stories (not just their own research) are just seeking publicity • Scientists who speak in the media contribute to science and society
View popularization as a process of recontextualization or adaptation, rather than simplification	At its best, popular science writing is a process of: (1) simplification; (2) adaptation; (3) translation; (4) recontextualization; (choose one answer)
View the relationship between science and society more as a dialogue and less as a one way transmission	Different people have very different views about the relationship between science and society. Please indicate your level of agreement with the following statements: • People who are skeptical about modern science lack adequate knowledge about science (e.g. evolution, climate change)

(continued)

Table 22.3 (continued)

Learning objectives[a]	Suggested item for assessment
	• People who are skeptical about technological applications of modern science lack adequate knowledge about science (e.g. GMOs, nuclear power) • A more scientifically informed public will more frequently side with scientists in controversies (e.g. vaccination, climate change) • Most members of the public are so ill-informed about science that their opinions about science and technology should not influence policy (e.g. stem cells, GMOs) • Public involvement in science related policy making threatens the research autonomy of scientists (e.g. stem cells) • Even if public involvement threatens the research autonomy of scientists, the public should be involved in science related policy making • The public will lose trust in science if they are exposed to disagreements between scientists • Even if the public will lose trust by being exposed to disagreements between scientists, disagreements should be made public • Explaining science to people and involving them in discussion of controversial issues is important for civic life • Just as the public must be educated on scientific topics, so must the scientific community be educated on public attitudes and opinions
Value media training for scientists	Media skills training is valuable for scientists; in an ideal world all science graduates would take a science communication course
Decrease negative assessment of institutional norms towards public engagement activities	Speaking with the media is… • A good idea to help one's promotion • Unlikely to affect one's promotion • Not worth the risk
Feel motivated and capable of communicating with the public using new media tools (e.g., blogs, social media)	I feel I have the ability to directly engage with members of the public using social media (e.g., Twitter, Facebook)
Knowledge	True/False/Unsure statements, multiple choice questions
Know the context in which science news media operates	Reporters sometimes have less than an hour to work on a science news item An interviewee usually has a chance to see the article before it is printed

(continued)

Table 22.3 (continued)

Learning objectives[a]	Suggested item for assessment
Knowledge about public understanding of science	The questions below were used to test scientific knowledge among COUNTRY adults. For each question, please estimate the percentage of people who gave the correct answer. For example, the statement "atoms are smaller than electrons" is false. Mark the percentile of adults whom you think said it was false Please estimate: What is the percentage of adult COUNTRY who know how long it takes for the Earth to go around the Sun?[b] What is the percentage of adult COUNTRY who disagree that "The greenhouse effect is caused by the use of nuclear power"?
Knowledge of the educational context	Please estimate: During the last 3 years what is the average percentage of COUNTRY students who earned a high school diploma/who complete a college degree?

[a] Learning objectives are specific statements about what a person should know, be able to do, or value as a result of accomplishing a learning goal. They form the basis for testing

[b] As much as possible, statements should be chosen from a relevant content world (e.g., climate change) and the results should represent the status in the country in which the communication is to be carried out (e.g., National Science Board, 2014)

in hope to bridge over gaps in scientific knowledge that exist between experts and laypeople. However, empirical support for these premises is mixed at best. Survey data shows that the relationship between scientific knowledge and attitudes toward science varies substantially between specific domains of science and technology (Allum, Sturgis, Tabourazi, & Brunton-Smith, 2008). The variance in public attitudes on controversial socio-scientific issues is better explained by values, emotions, ideology, social identity, and trust in scientific and other institutions than by scientific knowledge. Yet, despite the evidence against the deficit model, many science communication efforts seem to be still driven primarily by its premises (Nisbet & Scheufele, 2009).

Three other models of science communication reviewed by Brossard and Lewenstein (2009) are:

- The "contextual model" which recognizes audiences' tendency to process new information, sometimes quickly, according to its pre-existing psychological and social schemas. Like the deficit model, it conceptualizes that certain ways publics process scientific information are a "problem" that needs to be "solved."

- The “lay expertise model” which sees lay knowledge as expert knowledge in its own right as well, even if it is not validated by modern science. Accordingly, it argues that additional knowledge should be provided to communities acknowledging and building upon existing knowledge.
- Finally, the “public engagement model” aims to actively involve the public in science and science policy in various ways and levels of influence, including “planning, decision making, management, monitoring, and evaluation” (Stern & Dietz, 2008, p. 11).

We deliberately avoided a dichotomist “deficit model versus engagement model” conception, as recent data provides a basis to believe that scientists can simultaneously hold views that support both the deficit model and the engagement model (Baram-Tsabari & Lewenstein, 2010; Felt, 2010; Lewenstein, 2011). Also, to the best of our knowledge, holding to a more deficit-like or a more dialogic model of science communication has not been linked to specific behavioral outcomes. Yet, the views themselves are sometimes a learning objective (e.g. Miller et al., 2009) and therefore should be clearly identified (Table 22.3).

(3) *Knowledge*.
Finally, we know from our own experience that many scientists have limited knowledge regarding the context in which science news media operates and the general level of public understanding of science. Good communication skills and favorable views about communicating with the public are not enough if one simply doesn’t know that the science reporter she will talk to probably did not study science after 12th grade, and has three hours at most to work on the item.

We could not identify a theoretical base for this area, but instead identified learning goals by creating and validating a series of questions in this area (Lewenstein & Baram-Tsabari, 2011). Together, these questions were designed to elicit “scientists’ understanding of the public” or “public literacy.” Following are examples for constructs that could be explored (see also Table 22.3, last section):

- The context in which science news media operates
- The general level of public knowledge of science and statistics
- The general level of public’s concrete/formal thinking
- The educational context of one’s audience
- Specific knowledge of science-related controversies and the main arguments involved.
- Specific interests, information sources, concerns and lay expertise in one’s audience.

Assessment

A review of the literature on the evaluation of media training programs for scientists shows that the evaluation process is based primarily on questionnaires examining attitude change based on participants’ open or closed reports on their attitudes and feelings. This impression is supported by a 2010 survey that found that more than half of these programs did not include any type of evaluation, whereas the remainder used questionnaires that primarily examined components such as the teaching and organizational skills of the lecturer (Baram-Tsabari & Lewenstein, 2013). This type of evaluation is insufficient for assessing complex learning processes such as the ones required by the learning goals detailed above. Measuring attitude change does not necessarily indicate a change in skills, and measuring teaching effectiveness based solely on participants' self-reporting is not sufficient evidence of learning.

Only a handful of studies have addressed the question of how to measure the effectiveness of science communication training. Most describe assessments conducted at short training workshops. For instance, Gascoigne and Metcalfe (1997) held a two-day workshop for scientists and media professionals. At the beginning of the workshop, participants filled in a questionnaire, rating their opinion of journalists on a scale of 1–7. At the end of the workshop, they completed an identical questionnaire. In addition, participants filled out an evaluation form about the course itself. The results showed that participating scientists changed their opinion of journalists markedly, and that all of the participants found the workshop important and significant.

Miller and Fahy (2009) studied longer courses held by the ESConet (European Science Communication Network) in response to the European demand that scientists be more involved in activities benefitting the general public. The course consisted of nine workshops that addressed different media situations and developed skills such as writing for the general public, conducting media interviews, and dialogic communication. Each workshop was assessed using a four-level Likert questionnaire, and all workshops showed that most participants "completely agreed" that they learned "new, useful things." and that "the whole experience was beneficial" (Miller et al., 2009, p. 123). Qualitative feedback from course participants showed that the teaching method, which allowed application of theories learned in the lectures, was especially helpful. An interesting development of the self-report approach was introduced by Yeoman, James, and Bowater (2011) who examined whether a semester-long undergraduate science communication course in a science department developed communication skills among biology students. In a pre-questionnaire students were asked what science communication skills they expected to learn, and in a post-questionnaire they were asked if they learned what they expected. One of the skills students anticipated developing was "working with children." After completing the module "it was apparent that this module had been successful in allowing students to develop their skills in this area" (pp. 9–10).

An alternative to self-reports are methods that use performance observations, such as Sevian and Gonsalves (2008), who developed rubrics that can be used to monitor the effective delivery of presentations on scientific topics. Rowan et al. (2005) developed a coding scheme to assess the "adaptiveness" of written texts, and found that a one-hour instructional intervention significantly improved participants' explanatory writing.

These sparse and local assessment efforts led GradSciCom conference participants to identify lack of evaluation as a stumbling block to integrating science communication training in programs for STEM graduates. Their argument was economical; namely that without robust evaluation, it is hard to explain how integrating such training can provide a return on investment (COMPASSonline, 2013).

Clearly, the potential learning outcomes of an intervention depend on the conceptualization of science communication; the agenda of the organizers; and the learning goals of the specific workshop/course (different trainings by the same trainer can have different learning goals). The question of what learning outcomes to measure is therefore tied to the question of what the learning goals were to begin with. Teachers and researchers should choose assessments that are associated with their learning goals, rather than measure what is more easily assessed.

Based on the learning goals detailed above, two kinds of assessment instruments have been developed: A survey to use with science communication training participants, assessing their background, attitudes, and knowledge; and a rubric for assessing written popular communication by scientists, to evaluate the effectiveness of training programs for creating positive change in communication skills. These are described here:

An Online Attitudes and Knowledge Questionnaire

We developed a survey to be used in pre- and post-test mode to assess the value of communication training for scientists. The questionnaire went through a formal pre-test and check for face validity (Lewenstein & Baram-Tsabari, 2011). Interesting results occurred when we set out to establish test/retest reliability. For this study, 19 STEM graduate students completed the questionnaire twice, with an interval of approximately two weeks. The purpose of the procedure was to find out if the questionnaire itself teaches, if the simple step of filling out the questionnaire results in changes in knowledge or attitudes without any other intervention. For example, the action of completing the questionnaire might cause the responders to reflect on their views regarding a topic they do not usually think about. It might sensitize them to pay more attention to science in the media in the following days, or they might discuss the issue with friends and family. Therefore, some change of opinion is possible and even expected. In order to ensure the reliability of the questionnaire as a pre-post measurement tool, one needs to know if the questionnaire itself significantly changes views in a certain way. This is important in order to attribute potential pre-post changes to the media training and not to the measurement tool itself. Two weeks was chosen as the interval time between the questionnaires since it allows time to forget the details of one's answer, while giving enough time for new ideas to sink in, and for people to talk and think about them.

Histograms of the differences between the pre and post answers were examined for each question separately. No systematic changes were seen in the test/retest data of knowledge. However, in about 15% of answers to the attitudes section, responses shifted in the direction intended by media training (in 4 cases, the shifts were statistically significant at the 0.05 level, with 2 more questions significant at the 0.06 level). In the shifts, responders were more likely to:

1. Feel in control over their message in the media ($p = 0.056$).
2. View science in the media in a more positive way:
    i. Agree that there is overall enough science coverage and that the coverage quality of science by the media is satisfactory.
    ii. Rate mainstream media coverage of scientific topics as comprehensive ($p = 0.055$) and trustworthy, and less likely to rate it as biased and hostile.
3. Be less judgmental of peers who are being interviewed, by disagreeing with the statement "Scientists who allow themselves to be interviewed for stories (not just their own research) are just seeking publicity" ($p = 0.05$).
4. Believe in the importance of public engagement. They were more likely to:
    i. Disagree that "Most members of the public are so ill-informed about science that their opinions about science and technology should not influence policy (e.g. stem cells, GMOs)."
    ii. Disagree that "Public involvement in science related policy making threatens the research autonomy of scientists (e.g. stem cells)."
    iii. Agree the public might lose trust if exposed to disagreements between scientists, but also agree that even if the public will lose trust by being exposed to disagreements between scientists, disagreements should be made public ($p = 0.03$).
    iv. Agree that "Explaining science to people and involving them in discussion of controversial issues is important for civic life."
    v. Choose "public accountability" as an important benefit of science communication ($p = 0.05$).
5. View media training for scientists as important, agreeing that "in an ideal world…all science graduates would take a science communication course" ($p = 0.02$).

The findings of the test/retest emphasize that raising awareness and spending some time thinking about the issue of science communication may by itself change scientists' views, without any additional intervention. It also points to the fact that pre-post evaluation of media training, which does not usually include a control group, should take into account the potential effect of the questionnaire itself on the learning outcomes.

A Rubric for Assessing Written Popular Communication by Scientists[2]

A rubric was developed for assessing achievement of communication skills based on Baram-Tsabari and Lewenstein (2013). We chose to analyze primarily written skills (instead of other options, such as oral presentations to policy makers or televised interviews) to allow analysis of larger samples without the need to record and transcribe the responses, as well as to ease comparison across samples. Furthermore, analyzing oral communication would add another level of complexity, relating to tone, body language, charisma, etc. That said, we believe the questions described below can be used as a basis for evaluation of oral communication as well (for example by replacing the number of words asked for with a request for specific timing). The instrument can be used with a wide range of science communication education programs as a baseline survey, as a pre/post evaluation of the learning outcomes for particular programs, or as a form of formative assessment that promotes teaching and learning alike.

The students/trainees are presented with four practical tasks: identifying jargon in a list of words, describing one's own research, responding to a question about science in everyday life, and responding to a question about science's role in society (Table 22.3, skills section). In this section, we will describe various ways in which their answers can be meaningfully analyzed.

As described above, the analytical scheme addresses seven clusters of learning goals, divided into basic, intermediate and advanced levels (Table 22.1). Each cluster can be assessed using multiple criteria, which are described more fully in Baram-Tsabari and Lewenstein (2013). Below, we present three examples of how we approached the analysis of the questions: assessing clarity of language, assessing clarity of explanations, and assessing dialogic approach.

Assessing Clarity: Language

In order to assess the appropriateness of language used, we developed the "Science concept familiarity index" and "Jargon index" to code for the use of jargon (specialized vocabulary). This classification was based on *Google News* (news.google.com), an automated news aggregator which aggregates several million articles a day and makes it a reasonable proxy for broader media coverage of news. Science concepts were classified according to the number of hits on *Google News* in the past three years since the day of measurement[3]:

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[2] This section on assessing communication skills is closely based on Baram-Tsabari and Lewenstein (2013).

[3] For reasons explained below, these numbers are subject to frequent changes, and are only used here as a demonstration of the classification strategy.

- Not jargon, if the word/phrase received over 80,000 hits (e.g. virus, galaxy, atom).
- Familiar science concept, if the word/phrase received between 8,000 and 79,999 hits (e.g. gravity, Nitrogen).
- Recognizable science concept, if the word/phrase received between 800 and 7,999 hits (e.g. phosphorous, magnetic field).
- Unfamiliar science concept, if the word/phrase received between 80 and 799 hits (e.g. bioremediation, uric acid).
- Strictly professional concept, if the word/phrase received less than 80 hits (e.g. meiosis, baryonic).

The main weaknesses of this method are its lack of transparency and instability. *Google News* does not report the actual number of hits, but an estimate. The exact way in which this estimate is calculated is not published. Furthermore, *Google News* occasionally changes its algorithms and data sources without notifying its users, which may result in changes in concepts' scoring and impair reliability. In order to address this problem one may compare a few search words using the same time frame and corpus or standardize the results by dividing them with a very common search term (such as 'www'). We have used anchors—several terms that were recorded repeatedly in order to pinpoint changes in the measurement. The strengths of using *Google News* are its comprehensiveness, it is continuously updated, and its ecological validity since we are interested in what scientists write for the media, which *Google News* addresses. An alternative approach for identifying and ranking scientific jargon based on closed professional and general language corpora is described in Sharon and Baram-Tsabari (2014).

After coding each of the concepts, we combined the scores to create a single "jargon index." This index is based on the idea that including undefined jargon in a text for the wide public should be coded based on the level of unfamiliarity of the word and not only by counting the number of concepts. Jargon words that were defined in the text were only counted once, regardless of their familiarity level, except for familiar science concepts that were defined—these were not counted at all. The formula we used for calculating the jargon index was let n(familiar,nd) be the number of jargon words at the level of "Familiar science concept" "not defined" (nd) in the text, n(recognizable,d) be the number of jargon words at the level of "Recognizable science concept" which are "defined" (d) in the text, and so on:

Jargon Index = n(familiar,nd) + 2n(recognizable,nd) + n(recognizable,d) + 4n (unfamiliar,nd) + n(unfamiliar,d) + 8n(professional,nd) + n(professional,d)

The following jargon-heavy answer helps demonstrate:

> I study how tissue damage by an intestinal parasite promotes an immune response. Our body is programmed to recognize toxins, cancerous cells, and infections (such as viruses and bacteria) by detecting "danger signals." These signals consist of molecules that are not found in the human body under normal conditions, such as the endotoxin secreted by bacteria. When an intestinal parasite, such as Trichinella, infects the intestine it destroys some of the intestinal epithelial cells and these cells release their own danger signals, called

> "alarmins." We are interested in a novel alarmin, called IL-33, which is required for the body to develop a potent immune response to the parasite. The same type of immune response, induced by IL-33, is involved in allergic asthma and autoimmune diseases such as ulcerative colitis (Baram-Tsabari & Lewenstein, 2013, p. 68).

This answer contains 16 jargon terms: 6 familiar science concepts (molecule, tissue, allergic, secrete, bacteria, parasite), 4 recognizable science concepts (toxin, epithelial, autoimmune, cancerous cells), 4 unfamiliar science concepts (intestinal parasite, endotoxin, Trichinella, ulcerative colitis), none of these were explained except "Trichinella" and "ulcerative colitis." In addition the text contains 2 professional terms (alarmin, IL-33,) which were explained. Therefore its jargon index is equal to:

6*(familiar,nd) + 2*4(recognizable,nd) + 4*2(unfamiliar,nd) + 2(unfamiliar, d) + 2(professional,d) = 6 + 8 + 8 + 2 + 2 = 26

This jargon index represents a high level of jargon use. On top of its excluding and intimidating effect it impedes the audience's ability to follow and understand. Therefore, it is not suitable for communication of science to a non-technical public. However, after attending a science communication course, we will expect to see a decrease in the jargon index, providing the teacher with an objective and quantifiable measure for improvement in clarity.

Assessing Clarity: Type of Explanation

Sometimes there is no way around using science concepts which are unfamiliar to the audience, and these need to be explained. Discussing new ideas also usually requires some explaining. This classification attempts at assessing the level in which the scientist tackles this fundamental challenge. It does not assess the correctness of the explanation or the suitability of the explanation to the audience and situation. Explanations were classified based on Rowan (1992) with some adaptations which are described below. All the examples in this section are taken from Baram-Tsabari and Lewenstein (2013, p. 71). Explanations were categorized as:

- Absent
- Definition. Example: "The internet is a virtual network." (A new category added by us).
- Elucidating explanation, which is definition with an example/non-example. Example: "Antibiotics only work on bacteria, which means that they can only be used for diseases caused by microbes belonging to the bacteria family. Flu, on the other hand, is caused by viruses."
- Quasi scientific, which are explanations that create an image in the mind of the reader, such as using an analogy. Example: "Consider each computer as a node, and the Internet as a web."

- Transformative explanation refers to addressing alternative frameworks which already exist in the learner's mind and aiming for a conceptual change in which one central concept comes to be replaced by another. This type of explanation is based on extensive work within the field of science education (e.g. Posner, Strike, Hewson, & Gertzog, 1982). In our analysis any explanation whose starting point was what the audience might think and progressed to point to dissatisfaction with the existing conceptions or explaining why the scientifically accepted theory is more plausible or fruitful was coded as a transformative explanation. Example: "I believe that the Bible must be interpreted in the context in which it was written. When the original text was written, people did not have our understanding of the natural world. They needed an explanation for their existence in terms that they could understand. That took the form of God creating them. Today we have proof that species evolve from one another and there is no reason to think that we are so special that we should not follow the same rules as the rest of nature."

We expect to see more and higher level use of explanations as a result of attending science communication training. First, scientists should be more aware of the audiences' prior knowledge, therefore, leave fewer concepts unexplained, and use the audience's knowledge as the starting point for transformative explanations. Second, scientists should acquire and practice a wider repertoire of communication skills, allowing them to flexibly respond with analogies, metaphors and everyday examples to challenging explanations.

Dialogic Approach: Acknowledge and Show Respect to Multiple World Views

The shift from a "deficit model" to a "public engagement model": of science communication requires an attitudinal change, but also acquiring new skills. Scientists are now asked to engage in a respectful dialogue– not only to deliver a clear and interesting monologue. This change from educational to democratic emphasis is the rationale behind assessing the dialogic approach.

Answers to the science in society question (Table 22.3, right column under "skills") were classified with regard to references they made to multiple world-views. All the examples in this section are taken from Baram-Tsabari and Lewenstein (2013, p. 77).

- Absent.
- Acknowledging more than one world view. Example: "there are a few scientists that do not believe that humans are at least partially responsible for the Earth getting warmer, but the overwhelming general consensus is… ."
- Explaining more than one worldview. Example: "The best way of testing this is to make the modified plant and monitor it for an extended period of time…."

> Europe and the US have differing ideas about what is an extended period of time and how much testing is sufficient. Although laboratory tests have shown GM foods are safe for human consumption, there is much more testing that could be done, including the effects of GMO fields on nearby crops. Because the EU has stricter regulations, they are waiting for more tests, while the US considers the testing that has already been done sufficient."

Answers to the science in society question were also classified with regard to the respect they showed to multiple worldviews, except for answers that made no reference to other worldviews. Possibilities included:

- Denying others' basis for beliefs, in either sarcastic or straight forward ways. Example: "The only reason people don't eat genetically modified foods in other countries is because people are scared of them."
- Accepting other's right to believe differently. Example: "Some people are willing to be convinced. Some are not. And that's OK."
- Accepting the possibility that others might be right. Example: "All of these things are debates and it's really crucial for science to not squelch debates. It is important to hear out skeptics, think through, and address them."

We expect that after attending science communication training, scientists will be more likely to acknowledge the existence of other worldviews, and treat with respect those who have trouble accepting the scientific consensus. This classification does take the extra step of looking into the incorporation of the public's ideas into scientists' work, as expected in a true dialogue between equal parties. Such outcomes are not likely to be found in short writing assignments like the ones used here.

Effective Pedagogies

The literature provides descriptions of teaching methods in various training programs, but we found very little discussion about the appropriate pedagogy for the effective teaching of science communication. Such pedagogies, based on constructivist and constructionist learning theories, will be described here in the context of a specific science communication university course.[4]

Course Description

The course "Science Communication in Theory and Practice" was first offered in the 2008/9 academic year and has been taught seven times since, at the Department of Education in Science and Technology at the Technion—Israel Institute of Technology. The first author of this chapter has been the course lecturer since its inception. The

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[4] This section is based on the M.Sc. thesis of Kallir-Meyrav (2014).

course is one semester long, elective, and open to both undergraduate and graduate students of all faculties of the technological university. The course objective is defined as a change in the individual's level of knowledge, skills, and attitudes towards science communication. This objective is aimed toward the larger goal of changing norms among local academics, so as to infuse more science into public discourse. Here we only address the course's direct objectives on the individual level.

The course's theoretical contents covered topics such as the need for, and importance of, communication with the public, public understanding of science, and different models of science communication (Table 22.4). The aim of the course is to produce a conceptual change in the attitude of the students towards supporting a strong and dialogic relationship between scientists and the general public. The course's practical section provides tools for communication through different media —face to face, written journalism and new media. The course's purpose is to provide future scientists basic skills in science communication, including jargon avoidance, analogy and metaphor use, framing, humor and storytelling.

"Science Communication in Theory and Practice" would be classified as "training combining skills and theory" according to Turney's (1994) classification. Using Trench's (2008) analytical framework of science communication models, we can say that while many of the practical tasks in the course concentrate on dissemination, and almost no dialogical practices were visited, much of the content learned and discussions in class focused on dialogue, attending to context and creating engagement, with constructivism being a natural starting point to any discussion of potential learning.

Three main pedagogies were used in the course.

Performance Tasks

Performance tasks are a teaching method as well as an evaluation tool. Learners are required to complete an assignment where they apply content and skills they have learned. Such an assignment harmonizes the teaching-learning-evaluation process. It is an open-ended tool, allowing for creative thinking and resulting in non-uniform products.

The practical tasks build on each other and develop science communication skills gradually (Fig. 22.1, Table 22.4): the students are asked to write a short news item, interview a scientist, present a scientific subject in a 3 min monologue, write a blog post, and produce a short video presenting a scientific topic in a way that appeals to an audience with no background in the area. Some of the assignments are prepared by students individually, others in groups. Students gain real-world exposure by publishing these products via mass media (selected interviews have been published on news websites, posts on an open blog, and some of the videos have been posted on YouTube), demonstrating that they too have the opportunity to create messages and share them with the general public directly, not only through the mediation of a journalist.

Table 22.4 Syllabus for the Course "Science communication in theory and practice"

Lesson	Topic	Content	Pedagogy	Task: online submission before next lesson
1	Introduction	Importance and goals of communicating with the public, knowing the audience and its interests, using different genres for different purposes, science in the media	Class discussion	Initial questionnaire
2	Writing a news item	Choosing a topic and newsworthiness, the title, the lead, the inverted pyramid	Modeling the process by an expert, small group work and class discussion	Draft news item
3	Language	The role of language in science communication, identifying and avoiding jargon	Lecture and class discussion	Editing two items written by peers
4	Interviews and framing	The concept of framing and its importance to science communication. Elements of style: analogies, humor and narrative. Conducting an interview	Lecture, analysis of televised interviews, modeling the interview process by an expert	Final news item and reflection (15% of class grade)
5	PR versus journalism	Between science communicators and science journalists: the job of the PR and the information officer	Guest lecture by the institute spokesperson	Draft interview
6	Models of science communication	Deficit, contextual, lay expertise and dialogic models of science communication: from dissemination to participation	Small group work and a role play advising "the minister of science" on engaging the public	Editing two interviews written by peers

(continued)

Table 22.4 (continued)

Lesson	Topic	Content	Pedagogy	Task: online submission before next lesson
7	Televised interviews	Media training for on-camera interviews	Mock television interviews in the university's studio	Final interview and reflection (30% of class grade)
8	Public Speaking	Public speaking training, the principles of public speaking	Mini-Famelab competition: 3 min monologues followed by lecturer's and peers' feedback	Those who did not perform in class upload their recorded monologue (10% of class grade)
9	New media: Blogs	Science communication in the new media, the role of Web 2.0 in enabling public deliberation and participation	Lecture and class discussion	Publish a blog post online
10	New media: Podcasts	Reaching new audiences for science communication, using narrative: telling a science story	Guest lecture by a leading science podcast creator	Comment on three blog posts by peers and write a reflection (15% of class grade)
11	Filming science	The role of visualization in science communication, emotions, attitudes and learning	Guest lecture by a science museum visual content creator: Analyzing scenes and experiencing with video camera	Synopsis of a science video
12	Science as entertainment	Science in reality, comedy and drama television, science comm. and gaming. Infotainment	Small group task: developing a synopsis for a science related game/non-news show	
13	Filming science	Creating a science YouTube clip in small groups. No face-to-face lesson (usually the groups worked about 10 h on writing, filming and editing the clips)		2–4 min science video (30% of class grade. Group task)
14	Presentation of artifacts and course summary	Watching and critiquing the video clips using the theory and experience gained in the course		Reflexive course summary, final questionnaire

Note Some changes were made in the seven repetitions of the course, but this syllabus is generally representative of the structure of all interventions

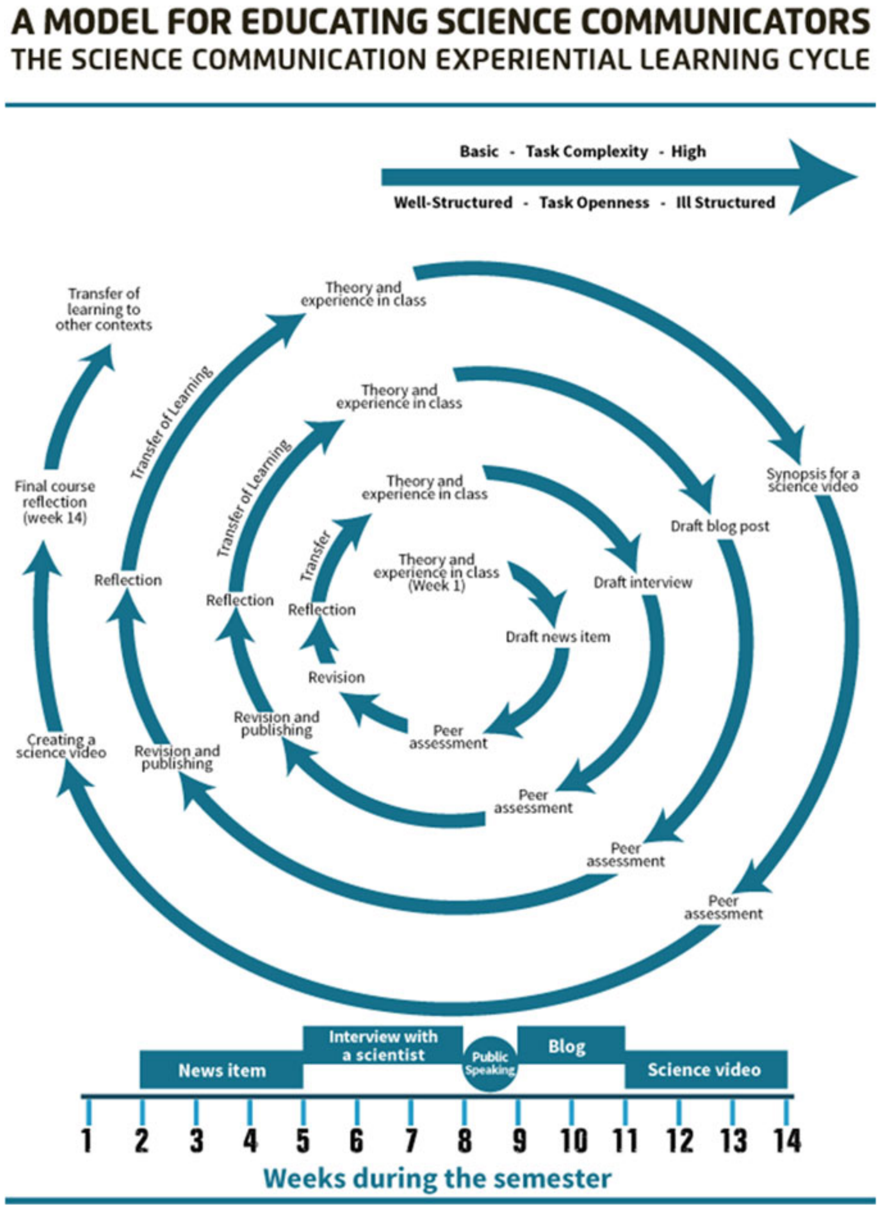

Fig. 22.1 A model for educating science communicators: an iterative experiential learning cycle for teaching and learning science communication

Peer Assessment and Revision

Peer assessment has students evaluate each other's work. The method enables lecturers in higher education to examine students' knowledge and skills from an additional angle, and validate their own assessment. Its benefits to the students include exposing them to a variety of other students' learning outcomes, a better understanding of assessment criteria and increasing motivation to learn (Topping, 1998). As part of the course requirements, students were asked to choose two written assignments by classmates and edit them. The instructions for "peer editors" were: "Point out problems of text comprehension, jargon use, and missing content. Correct grammar and awkward phrasing. Suggest additional ideas and questions, and a better title if you have one. Keep your feedback constructive and compliment if you like the work." The authors of the pieces received the feedback via the course's moodle website, and could revise their writing before submission for the course's lecturer.

Reflection (Self-assessment)

Reflective thinking is a process by which the thinking becomes the object of observation and analysis. In the reflective process, students identify the components of their work which define its quality, and decide to what degree their work matches the given indicator (Nicol & Macfarlane-Dick, 2006). In this course, the students are required to submit a reflection on the learning process along with each assignment. The reflection is structured in the form of 1–2 paragraphs addressing the following questions: "What did I learn about mass media in general and science communication in particular in the process of researching/writing/editing peers' work/revising? Please provide evidence for your statements. If you write, for example, that you learned it's important to not use jargon, present the original and the revised sentence."

These three pedagogies are part of an iterative experiential learning cycle. The learning outcomes of each cycle are being transferred and put into action in the next assignment (Fig. 22.1). For example, students focus on issues of content choice, knowledge organization and clarity when writing a news item (weeks 2–5). When conducting and writing an interview with a scientist (weeks 5–8) they have to add to these newly acquired skills elements of style, such as narrative, analogies and metaphors.

An evaluation based on 114 students' works and reflections (Kallir-Meyrav, 2014) paints a picture of communication skills acquisition: comparisons between the draft and final versions and between two successive tasks showed significant improvements using various performance indicators. The working process, which included draft writing, revision for others, reflection, and revision of the draft version (Fig. 22.1), was meaningful in terms of skill acquisition. Our findings suggest that a single assignment is not enough to achieve the same change in skill: several iterations yielded a gradual increase in the percentage of students demonstrating satisfactory writing skills.

The course was evaluated on two levels: assessing meaningful learning, while seeking to identify which course components were significant in contributing to learning. A large majority of the students identified performance tasks as a very significant factor for learning. Students also mentioned the overall multi-stage work process, which forced them to process content and implement the skills they acquired in class, while providing an opportunity to learn from errors and improve. Peer assessments were also highly important for the learning process, in that they highlighted logical errors, inaccurate wording and information gaps. Giving feedback allows assessors to express their skills whereas getting feedback allows the assessed to gain another perspective and overcome the “curse of knowledge.” The design of the course, which allows drafts to be openly accessed by all on the course website, led to spontaneous learning from peers’ success and mistakes.

The third component in the learning process was reflections on the assignments, which encouraged students to conduct meta-cognitive observations of their own work. Statements in the reflections presented self-assessment, conflicts and dilemmas about ways to apply the skills. Explanations about why choices were made connected the technical skills with the theoretical concepts underlying them. Bray et al. (2012) argued that students in communication courses must develop a broad understanding of scientific and social issues, rather than focusing on development of communication skills which, they claim, are narrow and technical. However, these findings suggest that the experience of creating science communication messages itself affects the writer’s attitudes regarding the need for science communication and ways to pursue it.

Indeed skill development is only one facet of science communication education. In order to achieve a wide range of learning goals, learning should combine practical (“hands-on”) experience with intellectual (“minds-on”) and emotional (“hearts-on”) experience. Based on these findings and rational, we propose this iterative experiential learning cycle (Fig. 22.1) as a potential model for educating science communicators in media skills for courses having similar learning goals.

Concluding Remark

An example for the lack of dialogue between science education and communication is that the very basic concepts from the research on the teaching and learning of science are still rarely used when educating and training scientists to engage in science communication. Science communication is a skill that is increasingly expected of scientists. But while much effort is being invested in science communication training, there is no conceptually-based list of specific learning goals, and the existing training efforts are rarely complemented with evaluation of learning outcomes. To make progress in preparing scientists to become better science communicators we need to establish clear, theory-driven learning goals and develop shared pedagogies and assessment tools for achieving and evaluating them. This chapter outlines one approach to this problem.

We presented a framework for learning goals in written science communication, which includes learning goals in seven areas, and items for assessing them. The analysis suggested should enable those teaching professional science communicators and scientists to say with some level of objectivity and reliability whether their students improve in engaging with the public as a consequence of attending a course.

This work led to several interesting research questions: Can scientific jargon be automatically identified? Does learning academic writing hinder scientists' ability to communicate with the public? What do scientists know about the context in which science communication takes place? How do scientists and public members change their attitudes and practice while involved in a Public Participation in Science project? The studies in this line of research all aim to help scientists to engage in a meaningful dialogue with different publics, while emphasizing the educational process that such involvement requires.

What is still clearly missing is the audience side. The validity of such an instrument should be tested against the actual interest, engagement and understanding of the actual audience, the receivers of the message. In this sense we have catered to our imagined audience. It's time to see what the real one thinks of all this.

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Chapter 23
'User-Generated' Educators: The New Frontier or a Far-Fetched Dream?

Maria Xanthoudaki and Enrico Miotto

> If we're honest about how we feel in museums, we have to admit that quite a lot of the objects leave us cold – and our thoughts turn eagerly to the possibilities of cake in the café. That's OK and compatible with being a good person – and being interested in and responsive to art. What makes an artwork great is what it can do for you. Life is short and not all works are doing things that you need. We tend to blame ourselves if we feel bored in an art gallery – but boredom can be an insight: a signal to yourself that nothing worthwhile for you is on offer. We are shy about recognizing the individuality of our responses to art. The prestige of art doesn't help us with this.
>
> Worship of the Golden Calf c. 1530 (De Botton & Armstrong, 2014, p. 59).

> Once Frank noticed a middle-aged woman pointing out some star-like holes in the ceiling of the Exploratorium to her companion. The holes were made by seagulls that had punctured the black-painted surface of a skylight with their feet. […] The woman casually commented to her friend that she supposed if she knew more, she'd understand what "those little things" meant. It didn't matter that the "lights" were seagull footprints. What mattered, said Frank, was that the woman and her friend "were perfectly happy as they went on to play with other exhibits" (Cole, 2009, p. 269).

Educators in museums are many, and diverse. You can perceive this just by noting the terms used for them across different institutions and countries, such as museum educators, informal learning experts, program developers, learning and engagement experts, face-to-face learning experts, explainers, facilitators, mediators—these are some of the most common terms for those professionals taking care of visitors' learning experiences (Rodari & Xanthoudaki, 2005; Richard, 2010; Rodari, Mathieu, & Xanthoudaki, 2012). Diversity can be found also in the educators' tasks in museums from direct interaction with visitors to program, activity, or resource development, to organization and evaluation, to front-of-house tasks—to name but the main ones.

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This makes things complex. Not only because we are talking about a multi-faced professional community, but also because training needs can vary greatly on the basis of the specific job combined with educational approach and museum identity (Richard, 2010). At the same time however, educators in museums are considered an extremely well-defined and committed expert group, and this is due to their long history in museums and to the shared belief in the value of their work in strengthening and enriching visitors' learning and experiences.

Educators' work in museums is mainly twofold: 'behind the scenes', as part of the process of developing what the museum feels it should create and make available to visitors (exhibitions, programs, activities, resources); and in direct interaction with learners. In both cases, educators have an important role; they are the "visitors' advocates" (Hooper-Greenhill, 2000), the ones knowing what learning in museums means, who the visitors are and what they expect, what kind and how many—and how unexpected—outcomes can be drawn out of a visit. Educators are therefore the ones contributing to create an engaging, constructive, open-ended, positive, personally-meaningful, memorable-for-a-lifetime learning experience, for each and every visitor walking in the museum. Not a small thing, certainly.

Here, we would like to focus on the role educators interfacing with visitors have in learning, in particular in the context of the contemporary museum and global changes. The world around us is changing fast; the notions of education and learning acquire new meanings, user-generated knowledge and connectivity seem to drive individuals' learning experiences, while educators are asked to 'prepare' the 21st century citizen. This means a lot, and a lot of new things, both for the field and profession of educators and for museums themselves.

We would like to reflect on the above issues by analyzing the current trends and their implications for museums, and by looking into educators' training through the case of the National Museum of Science and Technology Leonardo da Vinci (MUST). The first paragraph of the chapter summarizes the most important arguments on learning in museums aiming to create the basis for the following discussion. The second paragraph looks into the current changes, especially with regards to education and learning. The third and fourth explore the case of MUST and its approach to learning and training, followed by the discussion of two specific tools used to support educators' training. The second-to-last paragraph puts theoretical principles and practice together while the conclusions aim to explore the potential for a new role for museum learning experts for individuals' learning, experience and social engagement as they appear to be evolving today.

It Looks Like Fun, but Do They Learn?

This is (still, unfortunately) one of the most common questions demonstrating, in our view, a certain misunderstanding of what learning in museums is about. According to Gomes da Costa (2005), this question is directly connected to the one about the goal of the museum itself. Today, highly interactive and open-ended experiences are very much promoted in museums, encouraging visitors to take up an active behavior—ideally, a 'scientific stance'—and use observation, questioning, experimentation, critical thinking as tools for learning. Such an approach means that the museum has moved well away from teaching mono-directionally produced knowledge, towards embracing a more 'contemporary' definition stating that learning in museums is a multifaceted process with both affective, cognitive and socio-cultural dimensions, built on experience, investigation, experimentation as well as on imagination and intuition. The complexity of learning in museums lies in the short duration of the visit itself and on the decisive role of the visitor in learning, behavior, and memory (Hein, 1998; Adams, Falk, & Dierking, 2003; Falk & Dierking, 1992, 2000; Bevan & Xanthoudaki, 2008; Xanthoudaki, 2010; Claxton, 1999; Wood, 1988).

Building on the above definition means accepting a paradigm shift in the role of museums. On the one hand, it means substituting a "paternalistic approach" (Chatterjee & Noble, 2013, p. 2) with one that welcomes the knowledge built by the learner as equally valid and important; and on the other, 'relaxing' on the fact that learning is a lot more and lot of different things than what museums might expect and prize.

For educators, all this implies moving away from the 'explaining mode' into a more challenging and complex role, one that can really help visitors trust themselves and build a life-changing experience. "Museums are places for learning, not places for teaching" (Gomes da Costa, 2005, p. 1); therefore, educators should not see themselves as teachers, but as someone that helps someone else learn.

Today, this is of even more crucial importance. Today, from the United States of America to the European Union and as far away as Singapore, educators and policy makers are talking explicitly about '21st century skills and competences'. The '21st century citizen' is (should be) a confident person who has a sense of right and wrong, is adaptable and resilient, knows himself, thinks independently and critically and communicates effectively (Ito et al., 2013a; National Academies, 2012; Pellegrino & Hilton, 2012; Sutcliffe, 2011; Financial Times, 2014; Ministry of Education Singapore, 2010). Consequently, the shift to a learner-centered approach emerges stronger than ever because it seems to be the only solution for meeting the 21st century skills and competences goal. This has fundamental implications for education and schooling, the ownership of learning, the role of educators; while experience, personal interests, and values, and time and place take up new meanings and roles.

Museums have seen the value of a learner-centered approach before many other educational institutions (Wood & Wolf, 2008; Hein, 1998, 2006; Falk & Dierking, 1992, 2000). Museums can make the difference, because they are able to *instill* a methodology which is part of their very nature, integrated in the things they do well, do for a long time, and are unique at doing, for which they are widely recognized, appreciated and trusted, and which can be the key for building the 21st century skills.

In this context, the question 'It looks like fun, but do they learn?' acquires a whole new meaning. It becomes even stronger that we are not talking—and should *not* be talking—anymore about learning as the acquisition of an array of discrete concepts and facts, or as a process of “moving knowledge from ‘out there in the world’ to ‘in here in the head’”; but rather about learning as the development of increasingly sophisticated, autonomous, and active practices (Bevan & Xanthoudaki, 2008). The learner emerges as a “subjective agent with dynamic funds of knowledge and repertoires of practice” (Bevan & Xanthoudaki, 2008, p. 108), as an expert in her own right qualified to decide what and how to learn.

The question ‘What do they learn?’ should be answered by recognizing learning as “being—knowing—becoming” (Petrich, Wilkinson, & Bevan, 2013, p. 53), and by valuing individualized and self-directed approaches, or experiences based on competency and interest instead of time, age. The development of “critical and systems thinking, creativity, adaptability, conscientiousness, persistence, self-regulation, cultivation of interests” (Ito et al., 2013b, p. 6) today seem to acquire a strategic importance.

This has fundamental implications for educators in museums. As we are moving towards a learner-generated knowledge and experience (not only in the museum world), we should be also moving towards a redefinition of the educators’ role. We should certainly consider using the term ‘museum learning experts’ instead of the term ‘museum educators’, but can push this as far as introducing the term ‘*user-generated* learning experts’? What does it mean for the field? What are the consequent changes in skills and competences, training, program development, face-to-face interactions with visitors? How are learning experts expected to contribute to the consequent evolution of their own museum’s mission, policy, practice? These are the questions we would try to answer in this chapter.

Today’s Learning for Tomorrow’s World

It is very clear that we do not live, learn, and communicate the same way we did just a few years ago. Changes in technological platforms are taking place at an impressive speed. Today, digital and networked media provide new possibilities for inter-connectedness, an increased accessibility to knowledge and socialization, and allow for rapid appearance and evolution of new ways to connect, to meet, to learn, to participate, to protest, to (co)create (Black, 2012; Ito et al., 2013a; Bradshaw, 2013; McDermott, 2014; American Association of Museums, 2012; Meritt & Katz, 2013). New relationships between the individual and society are established, artefacts are developed as open-source, and process is valued more than the final product (Ito et al., 2013a; Price, 2013; Honey & Kanter, 2013).

For the visionary, technology and the outcomes of pioneer research would allow us to live longer, better, and with limited (physical, mental, intellectual) faults, and to work less, but more efficiently (Palacios-Huerta, 2014). At the same time, the more skeptical see technological developments leading to elitism and disempowerment, to surveillance and standardization and to ultimately-scripted scenarios rather than to open access, opportunity, and democracy (Cohen, 2013).

These changes encourage the development of a 'culture of participation' in which creative contributions and innovations are invited, supported, and decentralized (Fischer, 2011). Civic engagement is seen as a fundamental tool for tackling these challenges. Policies at an international level put at the center of their agenda the need for creating aware, informed, and self-confident citizens able to understand and be engaged in tackling those problems (European Commission, 2006, 2013; Osborn & Dillon, 2008; Winnie & Felt, 2007).[1] Wellbeing, democracy and human rights lie in the role that self-decisive, independent, and aware citizens can have in decision-making and social development.

In this context, meeting the goal for the 21st century skills and competencies means investing in a new approach to school and lifelong education and encouraging individualized, self-directed approaches in which learners collaborate with educators and with experts in their communities and around the world to customize rigorous learning experiences based on competency and interest instead of time and age (Knowledge Works Foundation, 2008).

Society, for the first time so clearly, acknowledges the importance of, and the need for a learner qualified (and free) to decide what and how to learn. This is not because we recognize the value of personalized learning suddenly, but because it seems to be a sound way to face change. Take the job market for example: Today, "every middle class-job is being pulled up, out or down faster than ever" and there is "increasingly no such thing as a high wage, middle-skilled job" (Friedman, 2013). The impact of technological innovation on unemployment increases; in many jobs, persons are gradually replaced by computers, but at the same time a series of new "emotive occupations" or jobs linked to goods and services are rising (The Economist, 2014). This means that (young) people are in front of a challenge and have to respond adequately to it. They, the 21st century citizens, need to be flexible, inventive, entrepreneurial, highly motivated, willing to take risks, and capable to innovate, because they need to create their own opportunities.

At the same time, educational opportunities expand as a result of a growing demand for lifelong education and the growing offer of learning settings and resources, especially with the help of IT (Financial Times, 2014).[2] Everyone, from children to the elderly, can potentially study when they want, without having to attend school. Opportunities for personalized, self-motivated education move away from the model of learning organized around stable, usually hierarchical institutions, and demand (as well as cause) change. A new directionality allows producers and users to be as one and has begun to be applied to a range of fields (Berthon, Massat, & Collinson, 2011; Dirks et al., 2010; Centre of Hitachi, 2012; Shapiro, 2005).

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[1] See also the policy and strategy of the European Union: http://ec.europa.eu/europe2020/index_it.htm; http://ec.europa.eu/education/policy/strategic-framework/index_en.htm.

[2] One of the most popular IT-based education contexts is MOOCS and other online courses: http://www.nytimes.com/2012/07/17/education/consortium-of-colleges-takes-online-education-to-new-level.html?_r=1; https://www.coursera.org/; http://online.wsj.com/article/SB10001424127887324906004578288341039095024.html.

In this context, current policy and practice call for a diverse "learning ecosystem" in which learning adapts to each learner instead of each learner trying to adapt to the instruction model (Bell, Lewenstein, Shouse, & Feder, 2009; Centre for the Future of Museums, 2011; Price, 2013; European Commission, 2013; Fenichel & Schweingruber, 2010; Xanthoudaki 2010).[3] Consequently, the learner is perceived, and valued, as the co-creator of knowledge, growing through personal meaning-making experiences, and seeing herself as a free, active agent in an increasingly de-institutionalized learning environment (Falk & Sheppart, 2006; Ito et al., 2013a; Price, 2013).

Thus, we need to see both museum learning experts and the related theory and pedagogy in the context of the current global challenges. Museums are fundamental for society, not only for their credibility and authority in researching and interpreting socially-relevant themes, but also because they have seen the value of the learner-centered experience, and since very early espoused a philosophy that now seems to be the (only?) one necessary for future success (Wood & Wolf, 2008; Hein, 1998, 2006; Falk & Dierking, 1992, 2000). In this, learning experts have a fundamental role and a prime responsibility.

Learning and Learning Experts at the National Museum of Science and Technology Leonardo da Vinci

We will discuss the role of museum learning experts through the case of the National Museum of Science and Technology Leonardo da Vinci. Drawing on our experience with training and professional development of our education staff, we would like to discuss how our approach to learning and facilitation can contribute useful elements to answering our main questions, those about the role of museum learning professionals in building 21st century skills.

Since its foundation on 15 February 1953, MUST has placed education at the heart of its mission, that of contributing to the scientific literacy of the young generations in a country at the time under transformation. Education at MUST was perceived as a service to society and seen as the goal of the Museum of "the world to-be" (Museo Nazionale della Scienza e della Tecnica, 1958, p. 191).

Education at MUST over the last 60 years has been characterized by several pioneer actions, which have also had an impact on today's approach. The first one is the 'Centre for Physics' born in 1955 to offer the resources necessary for the study of physics via an approach that "fosters a direct and dynamic engagement of visitors with experiments developed for that purpose" (Ghezzi, 1966, p. 23). The first users of the Centre were teachers attending demonstrations and directly experimenting

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[3] For further discussions about learning see also: www.exploratorium.edu/IFI/resources/constructivistlearning.html; http://caise.insci.org/news/99/51/ISE-Summit-2010/ d,resources-page-item-detail; http://www.nap.edu/openbook.php?isbn=0309053269; http://www.nsf.gov/pubs/2000/nsf99148/pdf/nsf99148.pdf; http://www.inspiringlearningforall.gov.uk/.

with the scientific apparatuses. Until the beginning of the '80s, the Centre devised and offered training courses, lectures, teaching materials and education exhibitions. On top of that, a science van, with equipment brought directly from the USA, travelled to schools for more experiments.

The '80s constituted a period of reflection and change for MUST, in line with the wider change taking place in science museums around the world. The influence of the science center movement strengthened the attention to the importance of direct experience, that is "from observation of objects to execution of experiences, in such a way as to awake attention and curiosity and to instill the desire and interest to know more" (Museo Nazionale della Scienza e della Tecnica, 1992). As a result, the second pioneer act takes place, that is, the birth of the first 'interactive laboratories' in 1993 inspired by the Exploratorium of San Francisco and the philosophy of Frank Oppenheimer.

The interactive laboratories (i.labs) are active areas in which visitors encounter real phenomena and engage in experiments directly, and when opened were the first of their kind at the national level. The i.labs developed in line with the history and specific identity of the Museum. The decision for thematic active areas implied a conscious choice not to transform the Museum into a science centre as it is traditionally defined (open spaces with a range of interactive exhibits for free use by visitors supported by floor staff), but rather create an approach that allows for a direct connection between themes of i.labs and exhibitions. This meant being able to offer a range of interpretative modes and communication methods that could appeal to a range of audiences and encourage meaningful and personalized experiences.

The i.labs are still present at MUST today, and growing, and their themes have been revisited. For example, Physics, at the start the prime topic of the Museum education programs, has today been incorporated into more inter-disciplinary themes such as Robotics or Materials, or is placed alongside other fields, such as Life Sciences. The Museum is thus seeking to reflect and interpret science and technology in a more global way and to bring society and everyday life into the narrative and experience.

Over the years, since the birth of the i.labs, MUST has developed a precise and distinct learning approach, based on inquiry and direct participation. This stems from the conviction that 'real things', or a phenomenon, that is, "something that occurs" (Miotto, 2002, p. 2), an object, or a question, should be the starting point of visitors' experience and stimulate a series of additional connected experiences in which visitors are actively involved. Learning is built on visitors' reactions and explorations and should integrate their personal context and consider their backgrounds, age, learning modes, and knowledge levels. Exploration and situated learning are more important than results, active participation and skill development are more important than subject-knowledge, the development of personal meaning and a 'scientific stance' becomes the ultimate goal (Bevan & Xanthoudaki, 2008). To do this, means considering i.labs not merely as active spaces, but rather as contexts for methodological research in museum learning.

At MUST, such research is fundamental for the development of approaches and tools that foster and strengthen visitors' learning. In this context, a third pioneer act can be seen in the launch of CREI©, the Museum's Centre for Research in Informal Education, in 2009. The birth of the Centre can be considered as the consolidation of the Museum's activity in education and training in the last 15 years, that is, since the turn of MUST from public institution to non-profit foundation.

The Centre is part of the Education and CREI Department of the Museum and was created to promote research into, and practice of, methodologies and resources for museum learning. More precisely, CREI© devises and delivers training courses for teachers on both STEM themes and inquiry-based/active learning methodologies, builds and disseminates teacher packs for experimental work in the classroom, organizes meetings and special events with scientists and experts, and offers free consultancy and support to teachers for their own projects.

So far, more than thousand teachers have participated in the different courses and events at the national and international level. Professional development at CREI© means supporting the teacher in the role of facilitator of students' learning through work in small groups, direct exploration and experimentation, and making the best use of the teacher's own personal context as learner in her own right and her competences as educator (Sekules, Tickle, & Xanthoudaki, 1999; Xanthoudaki, Calcagnini, & Cerutti, 2007).

In parallel to the work with teachers, CREI© also carries out methodological research. Knowing how complex it is to build meaningful learning experiences for visitors, reflecting on research results and education trends at international level helps us grasp stimuli, learn more and feed our work constantly. Indeed, this has brought us to define those interpretative and learning approaches that characterize our education provision today:

- *Inquiry-based learning* as the basis of the i.labs activities, using direct experimentation and the scientific method as tools for exploring, interpreting and understanding a range of STEM-oriented topics.
- *Tinkering* (inspired by, and developed with the help of, the Exploratorium of San Francisco) integrating scientific method with creativity in science.
- *Science and Society*, drawing attention to the society-oriented aspects of science and technology through tools that encourage direct dialogue between citizens and the scientific community.

Methodological research at MUST goes beyond the i.lab context and focuses on modes and resources for exploring the Museum's exhibitions and collections. Observation, questions, emotions, imagination, and story-telling become ways for building connections with visitors' personal context; the object-document is perceived as a 'mosaic' releasing gradually its constitutive pieces that find a place—unique—in the experience of each visitor. This is made possible by the Museum's interpretation strategy, narratives, and interactivity that allow for a diversified visit and experience.

All this is part of the tasks of the Education and CREI Department staff, responsible for devising, designing, and delivering all programs and activities for visitors. The Department has been a core internal structure since the first years of the Museum, for MUST believed in "a museum which is alive, open to all, especially to those interested in its educational mission" (Museo Nazionale della Scienza e della Tecnica, 1958). After various phases, the first arrangement similar to today's structure was given in the '90s when the Education Deparment took up all aspects of education provision. This boosted the growth of a first group of professionals that would constitute the nucleus for the evolution that followed.

A decisive change took place when MUST became a non-profit private foundation in 2000. This offered the opportunity not only to increase the number and type of education programs, but also to create a definite structure of the Department based on the need to meet the following objectives:

- adequately serve a range of audiences—from school groups to teachers, to families to adults—taking into account their needs, interests and learning modes;
- exploit a range of methodologies, tools and resources that encourage the development of meaningful learning experiences in the Museum;
- build an education provision that explores the themes of the Museum exhibitions and i.labs and their interconnections.

Today's structure includes staff with a variety of backgrounds, i.e. sciences, humanities, science education, pedagogy, informal learning, research, and consists of three main units:

1. *Research and Training* focusing on the professional development of teachers and museum education staff (of MUST and other museums at national and international level);
2. *Education Programs for School and Family Audiences*, working on the development of i.labs and activities and the organization and delivery of the everyday programs. Facilitators working in direct contact with visitors belong to this sector.
3. *Science and Citizens,* using Science and Society approaches to address mainly adult audiences.

The history and evolution of the Education and CREI Department together with the Museum's identity and educational mission have determined the basic characteristics of the work in and for museum learning:

- a distinct methodology building on engagement with phenomena and experiments, exploration of historical objects and exhibitions, and direct dialogue with scientists, as ways to create impact at cognitive, affective, physical and social levels;
- the i.labs themselves for the ways they engage visitors in STEM-oriented themes;
- a permanent service to schools, from the programs for school groups to teachers' professional development;
- commitment to facilitating dialogue between citizens and scientific community, to building scientific citizenship, and discussing socially-relevant topics;

- educators in the role of 'visitors' advocates' in all internal processes and work groups, from the design of exhibitions to marketing and fundraising.

The work of museums is ever more relevant. Global challenges set new goals for learning-oriented institutions especially in the context of the new education trends. However, no museum should ever think that its mission is accomplished by simply opening its doors and waiting for people to visit, however beautiful or important its exhibitions might be. Today, museums have a fundamental responsibility towards people's wellbeing and quality of life, that is, they need to contribute concrete and continuous support for education, for active participation in action and decisions, for cultural regeneration, and for social and economic growth. In this context, as Tran, Werner-Avidon, and Newton (2013) argue, "educators in informal learning environments […] need to have the capabilities to foster deep learning, engagement, and 21st century skills among its learners" (p. 333). This has important implications for professional development, which we would like to discuss taking our own experience at MUST as a case study.

Training of Learning Experts at MUST: In Principle, In Practice

Learning experts at MUST develop contents, methods, and resources that strengthen the Museum's learning approach and objectives, and at the same time they interact with a range of audiences. As said at the beginning of the chapter, we will focus on the staff mainly working in direct contact with visitors (for those we will use the term 'facilitators') and discuss our initial questions by looking into their training.

Today, Education and CREI includes two groups of facilitators: one made of twelve senior facilitators working part-time with a permanent contract, and a second group of twenty-two junior facilitators, university students between 20 and 24 years in a temporary job.

Training focuses on the following areas of interest:

- museum-oriented contents and related subject-knowledge;
- museum-learning and -facilitation principles and methods (basics and trends);
- institutional information (mission, vision, organization, services) (Tran et al., 2013; Rodari et al., 2012; Richard, 2010).

These areas are covered during initial training courses for newcomers, or are examined in more detail during in-service training meetings. However, what has always been important for MUST is that training builds on, and respects the methodological principles constituting our museum learning approach. The latter, evolving gradually throughout our history but structured more carefully in the last 15 years, is regarded as the requisite for 'guaranteeing' visitors' engagement in a way that unfolds all their potential as 'researchers' in a personal learning experience.

We have already presented the principles of our approach above; here we break them down to bullet-point statements in order to create immediate connections with the training of facilitators and with the facilitation process itself:

- All Museum experiences (should) address learning as a process for developing increasingly sophisticated, autonomous, and active practices as well as skills, knowledge, understanding, values, ideas and feelings; a process of active engagement with experience; and a process leading to change, development and the desire to learn more.
- We build as much as possible opportunities to engage in real immersive exploratory processes (experiments, exhibits, etc.) aiming to provide a deeper experience with a strong emotional dimension. The purpose of immersion is to diminish the distance between learner and representation allowing the former to fully encounter an environment.
- We integrate the notions of constructivism in the learning process: learners do not simply add new facts to what is known, but constantly reorganize and create both understanding and the ability to learn as they interact with the world. In connection to constructivism, the notion of "empowerment" has fundamental importance for the development of skills for it allows new information to be taken in, remembered, and later used independently and pro-actively as tools.
- We integrate inquiry-based learning methods in programs and activities encouraging visitors to:
    - *observe*: watch carefully, compare, contrast;
    - *question*: ask questions about observations or questions that can lead to investigations;
    - *hypothesize*: provide explanations consistent with available observations;
    - *investigate*: plan, conduct, measure, gather data, control variables;
    - *interpret*: synthesize, draw conclusions, see patterns;
    - *communicate and evaluate*: develop critical opinions based on observations and already-acquired knowledge.
- Programs and activities at MUST aim at maximizing visitor learning through opportunities for:
    - aligning and realigning the learning experience to the needs of the visitor;
    - creating contexts where learners feel safe and supported;
    - allowing for a variety of visitor learning outcomes;
    - supporting learners to develop questions and ideas that are new or challenging to them;
    - promoting both social learning and independent, self-directed learning;
    - taking part in playful, fun, enjoyable activities;
    - using a variety of senses;
    - developing interactions in ways that meet learners' needs;
    - learning how to learn;
    - supporting independent and self-directed learners;
    - relating new learning to their prior experience or knowledge;

  - encountering, observing and investigating real, authentic objects or specimens;
  - catering for a variety of learning styles;
  - promoting curiosity and interest;
  - providing choice and control;
  - stimulating cognitive engagement and challenge;
  - creating personal relevance;
  - supporting dialogue, literacy and/or research skills;
  - taking into account motivational and culture-oriented issue;
  - developing active citizenship;
  - interacting with highly skilled face-to-face learning staff (Learning Department, 2009; Dewitt & Osborne, 2007).

- Facilitating learning means being able to attend to the following:
  - create authentic scientific processes based on authentic questions;
  - pose follow-up questions that appreciate student answers;
  - make decisions about how and when to scaffold the learners experience with appropriate questions, information and activity;
  - engage in purposeful and reflective conversations;
  - encourage discussion among peers and with adults;
  - support learners in consolidating their understanding;
  - challenge the learner on a suitable level;
  - give room for reflection by the learner and/or among learners (i.e. invite to comparisons, establish conflicts etc.);
  - trigger an interest in knowing how the phenomenon works;
  - allow for full observation of the phenomenon;
  - allow for verification through empirical investigation;
  - allowing visitors to feel successful throughout the learning experience (Miotto, 2004; Calcagnini & Testa, 2004).

- At the same time, facilitation needs also to avoid:
  - a didactic approach (and the assessment of visitors' knowledge);
  - revealing the results of the experience before the right moment;
  - considering learners only as spectators;
  - seeking and dealing only with the correct answers or, even worse, with the correct questions;
  - rigid one-way scenarios not building on feedback from learners, therefore limited flexibility and potential for improvisation;
  - not listening (Miotto, 2002, 2004; Calcagnini & Testa, 2004).[4]

In addition to the above, training in facilitation integrates the role of original objects in visitors' experiences. We know that learning in the museum appears to be

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[4] On training see also the materials developed by the PILOTS EU-funded project available at http://www.thepilots.eu/results.html.

influenced by the nature of the real object acting as 'document' that holds and records meaning and information. It is capable not only of offering different kinds of knowledge at different levels of sophistication but also of enabling visitors to recall knowledge acquired in the past (Xanthoudaki, 1998). Consequently, the approach to learning with objects is based on the capacity (of objects—and of facilitators) to stimulate all the senses, to lead, through active participation, to the assimilation of new information and, finally, to relate the latter to previous knowledge and experience (Hooper-Greenhill in Xanthoudaki, 1998, p. 232).

Finally, aesthetic experience is another important element of visitors' experience, whichever the identity of the museum. It is the original setting, the museum itself, that evokes aesthetic experience, in Hargreaves' (1983) words, the 'conversive trauma', encouraging the development of interest and the desire to learn more. Indeed, research argues that ideas formulated with the help of original objects, original experiences and original contexts are integrated more easily in the visitors' personal context and experience, remembered longer and generate enthusiasm to know more (Hooper-Greenhill, 1987; Falk & Dierking, 1992, 2000). At MUST, visitors have the opportunity to engage with 'the real thing', in the exhibitions (with objects), in the interactive labs (with experiments) and in the Museum itself (a setting enhancing the socio-cultural context of science and technology).

All of the above is 'translated' into contents and tools for training. We will not describe how training is organized, but focus on two specific tools devised by the Museum trainers in the years aiming to reinforce our methodology in interaction with visitors and facilitation of learning. The first tool is an 'observation grid' created and implemented between 2002 and 2004; the second refers to apprenticeship, more recent (2012) and still used today. The two reflect the needs of the professional development of facilitators in two different 'historical periods'.

The Observation Grid

What is meant by 'good facilitation'? What are the aspects of interaction with visitors, and the related skills, that make facilitation successful in implementing a learning approach and help build meaningful experiences? These questions guided our thinking when devising training about 12 years ago. At that moment, there was the need to understand better the learning methodology then implemented by 80 freelance facilitators, establish a common approach, and raise standards. Moreover, there was the need to offer as much support as possible where needed at the individual level.

The observation grid was developed after long discussions about how best to monitor the facilitation method. The grid emerged from the attempt to 'translate' our learning approach to observable elements that could be easily recorded during the observation of interaction between facilitators and visitors, and demonstrate the existence, or lack, of the specific methodology. The grid was meant to record 'what happens' during an activity; it did *not* intend to evaluate facilitators, nor to document the observer's personal opinions.

According to the grid, the observer was meant to record whether the methodology made it possible for the facilitator to:

- keep the object/experiment at the center of attention;
- make sure that all participants can see and hear well;
- demonstrate and ask for a description/comment/hypothesis about what happens;
- not to hold a lesson (monologue);
- avoid specialized terms with no reference to the real object/real experiment;
- make connections with participants' everyday experience;
- stimulate and build on emotions and imagination;
- create clear logical connections between notions, situations, events;
- encourage everybody to participate and engage;
- listen to people and exploit what they say;
- listen to people and use their own terms;
- use body language;
- engage people through (a) open-ended questions, (b) closed questions, (c) manual activity, (d) discussion and exchange of opinions, etc.;
- when asked something out of context: (a) respond even when it relates to individual interests, (b) respond but building on it only if of common interest, (c) change the course of things to respond.

More general elements were also recorded (in this case, data refer to the experience as a whole):

- the topic of the activity is clear to participants;
- the course of the activity helps identify the key issues (regarding a topic, object, experiment, experience);
- the activity evolves (from global to specific or vice versa, from simple to more complex, etc.);
- the level of difficulty is adequate to the age and type of audience;
- conclusions are drawn where necessary.

The grid was used by the education staff responsible for the training of facilitators to observe moments of direct interaction with visitors. Following each observation, trainers and facilitators sat together in a debrief meeting to look into the data collected and discuss the implementation of the facilitation method and, consequently, of the learning approach. However complex the observation as method might be (given its qualitative and subjective approach in the data collection), it allowed 'observers' and 'observed' to enter a process of reflective practice looking deeply into what it means to implement a methodology, for example, in terms of relationship and interaction with visitors, investigation and exploration, or autonomy of the learner (Crowley & Allen, 2014). The 'observing eyes' were different among the various persons using the grid, facilitation styles were diverse among the staff working with visitors; however ongoing use of the grid, debriefing meetings and related training worked very much in favor of understanding better what it means putting principles in practice.

In our view, the grid is more than a mere suggestion of a specific tool supporting training; today, it could help 'translate' the 21st century skills into principles for facilitation in museums, and could therefore help reflect on facilitators' own role in visitors' learning and experience.

Apprenticeship

An important change in facilitators' profile and consequent training took place in 2012, when MUST decided to employ university students on a 'job-on-call' basis in parallel to the existing senior facilitators. The increase of the number of staff interfacing with visitors emerged from specific needs. On the one hand, the increase of the number of visitors engaging in programs and activities (400,000 per year, about 3,000 visitors per weekend between October and May); and on the other, the need to allocate the more senior facilitators during week days to work with schools.

The new junior facilitators work on-call mainly during weekends and can stay on the job until they are 24 years old. Short stay and regular 'turn over' of staff certainly mean that the Museum has the opportunity to 'transfer' its learning approach to a number of people possibly following science/technology-oriented careers, and to help build a community of professionals sensible towards, and skillful in, communication of science. At the same time, however, it means continuous change (sometimes before arriving to the 'age of departure') and less time to build experience and reflect upon facilitation and learning methodology, and calls for more frequent initial training programs.

To face this new situation, trainers at MUST decided upon a strategy that reinforced the usual training on contents and methods: apprenticeship. A period of 'training by example' was thus added as the final part of the preparation of new facilitators. What is important here is not the fact that new facilitators were able to see immediately a complete example of interface with visitors (given by MUST learning experts, either senior facilitators or program developers), rather the opportunity to build experience at three progressive phases:

(a) observe learning experts at work;
(b) co-conduct activities together with learning experts;
(c) deliver activities with visitors while observed by the trainers (followed by debriefing).

This structure of apprenticeship allows, first of all, to develop facilitators' own self-confidence in entering a new, 'public' situation and to reflect gradually on how principles are put into practice. Knowledge and skills built during training are transformed to observable elements and, in turn, become strategies supporting the complex situation of working with diverse audiences.

The decision to draw on apprenticeship to reinforce training and professional development of junior facilitators builds on the social and situational orientation to learning. Social learning theory argues that people learn from observing other people, in a social setting (Merriam & Caffarella, 1991). In this context, observation allows people to see the consequences of others' behavior and form an idea of how new behaviors are performed. On later occasions, this coded information can serve as a guide for action (Bandura, 1977).

Situated learning on the other hand places learning in social relationships and sees it as a process of social participation (Lave & Wenger, 1991). Learners gradually become more competent and move "from legitimate peripheral participation to into 'full participation'" in the socio-cultural practices of a community (Lave & Wenger, 1991, p. 37)—in our case move to the center of facilitating visitors' learning experience. At the same time, apprenticeship as tool for training at MUST helps build relations between "newcomers and old-timers", through "legitimate peripheral participation" fostering the creation of a community of practice (Lave & Wenger, 1991, p. 29).

Putting Museum Learning Experts' Training in Perspective

Over the past years, the shift in education and workforce (see Table 23.1) forced discussion on the role both formal education and out-of-school learning environments can have in the development of the necessary 21st century skills (Institute of Museum and Library Services, 2009). The latter are not only relevant for students and schools, but also for adult learners. All people, including children, spend the overwhelming majority of their lives in non-school settings such as afterschool,

Table 23.1 Shift in education and workforce (Institute of Museum and Library Services, 2009)

	20th century	21st century
Number jobs/lifetime	1–2 jobs	10–15 jobs (US Department of Labor, 2004)
Job requirement	Mastery of one field	Simultaneous mastery of many rapidly changing fields
Job competition	Local	Global
Work model	Routine	Non-routine
	Hands-on	Technical
	Fact based	Creative
		Interactive
Education model	Institution centered	Learner centered
	Formal degree attainment is primary goal	Self-directed
		Lifelong learning is primary goal
Organizational culture	Top down	Multi-directional (bottom-up, top down, side to side, etc.)

museum, and library programs. In these settings, they develop important skills, such as problem solving, collaboration, global awareness, and self-direction—not only for lifelong learning and everyday activities, but also to use back in school classrooms (Institute of Museum and Library Services, 2009).

These considerations are fundamental for museums. Current policy and practice seem to acknowledge their role in building significant lifelong learning experiences that can make a difference in people’s lives:

> Museums and libraries offer rich and authentic content, dedicated and knowledgeable staff with deep expertise, and safe, trusted settings for individuals and families, all of which invite and support effective learning. The collections in libraries and museums connect people to the full spectrum of human experience: culture, science, history, and art. By preserving and conserving our material and digital artifacts, libraries and museums link us with humankind’s history. These institutions operate as places of social inclusion that promote curiosity, learning by doing, and discovery. In them, we learn about ourselves and others, and enhance the skills that contribute to empathy, tolerance, and understanding (Institute of Museum and Library Services, 2009, p. 6).

Museums and their learning experts should be happier than ever. What they have always fought for—the centrality of the learner—gets into the heart of the debate and becomes an explicit set of skills in the course of developing generations of innovators, creators, investigators, actors, improvisers, makers, science-oriented thinkers (Price, 2013; European Commission, 2013; Xanthoudaki, 2010; Fenichel & Schweingruber, 2010; Bell et al., 2009). The learner becomes the cornerstone, the co-creator of knowledge and a self-confident citizen (Price, 2013, pp. 22–23; Ito et al., 2013a).

In terms of the implications all the above can have on facilitation and learning approaches in museums, going back to the case of MUST, we can argue that many of the constitutive elements of facilitation are very much in line with, and purposely support, the development of 21st century skills—even though when we started reflecting on the best possible methodology to foster museum learning and experience the debate on such skills was not there yet. On top of that, the grid and apprenticeship could be seen as useful tools reinforcing facilitation, not only in museums but in other contexts as well.

For example, one of the questions emerging from our own experience regards the impact the specific facilitation approach could have on the school teacher. Can we claim that museum learning and the related facilitation method can lead to change at school and instill a reflective-practice culture in teachers?

Often when working with students we do not address teachers as an end-audience. Still, teachers are there to observe, to assist, to reflect on things ‘done in a certain way’—directly or indirectly they participate in ‘mini-training courses’ on methodology. When they come back to MUST for their own professional development, learning methodology will be taken up during the courses; but even if they do come back, and especially if they do not, experiencing moments of interaction between facilitators and learners can have an important effect.

Teachers visiting MUST with their students argue that they often take up ‘pieces of method’ used at the Museum to explore in class, to reflect upon, and then to integrate in their own approach. In our view, this is a good proof of the contamination between museum and school learning. In this case, museum facilitation and learning approaches become the stimulus for reflecting on one's own practice. Change is a slow process but does take place, especially when teachers have opportunities for 'peripheral participation' into situations that seem similar to those of school practice but follow different but equally valid approaches.

Reflecting our original questions in this chapter—that is, on the role of museum learning experts—means understanding not only what it takes to foster a meaningful learning experience for every visitor; but also what the impact on learning at a wider level can be, including that in the classroom. Learning becomes a way of "being—knowing—becoming" (Petrich et al., 2013, p. 53), not merely the objective of education-oriented settings and institutions.

Conclusions. 'User-Generated Learning Experts': The Next Goal?

Looking into the current changes and challenges, we realize that educators in museums face a great challenge, that is, the inevitable need to transform their role into that of 'user-generated' learning experts. This means not only strengthening the learner-centered approach and open-ended personalized learning experiences as much as possible; in extreme terms, it means recognizing that visitors themselves need to contribute to their training.

For this to happen, building up experience from practice with visitors is not enough. It requires understanding the nature of learning and how knowledge is built. Museum learning experts need to think differently about the groups and individuals whom they are involved with, and understand how all of them may participate to the full and become authentic knowledge (co-)creators (Smith, 1999; Rogoff, Turkanis, & Bartlett, 2001). As McDermott argues:

> Learning traditionally gets measured as on the assumption that it is a possession of individuals that can be found inside their heads… [Here] learning is in the relationships between people. Learning is in the conditions that bring people together and organize a point of contact that allows for particular pieces of information to take on a relevance; without the points of contact, without the system of relevancies, there is no learning, and there is little memory. Learning does not belong to individual persons, but to the various conversations of which they are a part (Murphy, 1999, p. 17).

Moreover, museum learning experts need to conceive the intimate connection between knowledge and activity (Smith, 2003, 2009). This means being able to reflect on their understanding of what constitutes knowledge and practice, and of the difference between situated learning and 'learning by doing' (Tennant, 1997, p. 73). Perhaps one of the most important things to grasp here is the "extent to which education involves informed and committed action" (Smith, 2003, 2009). These are fascinating areas for exploration and, to some significant extent, take museum learning experts in a completely different direction to the dominant pressure towards accreditation and formalization.

All this is not simple, yet it is possible because, as we extensively argued above, learning experts in museums believe strongly in the centrality of the learner and possess the tools necessary for this transformation. Indeed, let us never forget what learning is really about:

> Suppose we assume that the purpose of learning and education is not to remember a lot of things, or to provide a product, but rather to change one's life; and people changing their lives means changing their relationships with other people, with the things around them, and with themselves. Learning has to do with the meaning of things, and those meanings have to do with the uses of these things in our lives –the meaning is the use (Paul Tatter, 2005 in Jenkins, 2014).

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Chapter 24
Teaching the Theory of Evolution in Informal Settings to Those Who Are Uncomfortable with It

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We know that evolution is a difficult subject to learn for a number of reasons. In part this is because the science is quite demanding, in part it is because evolution is less readily observed than many other scientific phenomena, and in part it is because evolution clashes with certain readings of a number of the world's scriptures. This chapter discusses issues to do with the teaching of evolution and examines what informal science educators might do to help teach evolution well to those who are antagonistic to it. I am therefore writing for science educators who accept the standard scientific theory of evolution; different considerations apply for informal science educators who do not accept this.

I argue that one can teach evolution in informal settings in ways that are true to the science *and* respectful of individuals who are uncomfortable with or antagonistic to the theory of evolution. A core conclusion is that it may often be better not to attempt to persuade informal leaners that the theory of evolution is correct but to attempt to get informal learners to understand what the theory is and why it is that some people, who may or may not have a sincere religious faith, accept the theory of evolution.

Context

My day-to-day work is as a science educator. I work on how we can teach science more effectively, both in schools and also through such out-of-school means as museums, the internet, and so forth. As I have a Ph.D. and undertook post-doctoral research in evolutionary biology and am also an ordained minister (a priest in the Church of England), it is hardly surprising that I have an interest in evolution and in why people for religious reasons do or do not accept the theory of evolution, in

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particular common descent and the notion of a very old Earth. I taught science in schools for five years in the 1980s and while I met a number of school students who did not accept these standard scientific conclusions about evolution and/or the age of the Earth, such individuals were few in number and very discrete. They tended to tell me their views on their own rather than announce them in class. I suspect if I had been asked then, I would have predicted that the number of people in the United Kingdom (UK) who believe in creationism would decrease over time.

And yet this has not happened in the UK, nor in many other countries. While we lack high quality social science evidence (the main problem is that the same questions have not been asked validly in successive surveys with sufficiently large numbers of respondents), it seems clear that creationism is not about to wither away either in the UK or elsewhere. Creationism exists, of course, in a number of different versions, but something like 50% of adults in Turkey, 40% in the United States (US), and 15% in the UK reject the theory of evolution and believe that the Earth came into existence as described by a literal (fundamentalist) reading of the early parts of the Bible or the Qu'ran and that the most that evolution has done is to change species into closely related species (Miller, Scott, & Okamoto, 2006; Lawes, 2009).

Allied to creationism is the theory of intelligent design. While many of those who advocate intelligent design have been involved in the creationism movement, to the extent that the US courts have argued that the country's First Amendment separation of religion and the State precludes its teaching in public schools (Moore, 2007), intelligent design can claim to be a theory that simply critiques evolutionary biology rather than advocating or requiring religious faith. In intelligent design arguments, no reference is normally made to the scriptures or a deity. Rather, it is argued that the intricacy that we see in the natural world, including at a sub-cellular level, provides strong evidence for the existence of an intelligence behind this (e.g. Behe, 1996; Dembski, 1998; Johnson, 1999). An undirected process, such as natural selection, is held to be inadequate (Meyer, 2010).

While a clear distinction can therefore be drawn between creationism and intelligent design, what they have in common is a rejection of key elements of the theory of evolution. It needs to be emphasised that the theory of evolution can be rejected on at least two different grounds. One, which does not apply to the standard (non-religious) version of intelligent design, is where a person believes that a particular way of reading and understanding scripture (whether the Christian, Hindu, Jewish, Muslim or any other scripture) precludes acceptance of the theory of evolution. The other, which applies to intelligent design and so-called scientific creationism, is where a person concludes that the weight of objective, scientific (and/or mathematical) evidence is such that the theory of evolution cannot be correct.

Scientific and Religious Understandings of Biodiversity

The scientific understanding of biodiversity is far from complete but the narrative is a powerful one. Around 3.5 billion years ago, possibly earlier, life evolved on Earth. Very little is known with any great confidence about this early history

(Maynard Smith & Szathmary, 2000), far less than is known, for example, about how stars form, grow and die. By the time of the earliest fossils, life was unicellular and bacteria-like. Fast-forwarding considerably, natural selection, aided by other mechanisms (genetic drift, etc.), eventually resulted in the 10 million or so species, including our own, that we find today.

The scientific worldview is materialistic in the sense that it is neither idealistic nor admits of non-physical explanations (here, 'physical' includes, as well as matter, such things as energy and the curvature of space). There is much that remains unknown about evolution. How did the earliest self-replicating molecules arise? What caused membranes to exist? How key were the earliest physical conditions—temperature, the occurrence of water and so forth? But the scientific presumption is either that these questions will be answered by science or that they will remain unknown (Reiss, 2011). Although some scientists might (sometimes grudgingly) admit that science cannot disprove supernatural explanations, scientists do not employ such explanations in their work (the tiny handful of seeming exceptions only attest to the strength of the general rule).

Religious understandings of biodiversity are more diverse (Reiss, 2014). Many religious believers are perfectly comfortable with the scientific understanding, either on its own or accompanied by a belief that evolution in some sense takes place within God's holding (compass or care), whether or not God is presumed to have intervened or acted providentially at certain key points (e.g. the origin of life or the evolution of humans). But many other religious believers adopt a more creationist perspective or that of intelligent design (Reiss, 2008).

Most of the literature on creationism (and/or intelligent design) and evolutionary theory puts them in stark opposition. Evolution is consistently presented in creationist books and articles as illogical (e.g. natural selection cannot, on account of the second law of thermodynamics, create order out of disorder; mutations are always deleterious and so cannot lead to improvements), contradicted by the scientific evidence (e.g. the fossil record shows human footprints alongside animals supposed by evolutionists to be long extinct; the fossil record does not provide evidence for transitional forms), the product of non-scientific reasoning (e.g. the early history of life would require life to arise from inorganic matter—a form of spontaneous generation rejected by science in the 19th century; radioactive dating makes assumptions about the constancy of natural processes over aeons of time, whereas we increasingly know of natural processes that affect the rate of radioactive decay), the product of those who ridicule the word of God, and a cause of a whole range of social evils (from eugenics, Marxism, Nazism, and racism to juvenile delinquency)—e.g. Whitcomb and Morris (1961), Watson (1975), Baker (2003), Parker (2006) and articles too many to mention in the journals and other publications of such organisations as Answers in Genesis, the Biblical Creation Society, the Creation Science Movement, and the Institute for Creation Research.

By and large, creationism has received similarly short shrift from those who accept the theory of evolution. In a fairly early study, the philosopher of science Philip Kitcher argued that "in attacking the methods of evolutionary biology, Creationists are actually criticizing methods that are used throughout science"

(Kitcher, 1983, pp. 4–5). Kitcher concluded that the flat-earth theory, the chemistry of the four elements, and mediaeval astrology "have just as much claim to rival current scientific views as Creationism does to challenge evolutionary biology" (Kitcher, 1983, p. 5). An even more trenchant attack on creationism was provided by geologist Ian Plimmer whose book title *Telling Lies for God: Reason versus Creationism* (Plimmer, 1994) indicates the line he took.

Many scientists have defended evolutionary biology from creationism—see, for example, the various contributions in Selkirk and Burrows (1987), Good et al. (1992) and Jones and Reiss (2007) and an increasing number of agreed statements by scientists on the teaching of evolution (e.g. Interacademy Panel on International Issues, 2006). The main points that are frequently made are that evolutionary biology is good science, since not all science consists of controlled experiments where the results can be collected within a short period of time; that creationism (including 'scientific creationism') is not really a science in that its ultimate authority is scriptural and theological rather than the evidence obtained from the natural world; and that an acceptance of evolution is fully compatible with a religious faith, an assertion most often made in relation to Christianity (e.g. Southgate, Negus, & Robinson, 2005), whilst more obviously true of many other religions—including Hinduism, Buddhism and Judaism—and probably generally rather less true of Islam (Mabud, 1991; Negus, 2005; Edis, 2007).

Changing One's Mind

In his recent book, *The Examined Life*, the psychoanalyst Stephen Grosz (2014) has a section (the longest section in the book) on 'Changing'. He begins with the story of Marissa Panigrosso who was on the 98th floor of the World Trade Centre South Tower on 11 September 2001, talking with two of her co-workers, when the first plane hit the North Tower. The fire alarm went off and a wave of anxiety swept through the office. Marissa Panigrosso did not stop to turn her computer off or even to pick up her purse. She walked to the nearest emergency exit and left the building. The two women with whom she was talking did not leave. In fact, many people in her office ignored the fire alarm—and what they could see happening in the North Tower. Some of her colleagues went into a meeting. A friend of Marissa's turned back after walking down several flights of stairs saying "I have to go back for my baby pictures" (Grosz, 2014, p. 122). This friend lost her life, as did the two women with whom Marissa Panigrosso was talking and the colleagues who went into a meeting. Marisso survived. As Grosz puts it:

> We resist change. Committing ourselves to a small change, even one that is unmistakably in our best interests, is often more frightening than ignoring a dangerous situation (Grosz, p. 123).
>
> We are vehemently faithful to our own views of the world, our story. We want to know what new story we're stepping into before we can exist the old one (Grosz, p. 123).

One way of interpreting the move from creationism to an acceptance of evolutionary theory is to see it as an instance of conceptual change. There is a large psychological literature on conceptual change with an *International Handbook of Research on Conceptual Change* edited by Vosniadou (2008a). As Vosniadou herself points out "The roots of the conceptual change approach to learning can be found in Thomas Kuhn's work on theory change in the philosophy and history of science" (Vosniadou, 2008b, p. xiii). What Kuhn (1970) did was to go beyond the standard understanding of how science advances, an understanding that at the time when Kuhn was working was in no small measure the result of Karl Popper's work.

Karl Popper emphasised the falsifiability of scientific theories (Popper, 1934/1972). Unless you can imagine collecting data that would allow you to refute a theory, the theory is not scientific. The same applies to scientific hypotheses, statements, and 'facts'. So the statement 'All swans are white' is scientific because we can imagine finding a bird that is manifestly a swan (in terms of its appearance and behaviour), but is not white. Indeed, this is precisely what happened when early white explorers returned from Australia with tales of black swans.

Popper's ideas can give rise to a hyper-rational view of science, in which knowledge steadily accumulates over time as new theories are proposed and new data collected to discriminate between conflicting theories. Much school experimentation in science is Popperian: we see a rainbow and hypothesise that white light is split up into light of different colours as it is refracted through a transparent medium (water droplets); we test this by attempting to refract white light through a glass prism; we find the same colours of the rainbow are produced and our hypothesis is confirmed. Until some new evidence causes it to be falsified (refuted), we accept it (Reiss, 2015).

Thomas Kuhn made a number of seminal contributions but he is most remembered nowadays by his argument that while the Popperian account of science holds well during periods of *normal science* when a single paradigm holds sway, such as the Ptolemaic model of the structure of the solar system (in which the Earth is at the centre) or the Newtonian understanding of motion and gravity, it breaks down when a scientific *crisis* occurs (Kuhn, 1970). At the time of such a crisis, a scientific revolution happens during which a new paradigm, such as the Copernican model of the structure of the solar system or Einstein's theory of relativity, begins to replace the previously accepted paradigm. The central point is that the change of allegiance from scientists believing in one paradigm to their believing in another cannot, Kuhn argues, be fully explained by the Popperian account of falsifiability.

Kuhn likens the switch from one paradigm to another to a gestalt switch (when we suddenly see something in a new way) or even a religious conversion. As Chalmers (1999) puts it:

> There will be no purely logical argument that demonstrates the superiority of one paradigm over another and that thereby compels a rational scientist to make the change. One reason why no such demonstration is possible is the fact that a variety of factors are involved in a scientist's judgment of the merits of a scientific theory. An individual scientist's decision will depend on the priority he or she gives to the various factors. The factors will include such things as simplicity, the connection with some pressing social need, the ability to solve

> some specified kind of problem, and so on. Thus one scientist might be attracted to the Copernican theory because of the simplicity of certain mathematical features of it. Another might be attracted to it because in it there is the possibility of calendar reform. A third might have been deterred from adopting the Copernican theory because of an involvement with terrestrial mechanics and an awareness of the problems that the Copernican theory posed for it (pp. 115–116).

What the work of Kuhn so usefully alerts us to, therefore, is that science changes for reasons that cannot entirely be reduced to the rational acceptance of new information. How much more is this true for science education and for learning in general?! Accordingly, the role of the emotions in science education has received more attention than it did previously (e.g. Alsop, 2005). One framework that has proved particularly useful for understanding why people do or do not accept the theory of evolution is that of 'worldviews'.

Worldviews

The notion of 'worldviews' in the context of creationism can be usefully introduced by considering the film *March of the Penguins* (Reiss, 2009). *March of the Penguins* is a 2005 National Geographic feature film. It runs for approximately 85 min and is accompanied by a book available in the original 2005 French and a 2006 translation into English (Jacquet, 2006). For a 2-min trailer see the official website (Warner Brothers Studios, 2014) which gives a good impression of the outstanding footage in the film. The trailer also includes the words of Morgan Freeman that begin the English (USA) film: "In the harshest place on Earth, love finds a way. This is the incredible true story of a family's journey to bring life into the world".

The film has been an exceptional success. It won an Academy Award (an 'Oscar') in 2006 for Best Documentary Feature, was awarded Best Documentary at the 2005 National Board of Review and was nominated for Best Documentary in 2005 by the Broadcast Film Critics Association. In terms of revenue, it is the most successful nature film in American motion picture history, taking US$77.4m at the box office and scoring 94% on the Tomatometer (2014). The reasons for the success of *March of the Penguins* are no doubt several: the photography is phenomenal; the emperor penguin's story is extraordinary; the adults are elegant; the chicks are irredeemably cute as they look fluffy, feebly wave their little wings and learn to walk; the way in which the birds survive the Antarctic winter is awesome; the plaintive cries of mothers who lose their chicks in snow storms are heartrending. But one perhaps unexpected reason is that the film has been a great success among the Christian right.

For example, if one enters '"march of the penguins" Christian' into Google, at the time of writing (4 October 2014) one finds over 60,000 hits. Number two of these is a review of the film by Helms (2005) on ChristianAnswers.Net, which describes itself as a "mega-site … providing biblical answers to contemporary questions for all ages and nationalities with over 68-thousand files" (ChristianAnswers.Net, 2014). After a fairly detailed summary of the subject matter of the film, the review goes on to discuss the lessons that the film has to teach about love, perseverance, the existence of God and friendship/commraderie. An extended quote from the review illustrates the presuppositions of the author:

> "March of the Penguins" has lessons to teach about:
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> "LOVE": According to the film, the penguins take this tremendous journey for "love" and to find a mate and reproduce. The dedication, cooperation, and affection are exemplary between the pair.
>
> PERSEVERANCE: We could learn a lot about perseverance from Emperor penguins. I was quickly reminded of the ant in Proverbs 6:7–8 "It has no commander, overseer or ruler, yet it stores its provisions in summer and gathers its food at harvest." No one is reminding these penguins what to do; they know what to do, and they do it. They are prepared, persistent and committed, much like we are called to be as witnesses for Jesus Christ. 1 Peter 4:15 "Always be prepared to give an answer to everyone who asks you to give the reason for the hope that you have."
>
> The penguins endure treacherous conditions, yet they continue on their journey, focusing on what lies ahead (new life). It may be a bit of a stretch, but I thought of what we, as Christians have to endure to get what lies ahead for us (eternal life). Philippians 3:14 "I press on toward the goal to win the prize for which God has called me heavenward in Christ Jesus."
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> THE EXISTENCE OF GOD: One year in the life of an Emperor penguin is a great indication of the existence and character of God. Romans 1:20 "For since the creation of the world God's invisible qualities—his eternal power and divine nature—have been clearly seen, being understood from what has been made, so that men are without excuse." He is absolutely perfect! Every detail has been taken into account, and every provision has been made. Witnessing all the love and care that He must have put into creating the penguins is small compared to what He put into creating us. Matthew 6:26 "Look at the birds of the air; they do not sow or reap or store away in barns, and yet your heavenly Father feeds them. Are you not much more valuable than they?" Leaving the theater, I was more in awe and in love with my Creator.
>
> (Helms, 2005)

In the well-known fourfold framework of Barbour (1990), this quotation manifests an integrated relationship between science and religion (as opposed to one of conflict, independence or dialogue). The worldview is one in which it is straightforward to read from penguin behaviour to human behaviour though it is worth noting that the argument is neither entirely anthropomorphic (where non-human behaviour is interpreted as if it was the behaviour of humans) nor one in which the natural world is seen as *the* source of instruction as to how humans should behave. Rather, it is scripture that has primacy; the natural world is held up not so much as a model for us to imitate but as an illustration of how the natural world can manifest that which God wishes for humanity.

Such a reading of nature in *March of the Penguins* is facilitated by the wonderful photography which enables the viewer to read into the footage as much as (s)e reads from it. Indeed, Luc Jacquet has been quoted as saying "My intention was to tell the story in the most simple and profound way and to leave it open to any reading" (Miller, 2005). So I, with a Ph.D. and post-doc in evolutionary biology (though also a priest in the Church of England with a conventional, albeit non-fundamentalist Christian faith), can see it as a manifestation of the extraordinary ability of natural selection over millions of years to enable an organism to survive and reproduce in the most inhospitable of environments while others can see it as a clear manifestation of Intelligent Design:

> To think that natural selection or even the penguins themselves could come up with the idea to migrate miles and miles multiple times each year without their partner or their offspring is a bit insulting to my intellect. How great is our God! (Gold, 2005)

Gold's conclusion is despite the fact that the film begins by talking about how Antarctica used to be covered in tropical forest before it drifted South and then says of the emperor penguins "For millions of years they have made their home on the darkest, driest, windiest, and coldest continent on earth", and is despite the fact that the film relates how females aggressively compete for males and depicts the way in which mothers who have lost their chicks may attempt to steal other chicks. The film is also honest, I presume to the chagrin of some conservatives, about the fact that most emperor penguins are faithful to their partners for only one season.

Metanoia

In the New Testament, *metanoia* (*μετάνοια*) is routinely translated 'repentance'. Strictly, it simply means 'changing one's mind'. As I have argued above, it can be difficult to change one's mind, just as repentance is difficult. The scriptures, of course, have plenty of examples of those who changed their mind, and of those who failed to change their mind. While the scriptures are sometimes read as if religious conversions were spontaneous (one reading, for example, of Paul's Damascus Road experience), it is more fruitful to see conversion, even if apparently occurring over a very short period of time, as having both a necessary preparatory phase and a necessary post-conversion phase.

For the Christian, of course, conversion is the biggest change one can make: "If anyone is in Christ, he is a new creation" (2 Cor. 5:17). And yet, changing from a position where one sees creationism as valid to one where one sees the evolutionary understanding of life as valid can, for some people, feel almost comparable. The science educator Meadows (2007) is one who has made this journey. He writes about his collaboration with David Jackson, a science educator at the University of Georgia:

> Our first work together, "Hearts and Minds in the Science Classroom: The Education of a Confirmed Evolutionist" (Jackson, Doster, Meadows, & Wood, 1995), chronicles David's growth as he learned how a different set of life experiences can deeply impact science teachers' approaches to evolution in the classroom. David, an agnostic, had never worked with science teachers who also held to a deep faith until he moved to Georgia in the USA.

> David was surprised to find some science teachers who were staunchly opposed to teaching evolution in their classes. At first, David tried to correct their beliefs about evolution, but then he began to realize that he had skipped the essential first step of listening to them before trying to influence them. He began to find that, rather than being uninformed, many of these teachers were thinking through their religious beliefs, their scientific beliefs, and the interplay between the two. He began to see that science teachers had to consider the hearts, as well as the minds, of their students. Many of the teachers in the study, and by extension religious students like them in science classes, are actively choosing not to learn about evolution … Evolutionary science pales in importance to the eternal issues of God, Heaven, and salvation.
>
> I know well this tension between the heart and the mind because I've lived it. I was raised in a Christian fundamentalist home and church, and I'm now a science teacher and educator. Working through this tension was a perspective I brought to the Hearts and Minds study. My own faith journey has led me away from fundamentalism, but I do still hold to the view that the Christian scriptures are the inspired words of God. I find truth in both worldviews. Science provides truth from the basis of evidence, but my faith also provides an intellectual, durable system of knowing the world (p. 149).

Informal Versus Formal Settings

Not everyone likes the term 'informal settings' and yet the term is a useful one. Setting aside issues to do with home schooling, attending conventional schooling is mandatory for many years of a student's life. Going to informal settings, of course, is not. While this can mean that access to informal settings are more differentiated by student background (e.g. socioeconomic status) that is access to schooling, and that educators in informal settings typically know their visitors far less well than teachers know their students, informal settings do have a number of advantages over conventional schooling.

One such advantage is that learners in informal settings are often more motivated than they are in school. In addition, they are typically in much smaller groups and are often accompanied by family members. This means that there can be greater opportunity for learning to be personalised and for the subject matter to be an immediate cause of animated conversation. Furthermore, informal settings often provide rare material (e.g. fossils) of a sort rarely available in schools. And those in informal settings responsible for the provision of teaching and information more generally often make a commitment of time to the preparation of these that is way beyond what a school teacher can manage.

What particularly interests me is what the aims of learning should be, both in general and in informal settings in the context of communicating about evolution. School curricula typically start with a list of subjects, taking for granted a dozen or so discrete school subjects and the knowledge they embody. An alternative to starting with subjects is to start further back, with aims (Reiss & White, 2013). An aims-led curriculum has a fundamental advantage in that it can start with the needs and wants of students, both students as they live in schools and students once they have left their schooling behind. John White and I have argued that that there are two fundamental aims of school education, namely to enable each learner to lead a life that is personally flourishing and to help others to do so too.

As far as teaching about evolution goes, I think the criterion of personal flourishing can best be met not only by enabling learners to learn about evolution but also enabling them to understand others who may have different views about evolution to their own. Indeed, the world would be a better and safer place if more people understood others rather than simply arguing for their own position, irrespective of the positions of others. This, therefore, is an argument for understanding, understanding not only of a subject but of one's fellow global citizens. One can teach evolution in informal settings in ways that are true to the science and respectful of individuals who are uncomfortable with or antagonistic to the theory of evolution. It may often be better not to attempt to persuade informal leaners that the theory of evolution is correct but to attempt to get them to understand what the theory is, that it is accepted by the great majority of the world's scientists and why it is that some people, who may or may not have a sincere religious faith, accept the theory of evolution while others do not.

Science museums have long had exhibits about evolution. Bennett (2004) examines the history of museum displays about evolution. He looks at nineteenth century studies in geology, palaeontology, natural history, archaeology and anthropology and "trace[s] the development, across each of these disciplines, of an 'archaeological gaze' in which the relations between past and present are envisaged as so many sequential accumulations, carried over from one period to another so that each layer of development can be read to identify the pasts that have been deposited within it" (Bennett, 2004, pp. 6–7). Bennett concludes that evolutionary museums "are just as much institutions of culture as art museums" (p. 187).

In one sense this is obvious—museums and galleries have to make selections about what to display and how to narrate such displays and these are clearly cultural decisions whether one is referring to art, evolution, mathematics or any technology. However, whereas a visitor to an art gallery is unlikely to presume that what is being viewed is the only reading possible, a visitor to a science museum might presume that they are being presented with objective fact (Reiss, 2013).

Monique Scott too has produced a book about evolution in museums (Scott, 2007). Scott's work, unlike Bennett (2004), is more to do with the now than with history. Using questionnaires and interviews, she gathered the views of nearly 500 visitors at the Natural History Museum in London, the Horniman Museum in London, the National Museum of Kenya in Nairobi, and the American Museum of Natural History in New York. Perhaps her key finding is that many of the visitors interpreted the human evolution exhibitions as providing a linear narrative of progress from African prehistory to a European present. As she puts it:

> Progress narratives persist as an interpretive strategy because they still function as a conceptual crutch. They are nearly ubiquitous in popular culture (can you imagine human evolution without imagining the cartoonish images of humans evolving single-file toward their destiny?) and they stand largely unchallenged in museum exhibitions which conventionally move case-by-linear-case from Africa to Europe. Many museum visitors,

> particularly Western museum visitors, rely upon cultural progress narratives – particularly the Victorian anthropological notion that human evolution has proceeded linearly from a primitive African prehistory to a civilized Europe – to facilitate their own comprehension and acceptance of African origins. Overwhelmingly, museum visitors relate to origins stories intimately, and in ways that satisfy or redeem the images they already have of themselves (Scott, 2007, p. 2).

Scott's work is an important reminder of the fact that it can be difficult to teach well about evolution, for reasons that have nothing to do with religion.

Conclusion

The academic literature suggests that it can be difficult for individuals to change from a position in which the theory of evolution is rejected for religious reasons to one where it is accepted whilst the individual still retains their religious faith. This is as we would expect. Individuals who reject the theory of evolution for religious reasons can fear that accepting the theory of evolution requires them to reject their religious faith and/or separating themselves from family and friends. Informal science settings have a particular role to play in helping visitors to understand the theory of evolution and to understand why many accept it, without specifically attempting to persuade visitors to accept the theory.

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Chapter 25
Addressing Nature of Scientific Knowledge in the Preparation of Informal Educators

Judith S. Lederman and Gary M. Holliday

According to a 2004 survey conducted by the Center for Informal Learning and Schools (CILS), there are approximately 2,500 Informal Science Institutions (ISIs) in the United States, including museums, zoos, aquaria, science and nature centers. Using a variety of techniques, science is presented to the visiting public through exhibits that may be interactive, hands-on (offering no feedback to the visitor), or static (such as a diorama in a natural history museum). Beginning in 1851 with the London Science Museum, such institutions have presented science and have displayed objects of curiosity to the public claiming to make major contributions to public knowledge of science and science literacy (Beetlestone, Johnson, Quin, & White, 1998; Wellington, 1990).

Is this the case though? Despite these contributions to a public understanding of science, it has been made clear that only one of five Americans is able to explain the concept of a scientific study beyond a brief statement (Miller, 2004). The United States is not alone; in 1988 34% of the British public surveyed knew that the Earth goes around the Sun once a year compared to 46% in the U.S. (Durant, Evans, & Thomas, 1989; Sturgis & Allum, 2004). Further, recent psychological research has found that intuitions regarding science that arise during childhood and are based on common sense or championed by 'reliable' and 'trustworthy' experts often persist into adulthood (Bloom & Weisberg, 2007). This lack of scientific knowledge and understanding of science has led to a 'deficit model', where the public at large is seen to be deficient and 'science' or scientists are seen to be sufficient (Sturgis & Allum, 2004).

As of 1999, only 17% of the U.S population was considered to be scientifically literate or had a sufficient level of scientific understanding to read and comprehend *The New York Times* science section (Miller, 2004). While Miller uses this definition, overall there seems to be little consensus as to how scientific literacy or

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science literacy are defined (Roberts, 2007). However, the discussion at hand will use the following definition for science literacy:

> The science-literate person is one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes (AAAS, 1990, p. xvii).

More precisely put, a scientifically literate person has the knowledge, attitudes, and abilities to respond to personal, social, and global issues!

At the same time, it has also been argued that expectations are too great and science literacy should be viewed using diverse measures—one for citizen roles, another for consumer roles, and one for a more general cultural understanding (Shen, 1975). Whatever the case, Bybee (2001) suggests that ISIs should be included in any attempt to produce a more scientifically literate public. However, while "no-one ever flunks a museum" (Oppenheimer, 1975), there is a need to be more specific when considering how ISIs contribute to scientific literacy.

ISIs try to provide science for all its visitors and this includes a wide range of ages and abilities. Just as the visiting population is highly variable, so are the goals of what is to be presented. Some ISIs are only concerned with producing a public that is aware and enthusiastic about science; others wish to deeply improve the public's understanding of science (Wellington, 1990). These considerations directly impact the decisions made when designing exhibits and their potential to not only influence visitors' attitudes towards science but also their understandings about science and how it works.

When considering the evolution of ISIs, McManus (1992) developed a classification system describing first, second, and third generation institutions. A first generation ISI includes natural history museums or any other ISI that have collections of objects relating to scientific research. Their goal was to contribute to scientific knowledge in conjunction with educating the public. Second generation ISIs basically include science and industry museums that have interactive and hands-on exhibits. There may be a focus on research into the history of science and attention is also paid to educating the masses. Finally, third generation ISIs are "concerned with the transmission of scientific ideas and concepts rather than the contemplation of scientific objects or the history of scientific developments" (Tran, 2008, p. 140) and ISI collections are used to "encourage visitor thought and manipulation as vehicles for communication" (Tran, 2008, p.140).

Bradburne (1998) stated that second generation ISIs are doomed and no longer relevant. As described in the studies presented here, creating ISI experiences that are positive, while well meaning, often reduced the processes of science to a series of products. It was seen as a real challenge to present the more controversial and debatable aspects of science in an exhibition; ultimately revealing that scientific knowledge is not definite (Endersby, 1997). Perhaps these challenges may explain why there are fewer of these types of exhibits or perhaps ISI exhibit designers and educators do not realize themselves how valuable they are in presenting to the public a more realistic and deeper understanding about science content, scientific inquiry, and nature of scientific knowledge and ultimately contributing to the promotion of scientific literacy.

What Is Nature of Science Knowledge?

While an untested assumption, science literacy is noted as requiring an understanding of nature of science (NOS), historically known as nature of scientific knowledge (N. Lederman, 2007). So, what do ISI educators themselves need to know about NOS to ensure the development of their own scientific literacy? What is the research on best practices to teach NOS? Only informed ISI staff with both NOS content and pedagogical knowledge will have the capacity to augment exhibits and programs with NOS and cultivate their visitors' scientific literacy. These augmentations could include identifying NOS connections in existing exhibits and programs, assisting exhibit designers to appropriately integrate NOS into new projects and designing curricular materials and programs to supplement them.

The phrase *nature of science* typically refers to the values and assumptions inherent to scientific knowledge and the development of scientific knowledge. Although there are disagreements about specific aspects of NOS, we have chosen to focus on seven aspects that are generally agreed upon, accessible to K-12 students, and important for all citizens to know.

First, people should be aware of the crucial distinction between observation and inference. Observations are descriptive statements about natural phenomena that are "directly" accessible to the senses (or extensions of the senses) and about which several observers can reach consensus with relative ease. For example, objects released above ground level tend to fall and hit the ground. By contrast, inferences are statements about phenomena that are not "directly" accessible to the senses. For example, objects tend to fall to the ground because of "gravity." The notion of gravity is inferential in the sense that it can *only* be accessed and/or measured through its manifestations or effects. Discussions about gravitational forces being responsible are largely inferential.

Second, closely related to the distinction between observations and inferences is the distinction between scientific laws and theories. Laws are statements or descriptions of the relationships among observable phenomena. Boyle's law, which relates the pressure of a gas to its volume at a constant temperature, is a case in point. Theories, by contrast, are inferred explanations for observable phenomena. The kinetic molecular theory, which explains Boyle's law, is one example. Theories and laws are both very important to science and they are different types of knowledge. Theories do not mature into laws.

Third, all scientific knowledge is, at least partially, based on and/or derived from observations of the natural world. All of the theories and laws developed by scientists must be checked against what actually occurs in the natural world.

Fourth, although scientific knowledge is empirically based, it nevertheless involves human imagination and creativity. Science involves the invention of explanations and this requires a great deal of creativity by scientists. This aspect of science, coupled with its inferential nature, entails that scientific concepts, such as atoms, black holes, and species, are functional theoretical models rather than faithful copies of reality. All "inventions" are not equally appropriate. When scientists construct knowledge by making inferences from observed data, their inferences must be consistent with the natural world as well as the current knowledge base in science. Scientists are not free to speculate without any constraints.

Fifth, scientific knowledge is at least partially subjective. "Subjectivity" in relation to scientific knowledge refers to the influence of accepted theories in the scientific community as well as the individual backgrounds of researchers. The key point is that scientists do not collect and interpret data without preconceptions and biases. Scientists' theoretical commitments, beliefs, previous knowledge, training, experiences, and expectations actually influence their work. All these background factors form a mind-set that affects the problems scientists investigate and how they conduct their investigations, what they observe (and do not observe), and how they interpret their observations.

Sixth, science affects and is affected by the various elements and contexts of the culture in which it is practiced. These elements include social fabric, power structures, politics, socioeconomic factors, philosophy, religion, and other factors. In short, we say that science is socially and culturally embedded.

Seventh, it follows from the previous discussions that scientific knowledge is subject to change. This knowledge, including "facts," theories, and laws, is tentative and subject to change. Scientific claims change as new evidence, made possible through advances in theory and technology, is brought to bear on existing theories or laws, or as old evidence is reinterpreted in the light of new theoretical advances or shifts in the directions of established research programs (N. Lederman & J. Lederman, 2004).

While there may be some dissension about the overall definition of NOS, there is general agreement that the above aspects are appropriate for K-12 education and students (N. Lederman, 2007). Past science education reform documents placed a strong emphasis on students' understandings of NOS (AAAS, 1990, 1993; NRC, 1996). With the emergence of the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013), it is apparent that the teaching and learning about NOS continues to be an important goal of science education. The NGSS addresses nature of science in Appendix H. The understandings of NOS are included in both the Science and Engineering Practices and Crosscutting Concepts as:

- Science is a way of knowing;
- Science is a human endeavor;
- Science addresses questions about the natural and material world;
- Science models, laws, mechanisms, and theories explain natural phenomena;
- Scientific knowledge is based on a variety of methods;

- Scientific knowledge is based on empirical evidence;
- Scientific knowledge is open to revision in light of new evidence; and
- Scientific knowledge assumes an order and consistency in natural systems.

With this continued emphasis on understanding NOS to develop scientific literacy, ISIs should be asking how to design exhibits and instruction to address NOS within the context of these new standards.

Teaching NOS

There has been a great deal of classroom-based research that supports that K-12 students are capable of learning about NOS (Aydin, Demirdogen, Muslu, & Hanuscin, 2013; Khisfe & N. Lederman, 2007; J. Lederman, Bartels, N. Lederman, Gnanakan, 2014). Explicit classroom instruction of NOS has been shown to be more effective, "drawing the learner's attention to key aspects of NOS through discussions and written work following engagement" (Akerson, Hanson, & Cullen, 2007, p. 753). When considering literature addressing science classroom teachers, it has also been found that effectively teaching NOS and inquiry requires teachers to have knowledge of NOS and inquiry along with the pedagogical knowledge for each (Schwartz, N. Lederman, & Crawford, 2004). It is argued here that the same is true for ISI exhibit designers and, in particular, education staff (Holliday & N. Lederman, 2013; Holliday, N. Lederman & J. Lederman, 2013).

Such explicit instruction of NOS would also be necessary during professional development of K-12 teachers and ISI educators. Doing this would hopefully enable both groups to address NOS during class trips or ISI programs while working in preexisting exhibits or exhibitions that may not have been designed with NOS or SI in mind. For example, the Field Museum of Natural History in Chicago, IL has a permanent exhibition called *Evolving Planet.* This exhibition deals on the subject of Evolution by telling the story of life on earth through interactive displays, videos, and fossils from the museum's collections. In one hall of the exhibition, there are large murals depicting dinosaurs interacting with their environment and each other. The paintings were completed in the mid-1900s. However, they no longer reflect current day scientists' conceptions of what these animals might have looked like. A great deal more evidence has been collected since they were painted and our views of these extinct animals and their genetic histories have changed.

There are benches in the same hall with drawings that represent more current inferences about what we now believe their appearances might be. The average visitor is not likely to compare these different and changed sets of images and think "what a wonderful example of nature of scientific knowledge!" We know these implicit representations do not cause these connections to naturally happen. However, an ISI educator could use these images, along with the displayed fossil remains of dinosaurs, to explicitly illustrate aspects of NOS. Both sets of pictures represent inferences about dinosaurs based on observing the empirical data and what was known during the time they were made. The representations changed because scientists adjusted their views as more fossils were found and analyzed and added to the pre-existing body of evidence. As a result, scientists adjusted their inferences about what dinosaurs looked like and how they behaved. In some cases, a few fossil fragments were used to recreate models of entire skeletons.

As a result of scientists observing and inferring form and function, creatively organizing and analyzing the empirical data, and taking into account what was already known, they produced a plausible new model. Of course, there always remains the possibility for this model to change if there is new evidence found or if other scientists consider the same data, but interpret it differently based on the scientific information they know and bring to the data analysis process. Their model, their inferred representation, could be very different from the previously accepted one. However, for this new version to be accepted and replace the old model, they would need to supply strong and convincing empirical evidence to their peers in the scientific community.

Clearly, this exhibit provides the opportunity to teach a number of aspects of NOS. However, ISI educators need to know enough about NOS themselves in order to recognize the potential to do so and also have the pedagogical knowledge to create the corresponding explicate instruction. This could take the form of additional text materials for the casual visitor, curriculum and professional development for teachers, or programs for students or visitors.

The following is an example of a possible ISI education lesson that could be used after a visit to the *Evolving Planet* exhibition that continues to focus on explicitly teaching NOS. This could be used as part of a professional development program for teachers or as an activity for students or visitors. It is included in this chapter to support and continue what has already been written about NOS and how to most effectively teach it.

Mystery Skeleton Example

Groups of participants (usually 4–6 members) are given large envelopes with sets of cut outs of paper bones (see Fig. 25.1). They are told that these bones were newly discovered! They will be acting like scientists and will be expected to observe the bones carefully and then assemble them into an articulated skeleton using what they know and what they infer from the shape of the bones in the set.

After the groups have worked on this for a while, have them go around and look at how the other groups put the bones together. Participants are given the opportunity to go back and make adjustments to their inferred models based on what they learned from the other groups, if they wish. The groups are then asked to explain why they produced the models they did. After all the groups have shared their results, it should be noted that even though their results were different, they all could defend their reasoning with empirical data, and all of the models were

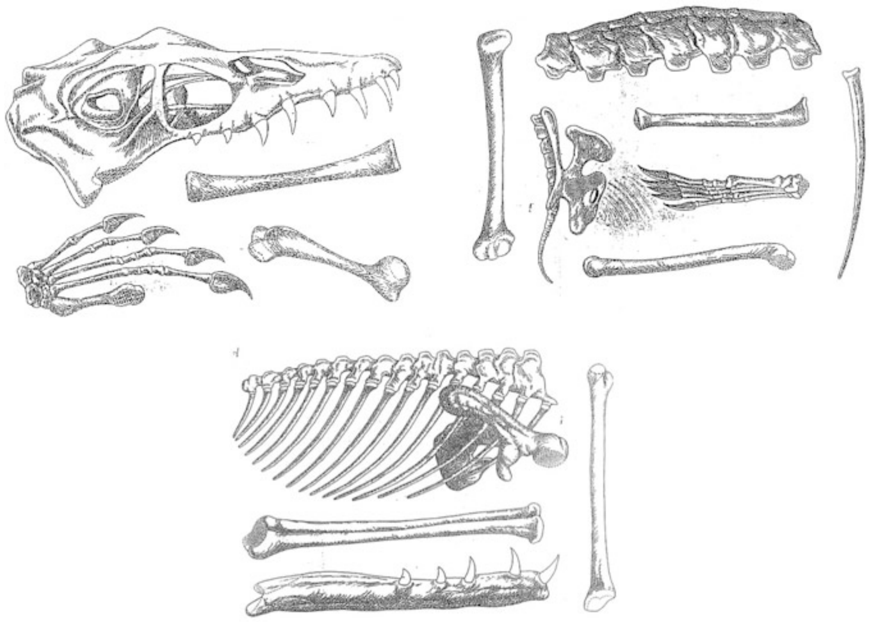

Fig. 25.1 Mystery bones (N. Lederman & J. Lederman, 2005)

plausible. The intellectual creativity they applied to the task should also be noted and as such their results reflected the creative nature of science.

At this point the ISI educator can ask why each group produced a different inferred model of the skeleton even though they all had the same sets of bones. The discussion should be guided to support the understanding that the people in the different groups may have brought different knowledge about vertebrates to the problem solving activity, may have inferred a different form or function of the bones, and may have had preconceived assumptions about how the animal moved around. All of these are differences in knowledge and thinking could have led to different inferred conclusions. This is an opportunity for the ISI educator to discuss how this works in science as well and illustrates the subjective nature of science. If any of the groups changed their configurations as a result of looking at the other groups' work, the ISI educator could bring in the tentative nature of science as well at this point in the activity.

Next, the groups are shown this rendition of what scientists believe the most reasonable version of the skeleton was based on what they know, observed, and inferred. In addition, images of what the animal might have looked like on the exterior are shared (see Figs. 25.2 and 25.3). Participants are usually surprised by

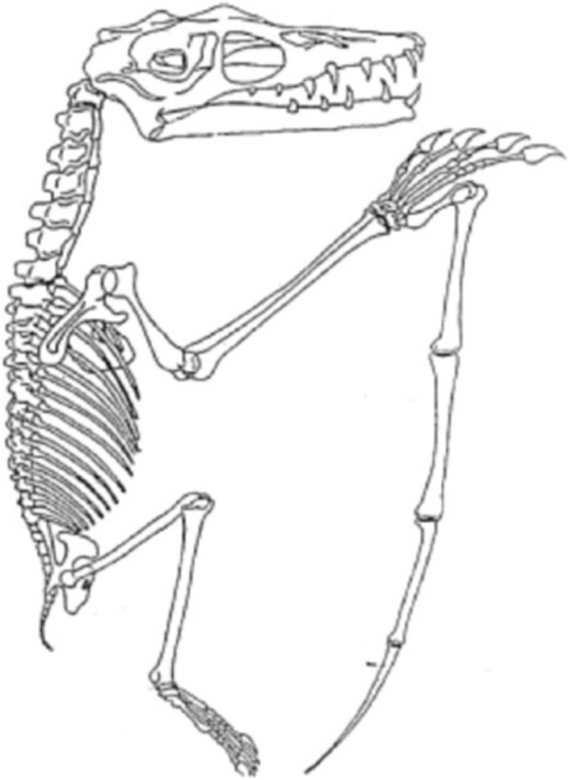

Fig. 25.2 One paleobiologist's reconstruction of bones (N. Lederman & J. Lederman, 2005)

these versions! When asked why they did not think of these options, they realize flying vertebrates are not familiar and so their inferred conclusions were biased by what they knew. Here again, subjectivity could be addressed.

Finally, the participants are told that since the first version was released, more data and fossils have been found. As a result of this new empirical data, scientists have adjusted the skeletal model for this animal and have inferred a new version of how the bones on the limbs may have been articulated and what the animal may have looked like (see Figs. 25.4 and 25.5).

These changes are good examples of the tentative nature of science and an opportunity to explicitly discuss how all scientific knowledge is subject to change. A concluding discussion may reflect on the activity and how it supports science as a way of knowing and science is a human endeavor. These support the whole notion of why scientific knowledge is subject to change and never considered absolute. It is why scientist might disagree with each other even though they have the same data. Human beings do science and scientific knowledge is subject to all the strengths and flaws of humans processing data.

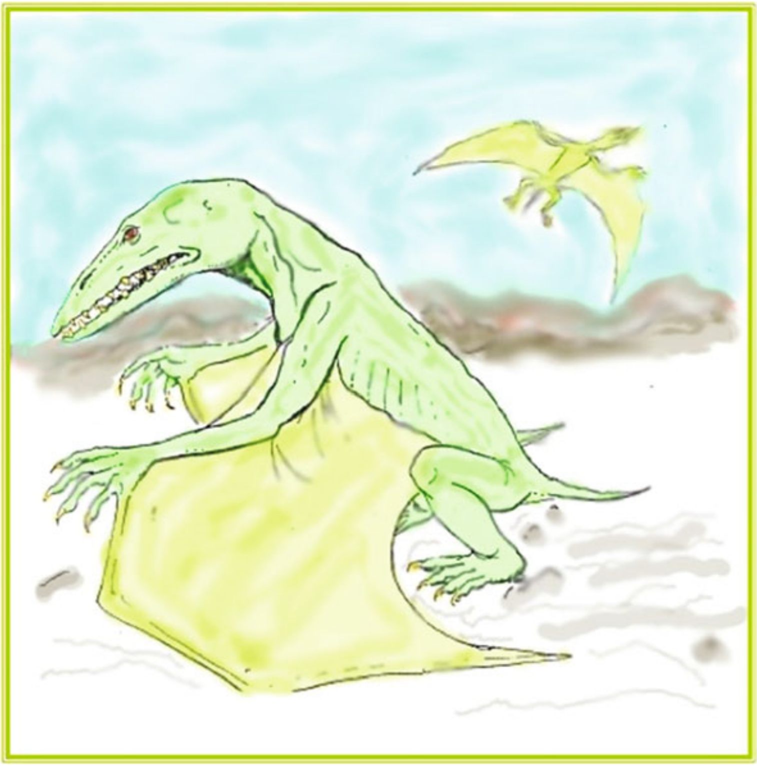

Fig. 25.3 One paleobiologist's imagination (N. Lederman & J. Lederman, 2005)

It should be noted that not all of the aspects of nature of science were included in this post-activity discussion. This is not problematic. Every activity or exhibit does not lend itself equally well to address all aspects of NOS. The objective is to address them where they make the most sense!

After approximately 50 years of empirical research on NOS, a few generalizations can be made:

- K-12 students do not typically possess adequate conceptions of NOS.
- K-12 teachers do not typically possess adequate conceptions of NOS.
- Conceptions of NOS are best learned through explicit, reflective instruction as opposed to implicitly through experiences with simply doing science.
- Teachers' conceptions of NOS are not automatically and necessarily translated into classroom practice.
- Teachers do not regard NOS as an instructional outcome of equal status with that of traditional subject matter outcomes (N. Lederman, 2007).

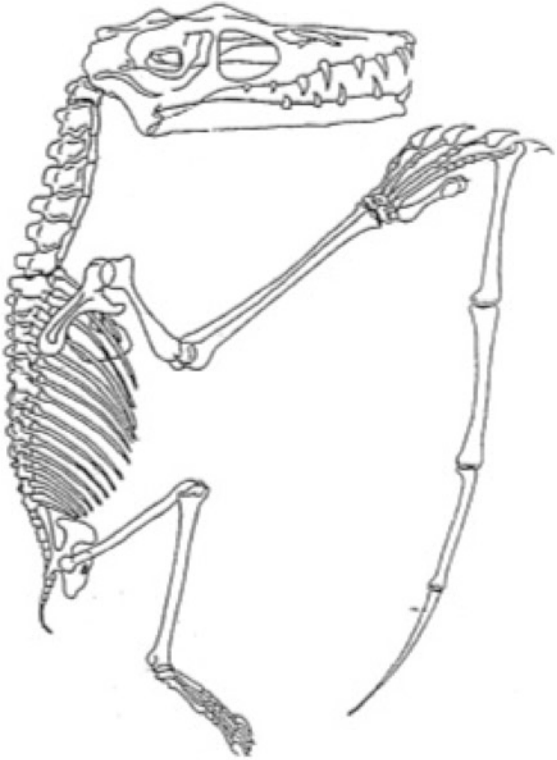

Fig. 25.4 Revised reconstruction of bones (N. Lederman & J. Lederman, 2005)

Given this data, it is fair to assume that most ISI education staff, exhibit designers, and visitors have naïve or perhaps non-existent knowledge of nature of scientific knowledge. Since ISI's are considered to be the most likely places for people to supplement their post high school knowledge of science, then similarly they have the potential to teach NOS as well.

NOS in Exhibitions

In general, science center exhibitions present scientific knowledge in interactive, engaging, but uncritical ways. The emphasis in such exhibitions seems to be on "learning science" (the facts, laws, theories) with little emphasis on the scientific processes or the socio-cultural context of science. However, these exhibits present what can be augmented to expand visitors' understandings of science, including a critical examination of NOS. An ISI educator with informed understandings of NOS can identify relevant aspects of NOS and create opportunities to integrate them into an exhibit.

Fig. 25.5 Revised paleobiologist's imagination (N. Lederman & J. Lederman, 2005)

Rennie and Williams (2002) focused on whether the science-related experience helped people think differently about science as well as the perceptions of NOS by staff. Specifically, the study looked at the perceptions and ideas of the center staff and visitors at the science center. The study took place at an interactive science center in Western Australia, which was selected since its mission was "to increase the interest and participation of Western Australians in science and modern technology" (p. 709). While Rennie and Williams (2002) noted that staff had more informed views about NOS, it also has been found that full time ISI educators displayed misconceptions regarding scientific models, theories, laws, and the certainty of science (Holliday & N. Lederman, 2013).

In terms of visitors' views, a trend was seen indicating a more positive perception about science, however this positive view also indicated a less scientific one. Upon leaving the science center, visitors were "more likely to think that scientists always agree with each other, that scientific explanations are definite, and that science has the answers to all the problems" (p. 723). One education staff member and another in visitor services felt that NOS should be addressed more directly at the center. However, this did not necessarily fit neatly with the statement mentioned above regarding positive views about science, since it was felt that dealing with “real” NOS involved presenting the more controversial aspects of science along with the fallibility of scientific knowledge. It seems that science centers are more likely to present concepts of science in small segments but, in general, portraying NOS in exhibits was difficult. Also, visitors were used to seeing the marvels of nature and advances in technology when visiting exhibitions while the scientists and engineers were portrayed as being clever for figuring it all out.

The authors (Rennie & Williams, 2006) discussed that it is often difficult for museums and science centers to produce exhibitions that communicate the uncertainty and controversy in science yet this is essential in order to promote scientific literacy among its visitors. Even so, science centers and museums are failing to present NOS and scientific knowledge to the public. Perhaps this was due to the institutions trying to present science as an enjoyable, but nonetheless, unchallenging experience. It is necessary to present NOS in an explicit manner in order to have an impact upon visitors (Schwartz et al., 2004). In this study, the museum and science center staff noted that their aim was to present science in a way that the public could understand, however this seemed to have a detrimental effect. The authors felt that the findings discussed were also supported by other research, in which the visitor’s own agendas often interacted with the opportunities provided while visiting informal science settings.

While many studies address how exhibitions contribute to the learning of visitors, few look at the underlying assumptions of the exhibitions that are planned and created at science and technology centers (STCs). Davidsson and Jakobsson (2008) investigated how science center exhibit designers’ views impacted the development of new exhibitions. When discussing the results, the authors stated that the analysis revealed that staff members felt that learning processes differed in formal versus informal contexts. Distinctions were made between hands-on or theoretical learning, and serious or non-serious learning. Overall, participants felt that when a visitor interacts with an exhibit, it was more important to create an interest about the content rather having the visitor actually learn the content.

In short, the authors determined that the staff members obtained their scientific knowledge by referring to members of the natural science community and staff felt that this was important in order to keep up to date. At the same time, there was no discussion about how this reference to the natural science community happened. When it came to knowledge about how visitors learn from their exhibits, participants stated that this was informed by their own personal and professional experiences.

Further, an example was given in which the participant stated that she would refer to other staff members who were museum educators when there were questions regarding pedagogy, but otherwise she did not have the theoretical knowledge herself. Knowing that ISI educators’ professional experiences can be incredibly varied (Tran & King, 2007), it was not made clear how these educators had been prepared when considering their pedagogical expertise. The authors suggested that future studies focus on staff members’ actions and assumptions about visitor learning when constructing new exhibitions.

In a larger study, also conducted by Davidsson and Jakobsson (2007), the researchers dealt more specifically with how science was manifested and displayed in ISI exhibitions. It was indicated that staff members felt that scientific processes could be made explicit through the display of scientific products and applications, if shown within a societal perspective. However, this was seen to be insufficient since the process of scientific knowledge development was not included.

Presenting Controversy in Exhibits

When visiting a natural history museum in the United States, one will very likely come across dioramas depicting realistic looking landscapes and the organisms that live there. While they may include contemporary environments, they can also depict environments and organisms that existed before modern times; including dinosaurs or ancient hominids. When created, dioramas can include objects, taxidermy (mounted animals), and reconstructions. These reconstructions have to be carefully considered, because the displays can appear to be a 'window onto knowledge' to visitors viewing them (Endersby, 1997).

Exhibit designers make decisions about what to present and how to present it so the visitor can understand the information easily. Scientists also assist in the process by providing scientific concepts and information in order to inform the interpretation. Considering this, the museum diorama is not representing 'nature' but is a construct of how humans (in this case exhibit designers and scientists) think nature may have looked during that time. For instance, recreating a dinosaur with its external physical dimensions including skin color based on skeletal remains. Unfortunately, visitors often perceive the depictions as real when they are not.

In addition, the objects or recreations shown in the display are often seen as the end results of science. The complex processes of exploration, experimentation, and debate are lost to the visitor. This is true for both the scientific inquiry process and the exhibition development process (Arnold, 1996; Endersby, 1997). It also has been shown that those visiting science centers and museums often interpret the information presented in exhibits in a way that was personally meaningful and not always in line with the intentions of exhibit designers (Layton, Jenkins, MacGill, & Davey, 1993; Rennie & Stocklmayer, 2003). Yet another layer of interpretation occurs when an ISI educator is using the exhibit for educational purposes and makes choices about how and what to present to a group of students (Rose, 2006).

In order to provide representations of science that are not monolithic, objective, and apolitical, ISIs must consider presenting science to the public in a manner that may be considered unsettling and controversial (Pedretti, 2002). Such exhibitions would require visitors to be challenged, shifting from the individual experience to larger societal concerns, and would contribute to their scientific literacy (AAAS, 1990). In the process, instead of just 'feeling the fun' (Pedretti, 2002), the emotional and affective dimensions of learning would be tapped into as well. Considering all of this, it is difficult to communicate such issues that are not phenomena based and can be very complex. Again, it has been noted that visitors often come to an exhibition with their own set of personal framework and interests (e.g., Afonso & Gilbert, 2007). Often, they do not challenge what is presented in an exhibition.

Summary

First and foremost, it would seem that a more defined role is needed for ISIs and their exhibits, along with a better understanding of what we want the visitors to come away with when visiting an ISI. Do we want them to be more scientifically literate? If yes, what does that mean and what does it look like? Do we want visitors just to have an appreciation for science or a deeper understanding? If understanding were the aim, at what depth would be appropriate?

In the reviewed literature, ISI exhibit developers and staff were depicted as being more interested in visitors coming away with positive experiences and attitudes about science while visiting the science center or museum rather than having them learn the science content or understand scientific processes (Cox-Peterson et al., 2003; Davidsson & Jakobsson, 2008; Rennie & Williams, 2006; Tal & Morag, 2007).

This is especially interesting since a large majority of the research done in informal education focuses on the general visitor's learning that takes place when visiting these institutions (Rennie, 2007; Vadeboncoeur, 2006). While visitors may enjoy visiting ISIs, it has been shown that often the experiences reinforced previously held conceptions rather than introduced new knowledge (Afonso & Gilbert, 2007; Medved & Oatley, 2000). It seems unrealistic to see an impact upon visitors' understanding of scientific processes or knowledge development under these circumstances.

If a public understanding of science is desired, and when considering NOS in particular, this involves a deeper understanding on the part of ISIs and its staff. Having a grasp of visitor and installation relationships; the nature of learning; NOS; scientific inquiry; visitor characteristics and expectations; and a well-defined message are all necessary (Pedretti, 2002). Producing and interpreting exhibitions that have a deep context and rich connections to personal, socio-cultural, and physical components (Falk & Dierking, 2000) would provide an immersive experience for visitors that motivates them to learn, creating a flow experience, as described by Csiksentmihalyi and Hermanson (1995), would allow for the shift from the individual to larger societal concerns (Pedretti, 2004), but would also require designers to be more daring when producing exhibitions (Durant, 1996). But again, these implicate that representations are not enough. They are a starting point for an ISI educator to infuse explicit language, experiences, and instruction about nature of scientific knowledge.

It does not seem feasible to create more appropriate representations of science in ISIs until ISI education staff develops their own understanding about NOS in the first place. It is only when they have content knowledge about NOS and Scientific

Literacy that they can apply this knowledge to the development of programs and exhibits. Impacting the scientific literacy of ALL visitors is more than a daunting task, but when ISI educators are equipped with knowledge of NOS and how to best integrate it in, the goal of impacting the scientific literacy of the visitors can not help to be more likely attained!

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Chapter 26
The Attributes of Informal Science Education: A Science Communication Perspective

Susan M. Stocklmayer and Léonie J. Rennie

In 2013, Ellenbogen wrote about the "convergence of informal science education and science communication" (p. 11). She suggested benefits from exploring the ways the two fields might be strengthened by taking more notice of each other, given that both are working toward a common outcome: enhancing public interest in and awareness of science. In this chapter, we take up this challenge by examining these two fields and identifying the salient characteristics of each. We begin with an overview of informal science education that enables us to identify the attributes that encourage engagement by a broad public. This is followed by an historical overview and synthesis of the field of science communication, leading to the identification of three modes of communication that involve engagement with the public. We then combine these attributes and modes of communication to provide a framework that allows us to draw out the skills and knowledge required for successful science communication that may guide informal science educators to become more effective communicators of science.

Informal Science Learning

Informal learning has been defined and described by many authors, frequently by contrasting it with "formal" learning. Wellington's (1990) oft-cited analysis, for example, compared in-school and out-of-school contexts, whereas Martin's (2004) approach was firmly positioned in specific socio-cultural contexts, thus encom-

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passing a broader diversity of informal learners. With a greater focus on adult learners, Eraut (2004) and Malcolm, Hodkinson, and Colley (2003) provided comparisons of formal and informal learning in the workplace. Regardless of their perspective, all of these authors echo Dierking, Falk, Rennie, Anderson, and Ellenbogen (2003) in stressing the intrinsic nature of learning as a lifelong process:

> learning is an organic, dynamic, never-ending, and holistic phenomenon of constructing personal meaning. This broad view of learning recognizes that much of what people come to know about the world, including the world of science content and process, derives from real-world experiences within a diversity of appropriate physical and social contexts, motivated by an intrinsic desire to learn (p. 109).

More recently, in their comprehensive report about the "people, places, and pursuits" of informal learning in the United States (US), Bell, Lewenstein, Shouse, and Feder (2009) also emphasized the lifelong nature of learning, in which self-motivated learners seek out information, knowledge and skills. As well, these authors referred to "life-wide learning", to include the range of social settings and activities in which learning might occur, and "life-deep learning" as the beliefs and values that ensure learning is never culture-free. Bell et al. organized their discussion around every day informal learning environments, including family learning; designed environments, such as museums, libraries and like places; and the more formal out-of-school and adult programs. All of these avenues provide opportunities for people of all ages to engage with and learn about science.

For several decades, international research has investigated informal science education in a wide range of contexts with a variety of groups, including elementary students, high school students, parents and the wider public. We will not go into detail here because the nature of informal science education is the subject of other chapters in this volume. Instead we refer readers who wish to go beyond these chapters to recent comprehensive reviews, including those by Bell et al. (2009), Falk et al. (2012), Rennie (2007, 2014), and Lloyd, Neilson, King, and Dyball (2012).

In their overview of research findings in informal settings, Stocklmayer, Rennie, and Gilbert (2010) considered museums and other designed environments such as science centers, zoos, aquaria, planetaria and interpretive centers; community and government organizations, including those that aim to inform the public about issues relating to health and the environment, as well as specific science-related activities and events, such as science festivals, science theatre, cafés scientifique, etc.; and all forms of media, both print and electronic. Stocklmayer et al. (2010) used their review to tease out the attributes that research had found to foster engagement in these informal settings. The twelve attributes they identified are shown in four clusters in Table 26.1. The first cluster of affective attributes is recognizable as underpinning key characteristics of informal learning: it is voluntary and intrinsically motivated. The other eight attributes are presented in three clusters based on Hodson's (1998) tripartite view of science education: Learning science refers to acquiring and developing science knowledge, learning about science involves understanding science in a broader historical and social context, and doing science means engaging in and developing skills for scientific investigation.

In identifying the attributes described in Table 26.1, Stocklmayer et al.'s (2010) purpose was to explore ways and means of including more experiences from the informal sector into formal school education; however, understanding these

Table 26.1 Summary of attributes that encourage engagement in science in informal settings (based on Stocklmayer et al., 2010, p. 25)

Attribute	Explanation
Affective attributes	
Providing for free choice	Gives learners a sense of ownership and control
Internally driven and challenging	Learners' intrinsic motivation is powerful, particularly with a sense of challenge or a quest, offering curiosity and surprise
Encouraging wonder, delight and awe	Wonder comes with a sense of discovery and can be exploited to appeal to the senses
Entertaining, interesting, enjoyable	Engagement will be sustained if activities are interesting and enjoyable
Attributes relating to learning science	
Holistic	Science in the real world is multidisciplinary, so learners find an holistic approach to be more accessible than reductionist explanations
Useful, powerful and transferable knowledge	Constructivist inquiry learning recognizes learners' prior experiences and knowledge and encourages transferability
Strongly emphasising narrative	Narratives engage learners, particularly if they encourage personal meaning-making
Presenting science which is simply explained, jargon-free and in the active voice	Presenting "science as story" using analogies and models enhances understanding
Attributes relating to learning about science	
Facilitating social and community interaction	Making the connections to community explicit aids understanding of experience, and facilitates "border crossing"
Presenting science as messy, human and exploratory in nature, addressing real and current problems	Showing science as a human endeavour involving real people is critical to interest and engagement. It is important to emphasize nature of science and science processes
Attributes related to doing science	
Facilitating inquiry-based science	Successful inquiry learning requires real contexts and real data. Encourage interactivity, experimentation to enhance engagement and build confidence
Involving real projects with real outcomes	When real scientists can be involved, learners can see the importance and relevance of projects

attributes can also contribute to more effective ways of engaging the public in science-related experiences. Indeed, all of these attributes are found within the effective practice of science communication in a variety of contexts and with a variety of publics, as we explain in the following section.

Science Communication

Science communication is a relatively young discipline, which has only achieved its own disciplinary framework over the past three decades. Until the end of the twentieth century, one mode of communication tended to dominate the communication of science. Sometimes termed the 'transmission model' after Shannon and Weaver (1949), this one-way communication was grounded in a belief that the public needed to be 'educated' in science. This view of the public had been termed the 'deficit model' as far back as 1991 (Layton, Jenkins, McGill & Davey, 1993; Wynne, 1991; Ziman, 1991).

The transmission model for communication of science is fundamentally flawed, in that it supposes that the 'message' being transmitted is going to be received in exactly the same way as it was sent. Today, we recognize that a multiplicity of audiences, with their diverse backgrounds, understanding and experiences, will inevitably result in different processing and acceptance of any scientific 'message'. Indeed, the idea of a message has itself fallen into disrepute along with rejection of the deficit model.

> The one-way model has also been widely criticized for its underlying implication that the transmission of information is from 'expert' to 'layperson' … and has now been comprehensively rejected in favor of a style of engagement that respects public knowledge as well as the knowledge of scientists, and regards the public and scientists as equal players in science communication endeavors (Stocklmayer, 2013, p. 20).

The shift from the deficit model of the public toward a more respectful model has led to a critical examination of the fundamental relationships between science and society and a wider framework for science communication theory. The process began with a seminal report from the British Parliament (House of Lords, 2000), in which the outmoded term 'public understanding of science' was deeply criticized:

> Despite all this activity and commitment, we have been told from several quarters that the expression "public understanding of science" may not be the most appropriate label…. It is argued that the words imply a condescending assumption that any difficulties in the relationship between science and society are due entirely to ignorance and misunderstanding on the part of the public; and that, with enough public-understanding activity, the public can be brought to greater knowledge, whereupon all will be well. This approach…is felt by many of our witnesses to be inadequate; the British Council went so far as to call it "outmoded and potentially disastrous" (p. 140).

The immediate response was to seek other terms for the relationship, which now include public engagement, dialogue, knowledge sharing and knowledge building (see, for example, Research Councils UK, 2002; Welp, de la Vega-Leinert, Stoll-Kleeman, & Jaeger, 2006). In the twenty-first century, the deficit model has been discredited. In some cases, however, it is still used to describe all forms of one-way communication including, for example, the media, science shows and science lectures. There is no doubt that two-way communication has the potential for establishing greater understanding and creativity in science, but one-way communication forms a very large part of science communication practice. Some of this communication has the intent to 'educate' the receiver of the message; in other cases the intent may simply be to inform, without connotations of traditional learning. In this category, we might include the media – both print and visual, the Internet, or many of the activities of science centers. Stocklmayer (2013) pointed out that in these forms of communication

> There is clearly no expectation by the writers, designers and producers that they will engage in two-way communication, but rather that they are 'transmitting' information to whatever audience is willing to listen, play, read or watch. All these examples nevertheless contribute to a view of scientific knowledge as knowledge worth having, interesting or important to a variety of people (p. 22).

Modes of Science Communication

Many authors have identified science communication as loosely fitting into three categories (for example, Trench, 2008). These categories generally encompass three different modes and three different kinds of intended outcomes that essentially form a continuum (Stocklmayer, 2013) in which the first mode is communication *to* the public. This characterizes one-way communication which applies to dissemination of knowledge. The intended outcome is to inform. The response of the 'audience' to this knowledge will depend on many factors, not least its immediate relevance and accessibility. This mode applies to any science communication process which does not invite comment, response or feedback. The intent may be to provide information that the audience requires or in which there is some interest. Equally, there may be an intent to change behavior or influence attitudes. Much climate change communication has been in this category, for example, with problematic outcomes.

This mode of communication is the kind one encounters through the media, science shows, science lectures and science fairs and exhibitions. Although this is essentially one-way, it is not designed to educate (as in the deficit model) but to interest and inform. This one-way communication may inform the listener or reader, it may inform policy, or inform research. The 'recipient' of the information may choose what they want to take home and what they wish to ignore. If it is designed to educate, however, then this kind of communication rests firmly within the area of formal education, even if it is notionally in the informal (or, in some cases, 'non-formal') domain. We think this distinction important for informal learning research and will return to it later in this chapter.

The second mode of communication is 'knowledge sharing' (Stocklmayer, 2013, p. 30). This mode involves two-way communication: the intent may simply be to understand other perspectives, or to encourage participation in scientific matters to ensure consensus outcomes. This mode is respectful of other points of view but does not imply embracing them in one's own scientific framework. The term 'dialogue' has frequently been applied to this mode, where there is a willingness to listen and to compromise, particularly to inform science policy. It may be termed communication *with* the public, which is the kind of communication that is consultative, deliberative and dialogic. This kind of communication of science, often associated with consensus conferences, may have concrete outcomes for policy and action. In the informal learning domain, this mode corresponds to mutual determination of learning goals, with the facilitator taking a low-key role and including other knowledge from the group. The outcome here is sharing of knowledge, which often represents an exchange between people in the group who come from different disciplines and experiences.

The third mode is 'knowledge building'. In this mode, various knowledge frameworks are given equal weight in striving for greater scientific understanding of a phenomenon or an environment. Knowledge building is essentially cross disciplinary and multidisciplinary, drawing from the sciences, the social sciences, and the arts to construct new knowledge that has elements from all contributing disciplines. Communication *among* the public is thus characterized by many contributing perspectives, many kinds of knowledge and many modes of learning. It involves not only sharing of knowledge but building new knowledge together in a respectful and open environment. In this case, different people not only bring their knowledge to the table to share, but construct new knowledge together. Some examples of citizen science are in this category, in which people contribute their observations or findings to a central bank, to be assimilated and analyzed to generate new information of importance to all the contributors. We note that not all citizen science is like this; some projects do not share with the contributors in a useful and respectful way. We would not classify such projects as informal learning in a very deep sense.

These three modes of communication apply to informal learning in different ways and to different degrees. Traditionally, informal learning has been characterized by having an 'expert' and a 'learner' but this is changing. Cooperative learning, citizen science, and the many modes of lay interaction have important learning outcomes, increasingly recognized as important to the overall levels of public awareness of science and to science education more generally. If we are to embrace this wider approach to informal learning, however, those strategies that have been recognized as important for successful engagement need to be embraced also. It will not be enough to approach these modes of interaction within a framework of education that rests soundly on the deficit model. These considerations are also relevant to more traditional forms of informal learning, where transmission of information has often been the default approach.

Just as affective emotions underpin successful informal science education (see Table 26.1), a fundamental need in communicating science in all three modes, is therefore incorporation of a range of strategies to excite interest, curiosity and enjoyment. Science communicators need to know how to evoke these emotions, so as to encourage motivation and engagement. Without engagement, neither science communication nor informal education can result in any learning of science.

Encouraging Motivation and Engagement in Science Learning

The communication of science in the public domain includes many environments in which informal learning occurs, but it is relevant to this discussion to examine the skills required where the desired outcome is intrinsically motivated learning as opposed to more formally constructed programs with specific outcomes. Even when the communicators have an overt, expressed science-based outcome, such as attitude or behavior change, the process of change must occur through intrinsic motivation if it is to be effective and long term. In this regard, Brophy (2008) stated that it is important to pay attention to "the learner's beliefs and feelings about the content, as well as the processes involved in learning and applying it" (p. 132). He identified theories of Situational Interest (SI) as relevant to this goal. SI has three major components; the first two are "emotion (specifically interest and enjoyment) and value. These two components, along with knowledge, form the major components of SI" (Walker, 2012, p. 22).

The 'Value' component, in this sense, broadly refers to a sense of relevance for the individual who is undergoing the science experience. It gives the experience personal meaning. The importance of relevance often leads, however, to a belief among educators that science should be related to everyday life. While this is true, and important, there is more to this idea than simply putting applications into the science content. There are three levels of value or relevance: The highest level relates to a deeply personal judgment of the value of the science to the individual, as opposed to ensuring that the science appeals to a particular group or demographic (Level 2), or is located in a real-world context (Level 1). Level 3 is "a more consistent and stronger predictor of motivation than the other two" (Walker, 2012, p. 279). The perceived *value* of the science is thus the catalyst for engagement, and it can only be successful when a communicator understands the audience. This seems an obvious and fundamental point, yet it is a point often neglected in research and practice. How, then, do we use different aspects of communication skills to provoke motivation to learn?

Inducing a sense of wonder and awe is frequently stressed as desirable, mainly anecdotally from those who have pursued careers in science and who were first excited by this sense of wonder. The sense of wonder, however, is embedded in the elements of interest, surprise and curiosity, which are drivers for engagement.

Emotion, especially as a combination of interest and enjoyment, is central to Intrinsic Motivation to learn. “Taken together, the emotional aspects of both Intrinsic Motivation and SI, in learning settings and everyday life, are dominated by interest and enjoyment” (Walker, 2012, p. 40). The importance of emotion or affect is not new to formal education research, but it is often assumed in informal learning that the experience alone will suffice to motivate. Going on a field trip, for example, is not always accompanied by careful attention to what is communicated, by whom, and in what manner.

Exciting curiosity is a critical element in science communication to the public. There are, however, two kinds of curiosity, which relate to different feelings. The first is I-type curiosity—a feeling of interest—and the second is D-type curiosity—a feeling of deprivation (Litman & Jimerson 2004; Litman, 2008). According to Litman (2010), I-type curiosity

> reflects a relaxed and pleasant ‘take it or leave it’ feeling towards new knowledge… potentially pleasurable but not a necessity…. By contrast, D-type curiosity is an intense and uncomfortable ‘need to know’… [it] motivates seeking specific, objectively correct and relevant knowledge in order to resolve the uncertainty (pp. 397–398).

In other words, D-type curiosity is more likely to motivate further investigation and learning. There seems to be no real link between surprise and D-type curiosity but I-type curiosity may be aroused by elements of surprise. There is considerable literature about the value of discrepant events in formal and informal learning, particularly in the area of conceptual conflict, but there is less known about how to produce them for an audience. Sadler (2004), however, investigated short- and long-term effects of science shows on the memory of participants and found that discrepant events were high on the list of most recalled demonstrations. He concluded that: “By looking at all the data available, it seems that by some considerable majority, demonstrations that are curious, novel, counterintuitive, or involve a challenge about the outcome, have most impact in the short and long term” (p. 50).

Of course these demonstrations must also have the factors of relevance and interest built in. “Interest is most likely to be the emotion in the human mind that continually influences mental processes” (Izard, 2007, p. 71). According to Silvia (2005), the effect of Interest relies on two factors: the novelty and complexity of the stimulus and a person’s ability to cope (or understand). Clearly, it is important also to address elements of novelty. The language of science needs to be simple, but the inherent conceptual complexity of science often intrigues rather than discourages. There is a fine balance to be achieved between these conflicting aspects of communication, particularly with adults. It is important to meet but not exceed their ability to cope with the information being addressed but, at the same time, not to ‘dumb it down’.

The three modes of engagement and the underpinning affective factors determining intrinsic motivation indicate considerable congruence with the attributes of informal learning that were introduced earlier in Table 26.1. In the next section, we explore these relationships in terms of research findings in science communication in order to draw out the essential skills of science communication that we consider will prove useful to informal science educators.

The Attributes of Informal Learning and the Modes of Science Communication

The attributes described in Table 26.1 included four affective attributes, and eight attributes related to learning science, related to learning about science, and related to doing science (Stocklmayer et al., 2010, p. 25). Table 26.2 compares these different attributes in terms of the three main modes of communication, as described earlier.

In creating Table 26.2, we recognized that there is considerable overlap among the attributes, and so we have cross referenced those that are dominant in each mode, while understanding that other attributes may also contribute, depending on the context of engagement. Further, in communicating science to a variety of publics, it is also important to recognize a multiplicity of voices. Models of science

Table 26.2 Cross-referencing modes of communication with dominant attributes that encourage engagement in science

Attribute clusters	One-way information (communicating science **to** the public)	Knowledge sharing (communicating science **with** the public)	Knowledge building (communicating science **among** the public)
Affective attributes	Encouraging wonder, delight and awe Entertaining, interesting, enjoyable	Providing for free choice Internally driven and challenging	
Attributes relating to learning science	Strongly emphasising narrative Presenting science which is simply explained, jargon-free and in the active voice	Useful, powerful and transferable knowledge	Holistic
Attributes relating to learning about science	Presenting science as messy, human and exploratory in nature, addressing real and current problems		Facilitating social and community interaction
Attributes related to doing science			Facilitating inquiry-based science Involving real projects with real outcomes

communication have attempted to recognize these different stakeholders (Stocklmayer, 2013); indeed some of these stakeholders may be at least as expert in the science under discussion as the scientists themselves. Others, more problematically, may be members of lobby groups which use accepted methods of marketing to persuade people to a particular, sometimes ‘anti-science’ point of view.

It is also clear that an understanding of the ‘audience’ is paramount in successful science communication. This includes an appreciation of their degree of knowledge of the science itself, a requirement that at times is very difficult to achieve. Nevertheless effective communication depends on positioning a discussion where the audience actually is, not where they might be assumed to be. This principle has strong echoes of constructivism, a principle well known to formal educational theory but not always applied in classroom practice. In the case of school ‘audiences’, strategies to determine prior knowledge are available to the classroom teacher: these include mind-maps, quizzes and so on. With adult audiences, however, such strategies are not available to the science communicator. It is imperative that the audience be engaged—but the means of doing so are much more difficult. It is easy to deliver information—making it relevant is the key. Quite commonly in informal learning, especially with adults, prior knowledge is not well understood, respected or addressed by the communicators. Consequently, the skills of science communicators must include the ability to consider various audiences. They must also be able to communicate within the three different modes, all important in informal learning.

The generic skills, which are expected of science communicators, thus include the need to apply constructivist principles in communicating. Recognition of social, cultural, and psychological contexts, and locating the science within those contexts, is critical. The ability to write for, or speak to different audiences is a skill that takes time to develop. The elimination of science jargon is imperative. Of course, underpinning these attributes will be a sound grasp of the science to be communicated, including likely misconceptions and assumptions. Critical thinking, too, is a skill that communicators require, but they also need to encourage critical thinking in their audiences.

Putting together these kinds of skills, the list of attributes and the modes of science communication that will provide for these attributes in Table 26.2, we now draw from research in the areas of informal learning and science communication to illustrate the importance of such skills in the provision of informal learning for all ages of learners.

Communicating Science to *the Public*

Communicating science *to* the public incorporates a range of strategies to excite interest, curiosity and enjoyment. These outcomes correspond to environments such as museums, zoos, and science show presentations in which the audience has no defined goal, or has a goal which is unknown to the communicators. Science communicators need to know how to evoke these emotions so as to encourage motivation and engagement; in other words, to encourage an outcome of intrinsically motivated learning.

To illustrate how these outcomes are related to the attributes listed in the first column of Table 26.2, consider the example of a science show or interactive lecture. This may be delivered purely for informative interest, or may have a more fundamental aim to change attitudes and behavior. There are many examples of science presentations which have a series of demonstrations around a loose theme, such as 'The wonders of chemistry' or 'The magic of physics', where the aim is often to entertain and, perhaps, to convince the audience that physics and chemistry are 'fun'. Such performances, however, do not follow the precepts of good communication that form the core of science communication theory. What are the communication skills required to do this well?

Consider, for example, the importance of narrative and of simple language. We know that formulae, graphs, and mathematics are not within the comfort zones of many of the public, yet they are often featured in a science show. The public is generally very forgiving and will gloss over these deficiencies, but there is a barrier set up which then has to be overcome. Narrative elements relate not only to the overall theme but the individual components of the theme. Is there a story? Is it easily discernible and relevant to the audience? Will there be human elements to the narrative as well as scientific ones? Will there be some humor? Is there an engaging start to the presentation (sometimes known as the 'hook') that will excite interest and perhaps curiosity? These points may seem obvious, or simple, but they are skills that are hard to learn and require much practice. Humor, for example, is a common element of science shows, but sometimes carried to extremes in the belief that clowning has the power to engage. Since research indicates that humorous content is often well remembered (Martin, 2007), an overuse of humor may mean that the science part of the presentation is less well recalled and has less power to motivate further engagement. Humor needs to be strategic.

Portraying science as an exploratory, often messy process is facilitated by inviting participation in conducting demonstrations. Asking 'what if…?' is a device that allows prediction and hypothesizing. Enabling interactivity during a science presentation, through whole audience participation and the use of volunteers, increases individual relevance and enjoyment. The nature of science as uncertain and exploratory is an important aspect of successful science presentations.

Presenting science has many parallels with communicating more generally, and with the theatre. Nevertheless there is always an underlying reason for science communication which differs from these more traditional aspects. That reason is that there is some science to be communicated. A complex topic needs to be translated with a specific audience in mind, and may then require even further adaptation for the group that is there on the day. This is indeed far from simple.

In summary, the key to communicating science *to* the public is not only to know and understand the audience, but to reflect their values. The communication must be structured so as to arouse curiosity and interest, through elements of surprise and discrepant events. There must be a clear and simple narrative, with minimum jargon. Audience interaction is desirable. The communication must also be entertaining, with elements of humor and storytelling. Science communicators not only need to have command of these presentation skills, but of the design skills required to construct such a communication.

Communicating Science with *the Public*

Communicating science *with* the public, on the other hand, requires understanding of a different communication style and structure. There is now an expectation that the public will contribute to the event in some way, and their own knowledge will be part of the discussion. The communication is two-way, and the object is mutual understanding of the science and, perhaps, of differing points of view: Exploration of the science itself is a shared goal. Essentially the attendance of all parties is voluntary. Falk and Dierking (2012) note that in the 21st century, learning

> is increasingly becoming bottom-up, controlled by the individual, and highly focused on the meeting personal needs and interests, particularly for adults. The majority of individual-generated science learning will be aimed at meeting identity-related needs unassociated with degrees and employment – science learning related to hobbies, personal curiosities, or individual needs such as environmental preservation in the neighborhood, or responding to health issues (p. 1075).

Clearly, knowing the audience is a high priority for the communicator because everyone's beliefs and values will now be contributing overtly to the outcome. Notions of perceived and real risk, for example, may profoundly affect the process. Many of the skills described above will be needed if the desired end is to be achieved, with additional skills relating to interactions with concerned, perhaps hostile, groups. The term 'dialogue event' has been used to describe an example of this kind of mutual discussion. Dialogue events are structured around a science topic of current interest, often a controversial issue. They have been described as "adult-focused, face-to-face forums that bring scientific and technical experts, social scientists, and policy-makers into discussions with members of the public about contemporary scientific and socioscientific issues related to the development and application of science and technology" (Lehr et al., 2007, p. 1470). The communicator of the science will be an expert in the field, who is prepared for public comment and public input into the content. The communicator will present the science openly, with acknowledgement of areas of doubt and uncertainty. After the science has been described and explained, the forum is organized for debate and discussion, with a synthesis of views at the end. Four goals have been identified for dialogue events. These are:

> (1) the promotion of collaborative talk; (2) the enhancement of equitable interactions; (3) the development of new or different understandings or knowledge; and (4) the enhancement of interest and engagement in controversial science-based issues in society (socioscientific issues) (McCallie (2007) cited in Lehr et al., 2007, p. 1475).

If the goals are realized, everyone understands the points of view raised and the different knowledges that have been brought to the table. The skills required of the communicator include those of explainer, facilitator, and moderator. The initial science presentation will need to have many of the elements described above, with additional factors required during the discussion which include acute listening skills. The aim is to share useful and transferable knowledge, and there is a direct learning goal attached to the outcomes. This mode still, however, retains aspects of ‘expert’ and ‘learner’ and the position of the presenter is generally more powerful than those of the participants. The successful communicator needs to know how to alleviate the perception that they hold the balance of knowledge (and inherently, the power) in this situation. It is important to take time to know the audience, to strive to increase their ownership by suiting the overall message to the community. In cases where there are cross-cultural considerations, it is important also to respect patterns of authority and cultural norms.

A café scientifique also falls into the category of communicating *with* the public. Structured in a similar way to a dialogue event, the atmosphere of a café scientifique is more informal and convivial.

> All combine two essential ingredients. First, they take place in an informal social setting – usually involving food and drink – that encourages participants to interact with each other. They are often held in pubs, restaurants and coffee shops, but may also take place in museums and science centers. Second, they build upon participants’ existing knowledge and satisfy their curiosity about a science-based topic through lively interaction with a scientist (Hall, Foutz, & Mayhew, 2013, p. 178).

The presenters in dialogue events and cafés scientifique are carefully primed about the importance of their communication style and content. Hall et al. (2013) state:

> The guidelines stress the importance of knowing and connecting to the audience. Our youth will readily engage with a presenter on some hot science topic if it is accessible to them… The presentation needs to be free of jargon and delivered in an engaging manner… We ask the presenters to *tell a story* organized around one essential provocative idea or concept, which we refer to as the *Most Important Thing* (p. 182, italics in the original).

This ‘most important thing’ includes “an unanswered question, a dilemma or a controversy” that stimulates discussion and critical thinking (p. 182). The use of props and demonstrations is encouraged. Thus D-type curiosity and interest are stimulated.

In summary, the key to communicating science *with* the public is not only to know and understand the audience and their values, but to allow for these values to be publicly aired and respected. The communication must still be structured so as to arouse interest and engagement, through a clear and simple narrative, with minimum jargon and with honest appraisal of the science being discussed. Skills as a moderator and facilitator assist in ensuring that the balance of power in the discussion is as even as possible.

Communicating Science Among *the Public*

Communicating science *among* the public brings more skills to bear. In this mode, which is the most interactive of the three, there is no sense of 'expert' and 'lay public'. Rather, the knowledge of *all* participants contributes to the building of new knowledge and understanding. This mode is always attached to real projects with tangible outcomes. The communicator of the science needs to understand the social and community context of the project and its essential holistic nature. An example of such a project might be to determine the best and most sustainable future for a community site which includes a nature park or a wetland. How will the community balance the local interests with the scientific imperatives for the area? In this case, all views must be respected and incorporated into the solution. Everyone must have ownership of the outcomes. The scientific communication must be located firmly in the community context and be understandable to all. Teamwork skills are thus exceptionally important. It is often the case that the science needs further inquiry and this may require community participation. The increasing number of citizen science projects falls into this category.

In summary, communicating science *among* the public requires a sound understanding of the project under discussion and the competing voices which seek to influence the outcomes. It requires the ability to work in a team, perhaps as the team coordinator, and the ability to see how the science will have impacts on different sections of the community. It requires dialogic skills and skills of management.

The Importance of Persuasion

In order to achieve effective engagement in these three modes of communication, the skills of science communication must confer on its practitioners the ability to switch between modes, to be knowledgeable about the audience, and to be engaging and persuasive. A remaining aspect not yet discussed, which is always present in informal learning activities, but not often acknowledged as such, is that of persuasion.

> People who must create feelings of interest – entertainers, teachers, writers, artists, magicians and beleaguered babysitters, to name a few – need to know how to manipulate the emotions of other people. This requires understanding the dynamics of emotional experience (Silvia, 2006. p. 31).

The notion of persuasion is one that many scientists reject as being irrelevant to their communication with the public, yet it is the foundation of successful communication—if we are not persuaded that information is important or relevant to us, then we are not going to be engaged at all. Even worse, we may actively reject the information.

Six principles of persuasion are generally recognized (Cialdini, 1984). Of these, several are relevant to communicating science in the informal domain. The first of these is Reciprocity. Translated into the world of science communication this means that when needing to talk to someone about an issue that is controversial, we need to find out what matters to that person rather than assume that their values are the same as ours. *Know the audience*. The second principle is Commitment. In this case, it is important to make the audience feel that we value their concerns—that we can identify with what is important to them. The third principle is Social Proof. People identify with what their peers do and say. Therefore, peers have great influence—the role model in school, for example, is a recognized factor in the formation of student attitudes. Fourth is Liking. This is clearly one which matters—one is unlikely to relate to someone one does not like. It is, however, hard to anticipate what is effective for the communicator of science in this regard. It is a multi-faceted aspect of communication, easy to control in marketing but much harder in communication of science. The factor of Authority is one which is less relevant to the communication of science and, in fact, may have caused problems in the past. The implicit assumption that the voice of Authority rests with scientists led to the Public Understanding of Science movement in the first place and to its subsequent rejection. Last, the principle of Scarcity translates to urgency—the need to provide solutions to problems because the problem is immediate and pressing. Climate change, clearly, is in this category. Climate change communication, however, has used the principle of urgency with limited success, in that there are perceptions that the public is to some degree exhausted with the message of impending planetary doom (Zeyer & Kelsey, 2013).

Skills for the Communication of Science

The skills required to communicate science in all informal learning contexts are of a hierarchical nature, according to three modes discussed above. The more the learning is shared and interactive, the greater its contextual nature. Recognition and consideration of the emotions of the learners is an aspect often overlooked, but vital to successful evocation of interest, curiosity and enjoyment. Successful communication rarely results from providing an experience in isolation. The experience must be contextualized, carefully and consciously structured, and sensitively facilitated if it is to result in meaningful learning.

Science communication courses teach these skills. The context of informal learning has a very broad application in science communication, from the notion of a more passive audience through to a fully participatory experience. In summary, these skills are:

- The ability to match the communication to the beliefs, values and knowledge of the audience.

- The ability to 'translate' and present the science in a clear, jargon-free narrative, incorporating all the principles of good communication.
- An understanding of how social contexts affect the learning of science, including the myriad cultural and psychological influences that affect people's perception of the science in their individual environments. The ability to modify and change the communication to match these changing contexts.
- An understanding of people's perception of risk.
- The ability to design effective science communication presentations, either through active personal delivery or through written, visual or aural media. This includes the ability to construct useful demonstrations of scientific ideas and principles.
- The ability to design and present modes of scientific communication appropriate for peers, funding bodies, and publics, including being able to demonstrate a capacity to communicate research results effectively to both scientific and non-technical audiences.
- Drawing on a range of scientific and other sources, the ability to compose clear, persuasive and contextualized arguments for a range of audiences.

Of all these, the first is the most critical.

> future investigations of science learning need to situate the learner at the center rather than the periphery of the learning process; as an active co-constructor, not merely a passive recipient. In order to meaningfully understand what learning is but even more importantly, why it happens, studies also should frame learning within the larger ecological context of an individual's life and the learning landscape in which he or she participates (Falk & Dierking, 2012, p. 1076).

Application of these skills in all science informal learning environments is central to successful learning outcomes. We would argue that they are not always recognized as important. In particular, they are not always made explicit in the delivery of conventional informal learning programs and not always central to evaluation of effectiveness. Whether the informal learning occurs at a zoo, on a field trip, at a museum, a community center or some other public venue, or whether it is through science on the Internet or the television, those who provide the experience need to be doing so from an informed, professional perspective which incorporates and exploits science communication skills.

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Chapter 27

Sense of Conservation: When Is a Black Rat Snake (*Elaphe obsolete*) Really Just a Snake?

Patricia G. Patrick

Conservation Education (CE) includes a broad range of teaching methods, conservation topics, and audiences, and various researchers and national and local entities each have put forth their own definitions (e.g. Jacobson, McDuff, & Monroe, 2006; Association of Fish and Wildlife Agencies, 2015; International Zoo Educators Association, 2015; United States Department of Agriculture Forest Service, 2015). For the purpose of this paper, I aggregate their definitions and my own ideas about CE to develop a suitable definition.

Conservation Education is the art of (1) imparting scientific knowledge about conserving ecosystems, natural resources, wildlife, and wild places, (2) developing the public's critical thinking skills about ecological problems, (3) encouraging people to connect to the natural world or the outdoors, and (4) acquiring knowledge about the public's understanding of ecosystems, ecological problems, natural resources, and the natural world, and the public's beliefs about their responsibility in conservation action. This definition has implications for conservation educators as they develop their epistemological and pedagogical views of sound teaching methods. Epistemologically, as conservation educators look to the future of their profession, they must consider their audiences and the knowledge the audiences have of nature and the term conservation. Pedagogically, when conservation educators develop their approaches to teaching the community about nature, educators should consider their personal beliefs and the community beliefs about conservation and how those beliefs influence their program design. This chapter addresses the notion of considering the knowledge of the audience as we develop conservation programs.

In order to address audience knowledge and the implications for teaching, in this chapter I incorporate a recent study on middle level students' (ages 11–14) knowledge of plants and animals, with concepts about conservation education, to make suggestions for conservation educators. The main objectives of the study

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were to (1) identify children's knowledge of biodiversity in their local environment, and (2) reveal their beliefs about who is responsible for the conservation of local species. These results will aid conservation educators in differentiating CE from other types of education and addressing the public's beliefs about conservation. My goal in this chapter is to provide practitioners with a view of children's knowledge about the local environment and the view children have of their role in conservation. In this chapter, I define three important aspects of understanding the community in which CE takes place: local knowledge of flora and fauna, source of knowledge, and personal culpability. I term these aspects of understanding the community Sense of Conservation.

Middle Level Students' Knowledge of Local Flora and Fauna

Introduction

Identifying children's ideas about who is responsible for conservation and their knowledge of local biodiversity, flora, and fauna, is of great concern, because children's conceptualizations of local biodiversity "carry with them into adulthood, determining their capacity to learn about and interact with their world" (Sorin & Gordon, 2010, p. 1). Moreover, the conceptualizations influence the ways in which children understand conservation issues and eventually steer their conservation attitudes and behaviors (Shepardson, Wee, Priddy, & Harbor, 2007). When children are able to conceptualize local biodiversity, they are more likely to be tied to the commitment of conservation stewardship (Padmanaba, Sheil, Basuki, & Liswanti, 2013; Ugulu, Aydin, Yorek, & Dogan, 2008). Many researchers believe that a loss of knowledge of the natural world is leading to a growing isolation of the public from its natural surroundings (Kellert & Wilson, 1993; Nabhan & Trimble, 1994; Louv, 2008). For this reason, conservationists need to reestablish the links between children and nature if they are to bridge the gap between children and their desire to conserve (Balmford, Clegg, Coulson, & Taylor, 2002).

Conservation educators may maximize the knowledge students have of flora and fauna by becoming more aware of the vocabulary students utilize when they name organisms. In support of identifying the vocabulary children utilize in science, Mercer, Dawes, Wegerif, and Sams (2004) have determined that "One link between the learning of science and the use of language is the development of a specialized vocabulary for representing concepts and describing processes" (p. 263). Moreover, the language used by children "provides a familiar medium through which a child can describe their conceptions of phenomena in order that teachers assess a level of understanding (Ollerenshaw & Ritchie, 1998)" (p. 263). Children base the language they apply when naming an organism on their prior knowledge and experiences and frame that language by their social interactions. When children identify a plant or animal, they construct an image, which assists them in applying a name to the organism. Prior information they glean from visual representations (Atran & Medin, 2008), culture, community, family, and friends, through personal encounters (Tunnicliffe, Gatt, Agius, & Pizzuto, 2008), influences their images of flora and fauna.

In order to define how children conceptualize local flora and fauna, I begin with the idea that laypeople and taxonomists do not discriminate between the characteristics of organisms in the same way. Laypeople do not have the prior experiences that taxonomists do; therefore, laypeople name organisms at a superficial level. Taxonomists possess a multilayered understanding of species and are able to further discriminate between the members of a group hierarchically using binomial nomenclature, a system established by Carl Linnaeus in the late eighteenth century. The two-word name assigned to each organism, for example, *Elaphe obsolete*, conveys to biologist information about the organism's anatomy, morphology, physiology, structures, behavior, and genetic connections. However, laypeople are unaware of the organism's scientific name and the biological information the name connotes. Laypeople do not understand the taxonomic characteristics undergirding the system, but they do recognize the elemental differences of animal groups, such as the differences between a bird and a frog. People may use a common or local name such as black rat snake, black snake, or rat snake, or may be able to identify the organism only at the level of snake. Possessing an ability to identify the characteristics of organisms is an important aspect of appreciating the organisms' physiological needs and their ecological importance; therefore, we must understand the divergent and nonscientific ways children construct their understandings of animals, ecology, and, ultimately, conservation. Establishment of the basic knowledge of what an animal is, including its features and needs, must occur before children are able to assimilate the ideas related to wildlife conservation, such as habitat needs, biodiversity, and the organism's place in the ecological web (Patrick & Tunnicliffe, 2013).

This leads to the question, "When is a black rat snake (*Elaphe obsoleta*) just a snake?" If a student possesses the knowledge to recognize the characteristics of a snake, do they need to possess the ability to recognize the snake as a black rat snake or *Elaphe obsoleta*? In a study with 11 year olds, Ryman (1974) found that students were not able to classify organisms into taxonomic groups, because they did not possess the language needed to identify organisms correctly. The lack of vocabulary required to name an organism becomes a predicament for practitioners. When students view a photograph of a snake and attempt to name the organism, they may not know the name black rat snake, but may be aware that the snake is a snake. If so, then identifying the ability of students to recognize that a snake is a snake will aid educators in teaching them that a particular snake is a black rat snake or, at the least, to value the organism as an important part of the ecosystem. The premise for defining the difference is that students may not know the name *Elaphe obsoleta* or black rat snake, but they may be aware that snakes live in the local forest. Therefore, the study briefly described below sought to determine if students were able to name local flora and fauna and identify who is responsible for conservation of the local organisms.

Study and Findings

This study took place in two schools in North Carolina, USA. North Carolina has three distinct physiographic regions: Appalachian Highlands, Piedmont, and Coastal Plain. This study took place in the Coastal Plain and the Piedmont. Even though the ecosystems in the Coastal Plain and Piedmont vary widely, they have one ecosystem in common, the mixed pine/hardwood forest. The middle level schools in this study were near a mixed pine/hardwood forest. I collected data from 398 students in 15 rural middle school art classes, and 307 students in 12 suburban middle school science classes. The 705 students were 11–14 year olds.

Prior to the project, the teachers involved and I determined six animals and six plants from the mixed pine/hardwood forest for students to identify. The teachers agreed that these animals were common in both communities and students should be able to identify these animals. The plants chosen occurred on both school campuses: azalea, American beech, American chestnut, dogwood, short-leaf pine, and white oak. The animals chosen that commonly inhabit both coastal and Piedmont communities were: black rat snake, eastern box turtle, red shoulder hawk, white-tailed deer, wild turkey, and raccoon.

During class, the art or science teacher gave students a data collection sheet with one column for animals and one for plants. Each column had the numbers one to six with a line next to each number. The teachers told the students they were going outside and naming different types of plants they would find in the local environment. Students were to try their best to name the plants, but, if they did not know the name, to leave the line blank. On the same day, upon returning to class, the teacher used a projector to show students pictures of the animals within the animal's habitat. Again, students were to record the data on their data sheets. When students completed the identifications, they were to explain how they knew about, or where they learned about, these organisms, and to tell who they thought was responsible for conserving the organism and its habitat.

Data Analysis and Results

Plants and animals named. I aggregated the data from the two schools for this chapter, and reported the findings with N = 705. No student identified the organisms by using the scientific or taxonomic name; therefore, I tallied results using a partial credit approach. For example, if a participant correctly provided the whole name short-leaf pine, they received a "1". However, if the participant correctly identified the tree as a "pine", they received a partial credit of "0.5". No answer, or an incorrect answer, received "0". Hence, the following data analysis was used: (1) short leaf pine = 1, pine = 0.5; (2) dogwood = 1; (3) azalea = 1; (4) American beech = 1, beech = 0.5; (5) American chestnut = 1, chestnut = 0.5; (6) white oak = 1, oak = 0.5; (7) white-tailed deer = 1, deer = 0.5; (8) turkey = 1; (9) raccoon = 1; (10) red shoulder hawk = 1, hawk = 0.5; (11) eastern box turtle or box turtle = 1, turtle = 0.5; and (12) black rat snake or black snake = 1, snake = 0.5. The terms acorn, animal, bird, bush, flower, plant, shrub, and tree did not score as data. Analyzing the data using a partial credit score allowed data collection without losing nonspecific answers.

Table 27.1 represents the findings of the study showing the data as 1, 0.5 or 0. Students identified the short-leaf pine most successfully of the plants. A total of 79% of students scored 1 or 0.5, successfully identifying the tree as a short-leaf pine (1 = 7%) or pine (0.5 = 72%). Students next most recognized the dogwood (1 = 52%), which is the state flower, and the azalea (1 = 46%). Students were not as familiar with the American beech and the American chestnut, as 97% of the students were unable to name these plants even at the level of beech (0.5 = 3%) and chestnut (0.5 = 4%).

However, the participants were more successful at identifying local animals from pictures. All participants successfully identified the black rat snake, eastern box turtle, and white-tailed deer at level 1 or 0.5. However, a closer look at the data showed that students named the black rat snake at level 1 (91%) more often than they named the eastern box turtle (12%) and white-tailed deer (13%) at level 1. The most commonly used name for the black rat snake was black snake. However, a look at the overall results shows that 100% of the students named the white-tailed deer and eastern box turtle. The most frequently used terms for these organisms was deer, box turtle, and turtle. Ninety-nine percent of the students named the raccoon and 75% successfully named the wild turkey. The red shoulder hawk was the most difficult animal for students to identify, as 73% were unable to provide a correct name, providing most often the term bird.

How/where students learned about the organism. I used open and axial coding (Lincoln, Lynham, & Guba, 2011), to code written responses to the open-ended question of how/where students learned about the organism, allowing me to determine any recurring themes in the answers. After reading the students' responses, I found four themes that reappeared throughout: 85% home/parents/friends, 31% informal learning sites (ILS) (camps, museums, natural areas, nature centers, parks, etc.), 29% media (books, internet, television, movies, pictures, etc.), and 7% school. Students communicated interactions with home/parents/friends as sources of information most often (85%). Of the 85% (n = 599) of students who mentioned this theme, 572 of those students depicted outdoor experiences. In the excerpt below, Mack (all names are pseudonyms) described encounters he shared with his father and grandfather while hunting.

> Every Saturday in the winter I go hunting with my daddy and my papa. We hunt deer so that is how I know about them. Sometimes when we are in the deer stand we see wild turkies [sic]. They are so cool and really afraid of noises. Sometimes we see hawks too. My papa says that he remembers when he was a kid he would see them all the time, but there are not many around now.

Table 27.1 Percentage of students who scored at 1, 0.5 or 0 when naming local plants and animals. N = 705

Azalea		Dogwood		American beech			American chestnut			Shortleaf pine			White oak		
1	0	1	0	1	0.5	0	1	0.5	0	1	0.5	0	1	0.5	0
46	54	52	48	0	1	99	0	1	99	7	72	21	8	26	66
Raccoon		Turkey (wild)		Black rat snake			Eastern box turtle			Red shoulder hawk			White-tailed deer		
99	1	75	25	91	9	0	12	88	0	3	24	73	13	87	0

Another interesting finding was that students described outdoor experiences in their yards. Tammy shared that she was

> not really sure where I learned about these. Sometimes we see raccoons in the yard at night. We are always going outside and we seeing stuff. We have azaleas and dogwoods in our yard and we pick the red things off the dogwood and throw them at each other.

Even though the majority of the experiences students expressed were positive, if they mentioned the black rat snake most of the comments were negative. In the excerpt below, Mike recalled an interaction with a black rat snake.

> OMG. I know about the black snake because we have one living in our yard. My mom wants to kill it all the time and my pipa says we shouldn't. My pipa says he kills rats and mices [sic]. My mom says that he kills her baby blue birds.

Twenty-nine percent of the students referred to informal learning sites, which included camps, museum experiences, encounters in parks, and play in nature. Betty reminisced about an eastern box turtle day at her local state park.

> We spent the whole morning at the park learning about box turtles. We learned about how to tell the differenc [sic] between a male and female and we learned about what they eat. They can train dogs to find them. It was really cool.

Moreover, Isabel remembered learning about a hawk when she was with her dad in a state park.

> We were hiking on this trail across a field and this big bird kind of swoped [sic] down. I told my Dad OMG I think he has something in his hand. He landed close to us and he had a mouse or something he caught. It looked like a mouse, but not sure what it was. My Dad said it was a hawk and I think that is what the bird in the picture is. A hawk.

Even though this response included an encounter with her father, Isabel's response also was coded as an informal learning site, because the encounter occurred in a state park. This answer was indicative of the types of happenstances students described in relation to informal learning sites.

In addition to families and informal learning sites, students much less often named media (22%) and school (9%). Based on my biased belief that children rely on the internet for information, I thought students would mention learning about the organisms from the internet. I was surprised to find that students mentioned children's books more often than other types of media. For example, Lillian stated that her favorite book growing up was the *The Kissing Hand*, about which she said, "it is about a raccoon who is afraid to go to school." Tommy said he read *Rocket Raccoon*, which is "a comic book with a raccoon on the cover and is about a raccoon." Furthermore, students mentioned other books such as *Bambi*; *Oh Dear, Said the Deer*; *Piñata in a Pine Tree*; *A Porcupine in a Pine Tree*; and *Clovis Crawfish and Bidon Box Turtle*. Students who mentioned school as a place where they learned about organisms, described outdoor interactions with nature. Ariana shared a time when her teacher took the class outside.

> My teacher took us outside one time and read the The Lorax to us. After she read the book she asked us to pick a tree. We had to get to know the tree. Like we had to hug it. My tree was a beech so I can always tell when I see a beech tree.

The multidimensional ways in which students learned about these organisms is important as practitioners define their pedagogical approaches to CE. The multi-purpose aspect of learning can be perplexing for practitioners wishing to develop CE programs that focus on local communities and shared community knowledge of the local flora and fauna. By not taking into account the shared community knowledge, CE programs and opportunities risk limiting their reach to those who already see conservation as important.

Who is responsible for saving the local forest? After the students identified the flora and fauna from their local forest, they were asked to state who they thought was responsible for saving the organisms and their habitat. Of the 705 students that participated in the study, 35% did not provide an answer or stated they did not know. The remaining 75% (n = 529) provided one or more of the following answers: self (34%), others (29%), environmentalist (24%), conservationist (23%), forest service (people who work in the forest, the people who plant the trees) (22%), and scientist (9%). To determine if we can use knowledge of local organisms in the local forest to predict participants' feelings of stewardship of the forest, I performed a binary logistic regression. The dependent variable, which measures the participant's identification of self as responsible for saving the ecosystem, I coded as "1", and "0" meaning they did not identify "self" as responsible. To get a total picture score, I added together the scores each participant received when identifying the plants on the school campus and the animals in photographs. I used the total picture score as the independent variable in the logistic regression. I used the logistic regression model to predict if knowledge of the local forest would influence student identification of self.

When the binary logistic regression determined that knowledge of the forest did not predict feelings of stewardship, I performed an independent samples t-test to determine if participants who identified "self" as responsible for saving the local forest had a higher picture score than participants who did not identify "self" as stewards. The independent samples t-test (t(705) = 8.55, p = 0.005) indicated that students who identified "self" (M = 6.52, SD = 1.81) as responsible for saving the local forest successfully identified statistically significantly more organisms than students who did not name "self" (M = 5.42, SD = 1.49). This produced a Cohen's d = 0.66 and $r = 0.31$ for the findings. This indicates a possible relationship between the ability to identify organisms and a personal identity with stewardship; however, this study does not show that students must be able to identify the organism at the species level to know the organism. In fact, students are aware of organisms (mostly animals) in their local community, but use a local common name to identify the organisms.

Discussion

Fundamentally, CE implies teaching and learning about conservation; however, as I stated at the beginning of the chapter, CE is much more. A more complex definition of CE should take into account the ability of the educator and the knowledge level of the learner.

The students' ability to name organisms is an indication of their knowledge of the biodiversity of the local ecosystem, and provides a look at their connectivity to the local environment (Campos et al., 2012; Pilgrim, Smith, & Pretty, 2007; Pilgrim, Cullen, Smith, & Pretty, 2008). In fact, students are most likely to name organisms with which they are familiar and with which they have had direct contact or experiences (Campos, et al., 2012; Lindemann-Matthies, 2005). Supporting this finding are students' descriptions of how they know the organisms. Students named and described how they knew animals more successfully than they described how they knew plants. This data supports previous findings that students are more familiar with animals than plants (Patrick & Tunnicliffe, 2011; Jensen, 2014; Wagoner & Jensen, 2010), but is in contrast to the findings of Campos et al. (2012), which found that students named plants more often. The results of the study described in this chapter indicate that students' knowledge of plants is developed less than their knowledge of animals, but they are familiar with plants as tree or shrub.

Students name home as a source for their information about plants/animals more than media, ILS, and schools, naming schools least often. Moreover, when students talk about where they learn about plants/animals, they describe interactions with their family and the animals they have at home. Ugulu and Ayden (2011) found that when they asked Turkish students about their knowledge of medicinal plants, 83% stated they learned it from their families. Therefore, learning about plants and animals appears to be tied to interactions at home. This finding is important in developing students' conservation consciousness because if parents are the primary source of plant/animal knowledge, then it is necessary for educators to include parents in conservation education. Students could develop misconceptions from parents, which means conservation educators must expose the misconceptions and address them. Students see family members as experts, which means educators need to establish ways in which they may bridge the environmental interactions students have at home with classroom and informal science education experiences.

Additional studies have found that people learn about plants/animals (Patrick & Tunnicliffe 2011; Patrick et al., 2013) and science (Falk & Dierking, 2010) and gain biological (Gelman, 2009) and environmental knowledge outside the classroom. Students identify informal learning institutions as a place to learn about animals, but do not consider them to be places to learn about plants. This may be because informal learning institutions normally do not spotlight plants or have plant programs. For example, people regard zoos as places to see animals, not as places to learn about plants. As conservation educators develop programs and activities to teach students about plants/animals, it is paramount that the educators include hands-on interactions such as gardening (Fančovičová & Prokop, 2010; Jones, Weitkamp, Kimberlee, Salmon, & Orme, 2012; Passey, Morris, & Reed, 2010), dissecting flowers, touching seeds, comparing real plant parts (not plastic), touching animal hides, feathers, etc., observing animals on the playground, observing animals in nature, and asking students to share their interactions with plants/animals. Additionally, educators could ask students to use GPS to mark the locations of plants, collect data about the plants, and share the data on a phone application (app).

CE is multifaceted and evolving, with current research focusing on the learner and their knowledge and social and cultural beliefs. The focus of CE is no longer on the cognitive gains, but on the affective and emotive experiences that may lead to attitude and behavior change. Therefore, conservation educators must consider the relationship between their teaching and conservation related behavior. They no longer can focus solely on whether or not someone is aware of the scientific name of an organism. People should be aware of organisms in their local community, understand the organism’s importance in the ecosystem, and feel a personal connection to the ecosystem. Conservation educators must take into account that the attitudes and relationships people develop with the local ecosystem are based not on the interactions people have with educators, but develop through the cultural and social interactions people have at home, as shown both in the study I described in this chapter and in previous research (Blatt & Patrick, 2014; Bogner, 2000; Bogner & Wiseman, 2004; Chawla, 1998; Eagles & Demare, 1999; Korhonen & Lappalainen, 2004; Palmer, Suggate, Bajd, & Tsaliki, 1998).

Sense of Conservation Based on Sense of Place

When a conservation educator develops a CE program, they must take into account the conservation related knowledge of the community. People form emotional bonds and are familiar with local places. Those local places include the ecosystems and organisms of the area. The bonds and familiarity that form between people and their local environments do not form because people know the scientific name of an organism. The bonds form with the local natural community because people have a sense of where they live through their emotional reaction to the environment and personal orientation (Hummon, 1992). In 1998, Williams and Stewart described five characteristics of Sense of Place that should be considered when discussing ecosystem management. Williams and Stewart’s characteristics of Sense of Place relate to the importance of CE. Below, I rewrite the characteristics and correlate them with the notion that people have emotional bonds and strongly felt beliefs about local nature that influence the value they place on conservation. I term the knowledge and opinions people have about the local environment Sense of Conservation and define them in the following way:

- the emotional bonds that people form with the local environment and their familiarity with the local organisms
- the strongly felt values, meanings, and symbols that people place on the local environment
- the knowledge people have about conserving the local ecosystems, natural resources, wildlife, and wild places
- the value people place on the local outdoors
- qualities of a place people believe they are responsible for conserving, but an “outsider” may not consciously be aware of the beliefs
- the set of conservation meanings actively and continuously constructed and reconstructed within the individual minds, shared cultures, and social practices of a community
- the awareness of the cultural, historical, and spatial context within which meanings, values, and social interactions form

People develop a Sense of Conservation because they have had interactions with the local environment and have specific beliefs about the organisms within the environment. The beliefs people hold about their local environment and organisms form their Sense of Conservation. A Sense of Conservation is an individual belief and is built on prior experiences in nature (Blatt & Patrick, 2014) and, as shown in this study, with interactions with others. The interactions that inform our beliefs about conservation are from local myths or fictional stories, family histories, moral tales, and media that take place within the cultural context of the community. People learn to connect themselves to the environment through family stories, beliefs, and one-on-one interactions. The images people collect about their local environment lead to their Sense of Conservation.

Implications

This chapter describes a look at the knowledge middle level students have of the local environment in order to clarify the importance of understanding the knowledge people have prior to developing programs. The knowledge people have of the local environment and their relationship with local organisms are a part of their Sense of Conservation and may not be separated from conservation action. By taking into account the knowledge people have of local organisms, the conservation educator may develop a better understanding of the conservation meaning that people place on the local environment. Building a relationship between people and conservation practices that will preserve their local environment and organisms is difficult and will take a well-developed understanding of people and their knowledge, feelings, and interactions with the environment.

Conservation educators must be conscious of the public's knowledge of organisms and take that knowledge into consideration in the design and implementation of programs. Conservation educators should contemplate their practice by asking themselves the following questions:

- What do I know about the local community?
- What do I know about the Sense of Conservation held by the community as it relates to their knowledge of local organisms?
- How does the community identify with the local environment?
- In what ways do people in the community interact with the local environment?
- How will my program intersect with the individual's Sense of Conservation?
- How will my program aid people in constructing knowledge based on their current knowledge?

By examining, evaluating, comparing, and contrasting the knowledge people have of their local flora and fauna, conservation educators will be capable of linking their epistemological assumptions about learning to the pedagogical beliefs and practices that drive their teaching. Strong pedagogical practices will better develop the conservation awareness of the community. Some strategies that could be employed are:

- Connect people to their local environments by using local terminology for flora and fauna. In addition to community programs, this connection should occur within the home and neighborhood and in children's play places such as parks, playgrounds, and personally constructed areas like forts and treehouses.
- Study the ways in which people understand local nature and conservation. Conservation educators should promote conversations with people to make sense of their ideas about local nature and conservation. Even though people may not know the scientific names of the flora and fauna, they are aware of organisms in the local ecosystems. Their knowledge of organisms could be a catalyst for fostering conservation related activities and awareness.
- Include local natural areas to aid in construction of knowledge. Take people camping or on walks in the local environment. Along the way, have people share their personal stories about their knowledge of the natural environment.
- Begin connecting people with the local environment and building conservation awareness at the primary level (children ages 0–5). By working with primary age children, conservation educators will be able to develop early conservation connections that may carry into adulthood.
- Utilize social media as a means to connect people to the local environment and conservation efforts.

Fundamentally, all conservation efforts depend on the understanding and awareness people have of the need for conservation. We consider conservation programs successful if they take into consideration the audience, focus the program on audience knowledge, and collect measurable results that show positive outcomes. Moreover, conservation educators must recognize their epistemological beliefs about the knowledge level of their audience and consider that the perspectives of the audience may not align with the educator's knowledge level. Conservation programs are responsible for ensuring community awareness, while taking into account the individuals in the community as well as the community as a whole. Every person in the community has a role to play in local conservation and generating and creating an awareness of local opportunities to implement conservation practices.

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Chapter 28
Opening up the Dialogic Space. Using Questions to Facilitate Deeper Informal Learning

Martin Braund and Anthony Lelliott

> It is not that I'm so smart. But I stay with the questions much longer.
>
> —Albert Einstein

To help "stay with the questions", required Einstein to be engaged by each question in the first place. It is often thought that the good school teacher is a good questioner and listener. Asking the right question at the right time and responding to what learners say is a key skill that teachers learn in training and practice time and time again as their careers develop. Good questions open up a 'dialogic space' in which productive learning flourishes. But what about facilitating learning in places such as museums and other contexts in which learning can be said to be informal? What can educators in this sector (the informal) learn from research and practice in schools and other places that will improve learning experiences using questioning and make them more satisfying and challenging?

The aim of this chapter is to provide anyone working with visitors to informal learning settings with knowledge and ideas to help provide high quality learning experiences through better social interactions using questioning. Questions can be among learners and between learners, and (in the case of younger visitors) any number of adults. Good questions come from listening to provide further points in dialogue that challenge thinking and promote deeper learning. In informal spaces such as museums and galleries the challenge, for people not trained and experienced as teachers, is often to interact without reproducing the formalities of the classroom. Providing worksheets of closed questions can deaden the experience and excitement and limit meaningful free exploration. What is needed are careful strategies, sympathetic to informal learning environments, but capable of stimulating the sort of 'breakthrough behaviours' that lead to deeper engagement.

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In this chapter we discuss research on what makes questioning most productive and how this can be applied to informal settings. Several examples, used in museums, galleries and other places to help museum staff, docents, volunteers and teaching assistants interact with learners are shown and discussed. We conclude the chapter by discussing what can be achieved through training and collaboration with educators in the formal sector.

What Do We Know About Questioning?

Several researchers have stressed the importance of sociocultural aspects of learning science in informal contexts (e.g. Allen, 1997; Dierking, Falk, Rennie, Anderson, & Ellenbogen, 2003; Falk & Dierking, 2000). Sociocultural theory suggests that visitors engaging in conversation with each other and with museum educators enhance their learning experiences (Leinhardt, Crowley, & Knutson, 2002). There is considerable evidence from research that informal science educators could benefit from facilitation techniques that improve learning experiences of visitors to informal learning settings. For example, in a study of 30 school groups visiting museums in California, Cox-Petersen, Marsh, Kisiel, and Melber (2003) found that, while 35% of the educators started tours with thought-provoking open-ended questions, they did not revisit such questions later in the tour. Tal and Morag (2007), researching in four museums in Israel, found that 80% of the questions asked by guides were concerned with low-order thinking skills, confirming (in their view) Hein's assertion that museums hold a knowledge-transmission model of learning (Hein, 1998). Similar results have been found by Camhi (2008), analysing communication by guides at 35 sites in three countries. Tran (2007), looking at museums as teaching environments, found that, "the instructional modes and pedagogy of formal contexts were inadvertently, or even deliberately, transplanted into classroom-style programs in museums" (p. 292), including questioning strategies. Although of limited scope, these studies suggest there is considerable opportunity for informal science educators to improve their facilitation skills using questioning when interacting with visitors.

Questioning Strategies in Formal Classrooms

It is well known that getting learners talking in classrooms helps develop their thinking about the subject being learned. Studies in the 1970s and 1980s suggested that the dominant discourse in many classrooms was an Initiation-Response-Evaluation/Feedback (IRE/F) exchange (e.g. Sinclair & Coulthard, 1975). In this structure, sometimes referred to as 'triadic', the teacher asks a question (I) to which the learner responds (R) and the teacher then listens and provides an evaluation of the response (E) and may offer feedback (F). This structure has been found to have both positive and negative consequences. Although it means that learners are contributing to classroom talk, the nature of interaction often means that teachers ask questions to which they already know the answers. It has been found that these ‘funnelling’ questions result in limited learner engagement (Edwards & Mercer, 1987). Consequently, a shift from the dominant IRE/F, triadic structure is called for to promote better learner enquiry. This shift has been towards a more ‘conversation-like’ discourse in classrooms which, although challenging to execute (Brodie, 2007), results in ‘authentic questions’ and ‘interactive discourse’ between the teacher and learners (Nystrand, Gamoran, Kachur, & Prendergast, 1997). Nystrand and colleagues suggest using ‘authentic questions’ meaning that teachers ask ‘real’ questions to which they do not know the answer, thus authorising and endorsing learners’ ideas. Interactive discourse (sometimes called ‘dialogic’ as opposed to ‘triadic’) consists of closed chains of interaction of the type I-R-P-R-P-R … E (where P is a prompt by the teacher to generate a further response). Alternatively, there can be chains with no final evaluations, referred to as open chains (Mortimer & Scott, 2003). Examples of this type of interactive discourse in informal settings and their benefits are discussed later.

Scaffolding

A number of researchers have worked with the notion of ‘scaffolding’ in the classroom, whereby the teacher provides a temporary support for a learner which can be gradually removed as the learner internalises a concept. The idea of scaffolding is often linked with the work of Russian psychologist Lev Vygotsky, who believed that learners should be brought closer to the ideas the teacher is trying to put over by an amount of effort that is challenging, but not so great that the learner is perplexed and just gives up (Vygotsky, 1980). Scaffolding in an informal setting is a way to engage learners and prevent them just “wandering off” to a different activity.

Brush and Saye (2002) distinguished between ‘hard’ scaffolding, in which the support is incorporated into a task which is planned in advance, and ‘soft’ scaffolding where the teacher provides assistance in the form of questioning related to the lesson context and progress. Worksheets, such as those discussed in the following section, can be thought of as a form of hard scaffolding, while oral questioning by an informal educator that takes place in a museum can (if executed appropriately) take the form of soft scaffolding. Other types of scaffolding in informal contexts have been discussed by Yoon, Elinich, Wang, Van Schooneveld, and Anderson (2013) who found that digital augmentations, posted questions, and collaboration within groups assisted middle school students to improve their conceptual learning.

Cooperative and Collaborative Learning

According to studies on the effects of different learning strategies, cooperative or collaborative learning has an advantage, over individualised activities, equivalent to at least two examination grades (Hattie, 2013). In terms of learning theories on the acquisition of knowledge, cooperative and collaborative learning have an advantage over individualised methods because they allow for the construction of what Bruffee calls 'non-foundational knowledge' (Bruffee, 1995). Bruffee defines non-foundational knowledge as that which is derived through reasoning and questioning rather than by relying on teacher exposition and rote memory. These examples of social learning are effective because they shift responsibility away from the teacher as expert to the student as learner.

Cooperative and collaborative learning are at the heart of constructivist approaches but are not quite the same thing. In cooperative learning there is a specific goal, requiring all members of a group or team to work together to achieve that goal. An example in the museum setting is the building of an arched bridge (see later), where members of the group decide what blocks to place and where, and then how to build and test the bridge they built. In schools, cooperative learning tasks are thought of as being relatively structured and under direct teacher control. This is not so much the case in a museum setting because the nature of an exhibit and the suggested interaction provides the structure that a teacher would otherwise supply. In an interactive gallery or science museum there is an additional layer of independence as groups can travel around choosing what tasks they will engage in and for how long they will interact.

In collaborative learning, as opposed to cooperative methods, tasks are open-ended and outcomes more extensive. In a museum setting, groups might be set the task of discovering as much as they can about types, history, purposes and construction methods of different bridges. The outcomes might require decisions on what exhibits and data to collect, the most salient findings and how to present what has been learned to a larger group of peers. Collaborative learning projects ideally involve activities before, during and after a museum visit, thereby cementing the relationship between museum and school.

Classroom research shows that dialogue, in which a teacher and learners explore ideas together and ask genuine questions, supports the construction of meaning (Mortimer and Scott, 2003; Nystrand et al. 1997). This sort of dialogic, conversational co-learning, rather than the triadic IRE/F style commonly found in schools and discussed earlier, is at the heart of successful co-operative and collaborative learning. A study comparing the amount of triadic-IRE/F and dialogic talk that occurred in classrooms and on museum visits found that the same teachers used more dialogic talk and open-ended questioning on the museum visit than they did in their classrooms in preparation or follow-up work (DeWitt & Hohenstein, 2010). The same research study found that learners are much more likely to volunteer information and take turns in discussion in the museum setting. To illustrate this point there follows an example of non-triadic, dialogic discourse from DeWitt and

Hohenstein's study in which a teacher and two students are looking at a transparent model of a human, with various structures inside:

Sam: I was watching this program—10 o'clock news. And this woman, she was having brain surgery—!

Mr. Prichard: Yes?

Sam: And then they put this, like battery in, like, under her arm or something. So they could, like, they put these things around her brain. And put this battery thing there *(pointing to model)*

Mr. Prichard: Under her skin there? *(Pointing to himself, near his shoulder)*

Max: Yeah. What is that there for? *(Pointing to something else on the model)*

Mr. Prichard: It's to control the heart—It's called a pacemaker. So it could be—it could have some electrodes up in the brain.

Max: Yeah. See it?

Sam: Yeah. (DeWitt & Hohenstein, 2010, p. 462)

Here, Sam recalls something he has seen on television, and initiates the conversation. The teacher shows interest, and provides the answer to something the two boys see in the exhibit. The importance of the exchange is that the plastic model sparked interest in the boys, who led the interaction, instead of the teacher (as normally happens in school classrooms).

In a study at botanic gardens in England, Zhai and Dillon found examples of professional educators using prompts and open-ended questions such as; "What do you think?", "What did you see there?" and "How much do you agree?" These sorts of questions, "opened up the floor for students to contribute to the discussion and … [engaged] them in connecting their ideas with previous experiences" (Zhai & Dillon, 2014, p. 420). From these studies it seems that museums offer the potential for enhanced collaborative and balanced discourse where learners have more of a proactive role than they might otherwise have in school classrooms.

In the next section we offer examples where concepts of conversational discourse and authentic questions might be used to stimulate high quality and challenging learning experiences in informal settings.

Opening up the Dialogic Space—Some Examples from Practice

Examples using questions are shown for four areas of common learning activity in informal education. The first concerns text at exhibits, the second and third concern dialogues with and about artefacts and interactive exhibits or 'plores'. The fourth area looks, more generally, at the use of worksheets.

What's in a Label?

Places involved with informal learning expend a great deal of design effort on getting labels right. Text font type, and the size, colour, positioning and background of text are all important. But how much do we know about the quality of text, particularly about adding questions, in terms of educational outcomes?

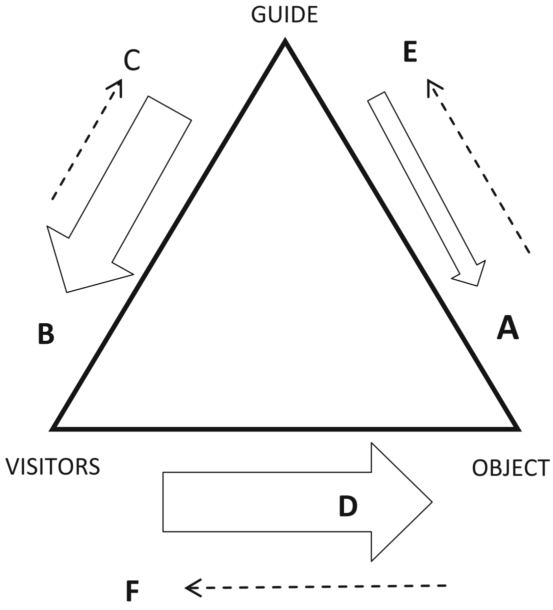
In one of the few research studies to have been carried out in this area, Hohenstein and Tran (2007) studied the effect of simplifying the text on exhibit labels and of adding a simple, open question, "why is this here?" They analysed visitors' conversations, including how many explanations and open-ended questions were raised. Hohenstein and Tran found that simplifying text had some impact but that just adding a question, even when the label text was still very dense, had a more dramatic effect. This was especially marked where exhibits included moving mechanical parts (a model of a steam-driven, 19th century workshop) or where the exhibit was about mechanics or mechanical movement (a sectioned motorcar). At a third exhibit, about the effects of nuclear bombs dropped on Japan on sand and made objects like ceramics, there was less of an effect from either simplifying text or adding the question. The authors postulate that, just because there were fewer explicit questions and explanations recorded at this exhibit, this does not mean that visitors were not engaging, emotionally or in more tacit ways. This reminds us that exhibits (and their labels including questions) may provide good stimuli for thinking, but that outcomes are not always easy to see and judge.

Dialogue with Artefacts

In most informal learning spaces natural or made artefacts or objects with specific scientific, historical and cultural value (such as fossils, paintings, ceramics, coins and so on) often form a focus for visitor learning. It might be expected that the visitor, as learner, will gain new information, knowledge, insights or beliefs about artefacts or how they fit within an environment or a story, such as in the production of steel or the interrelationships of animals and plants in a certain habitat. Here, the job of the museum educator is to scaffold and steer dialogue using questions about artefacts in directions that help learners think and make connections in new ways.

In an extensive study of hundreds of interactions with artefacts at several informal sites in different countries, Camhi (2008) analysed types of questions used by people guiding tours to communicate about artefacts. Camhi sees a triangular relationship between guide, visitor and object, summarised in Fig. 28.1. In pathway A the guide may "speak to the object" directly or through a third party such as a puppet or "become the object", so helping learners into a personal space for interaction. In pathway B, which Camhi found was the most commonly used (occupying 90% of all interactions), the guide explains the object to the visitors. Camhi found the problem was that communication along this pathway was often

Fig. 28.1 Six pathways of communication or information flow between the guide, the visitors and the object. The *width of arrows* show the relative amounts these pathways were used in Camhi's study (adapted from Camhi, 2008, p. 276)



quite didactic using mainly closed questions. More enlightened guides tended to use questions about the object to offer thought-provoking dialogue. Pathway C, in which visitors ask the guide questions about the project, was almost non-existent in Camhi's study, but in pathway D visitors are commonly asked to interact with an object to discover more about its structure or speculate about its history and interconnectedness with other artefacts.

An example of enhancement of interaction and engagement along the most commonly used of Camhi's pathways, B and D, is to use a type of questioning that has been a mainstay of museum education for almost a century. 'The object lesson' was established as a paradigm of museum education in the early 20th century (Hooper-Greenhill, 1991). Learners were allowed to touch and often told to describe and draw a range of unusual specimens and objects, often to enhance the curriculum areas of nature study, art and English.

Looking at objects in glass cases might raise questions about them, but sight is a rather distant sense and does not open up possibilities that handling provides. Handling should stimulate questions and speculation, e.g. about where the object came from, what it is composed of, how it relates to other objects or to the environment. Figure 28.2 shows how lines of questioning about an object, in this case a fossil ammonite, might be developed.

Handling invites the learner to explore with a degree of freedom using a number of senses. Handling enables 'holistic learning', which Hooper-Greenhill sees as, 'to know things in relation, to understand how parts relate to the whole' (Hooper-Greenhill, 1991 p. 102). In this way the fossil ammonite in Fig. 28.2 is

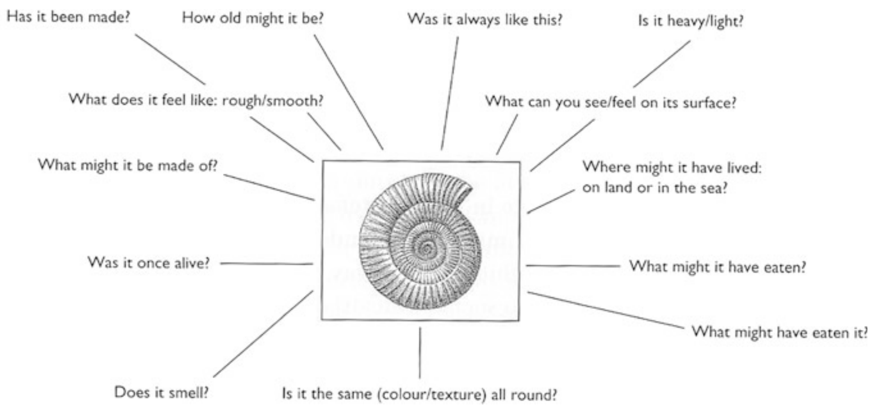


Fig. 28.2 Questioning objects and specimens (from Braund, 2004, p. 120)

questioned in terms of its possible relationship to other animals and plants, to the environment in which it lived and to the processes through which it was fossilised. In some museums there may be opportunities to handle and question specimens through macroscopic and microscopic observation within a sequence explaining a much more complex system, such as evolution of life on Earth. Object handling and questioning thus contribute to a more holistic learning experience where the 'object lesson' plays a part in a larger experience of learning about evolution.

Sight is a dominant human sense and, of course, for some learners it may be impaired. Removing it and challenging learners to guess or work out what an object might be is often a worthwhile experience. A common task is for learners to work out what objects might be from touch or smell. At the Eureka museum in Halifax, England, visitors are encouraged to feel the shape, texture and temperature of common kitchen utensils placed inside kitchen drawers. In some interpretative centres learners might be asked to lift a flap and to feel the skin of an animal and work out what it might be without being able to see it.

Questions and Challenges at Interactive Exhibits or 'Plores'

'Plores' are what psychologist Richard Gregory called interactive exhibits in the many hands-on science galleries and museums emerging in the late 1960s and early 1970s. Like Frank Oppenheimer, regarded as the founder of modern science museums (Oppenheimer opened the first hands-on museum in San Francisco in 1969), Gregory realised the potential power of 'plores' to challenge perceptions and expand learners' horizons (Gregory, 2013). Oppenheimer devised a 'cookbook' of plores that have become the staple of most science museums and galleries, a well-known example being the arched bridge (Fig. 28.3). At this exhibit learners are asked to assemble blocks of various sizes in the correct sequence to make a bridge strong enough to hold a person walking across it.

Fig. 28.3 The arched bridge at the Science Museum, London

Most visitors eventually interact successfully with this exhibit, but what they get out of the activity can be made much more challenging and satisfying by asking a few simple questions that widen and deepen the experience (Braund, 2000). Examples of questions that might be asked are:

- How many blocks are there? Does it matter where each one goes?
- Can you build a bridge without using the supports on each side (the large, wedge-shaped objects on each side of the bridge in Fig. 28.3). For example this could be done by two visitors substituting their own body masses for the supports.
- What makes the bridge stay up on its own?
- Is the bridge as strong wherever you stand on it? How can you tell?

As part of the activity learners could be challenged to work as a team, for example to build a bridge as quickly as they can without supports. These types of challenges are at the heart of problem-solving involving collaborative learning. Many other activities in informal spaces could be turned into more engaging tasks by using questions that provide challenges and stimulate thinking.

Worksheets

When school classes visit a place of informal learning they often use worksheets designed either by the museum itself or by the participating teacher. Although worksheets have been accused of replicating the formal learning of the classroom within an informal setting, there are ways in which they can be designed in order to enhance free-choice experience in informal contexts.

Kisiel (2003) identified six characteristics of worksheets that might allow a teacher to adopt a "concept agenda" (Falk, Moussouri, & Coulson, 1998) where the learners see less of the museum, but clarify a particular concept. This is in contrast to a "survey agenda" in which learners see most of the exhibits in the museum but they are rushing from one to the next. Concept-oriented worksheets would contain higher-order cognitive questions to allow for exploration of the informal environment, as well as object-dependent questions (so that students do not just obtain answers from exhibit labels), and questions encouraging them to discuss the answers with each other. Examples from an action research study at a zoo demonstrate how worksheet questions can be worded to encourage activity (a), choice on the part of the student (b) and collaboration and group discussion (c):

(a) How much taller is the Polar Bear than you? Give your answer in centimetres
(b) Now find an animal that you think is interesting or unusual. Describe one physical adaptation and one behavioural adaptation for this animal.
(c) In your group come up with a catchy slogan that the zoo could use on their information boards to educate the public about the plight of this animal (Dick, 2014).

These are examples of the ways in which worksheet questions play the part of 'hard scaffolding', discussed previously, as well as being concept-oriented. We also show an example of 'soft scaffolding', taken from a study by Nyamupangedengu and Lelliott (2012) which took place in a biology exhibition. In the extract below interactions are shown between school learners (L1), with the exhibits attended by university learners who acted as Explainers (E). The school learners were answering questions on a worksheet used to structure their visit.

At an exhibit stand about recycling, the following conversation took place:

L1: Is this the recycling session?
E: Yes it is
L1: Why do we recycle? (*worksheet question*)
E: You tell me. Why do we recycle? [*E throws the question back to the learners—a prompt*]

A discussion then followed between the learners and the explainer

L1: Because to save the environment
E: How do you save the environment by recycling? [*E probes the learner further, an example of soft scaffolding*]
L1: Because, like if you don't; OK it's like, I don't know how to explain, its pollution right OK, OK, you can explain [*L1 tries to explain but fails and passes over to L2*]
L2: You can save the planet by re-using bottles and you can re-use the leftover food as manure for your garden. You can stop polluting the seas; yah. [*L2 explains*] (Nyamupangedengu & Lelliott, 2012, pp. 92–93).

In this case the explainer did not give a direct answer to the learner who read out the worksheet question, but instead used soft scaffolding to prompt L1 to expand on her first utterance. Although she found it difficult to explain what the learners had discussed together, L2 completed the answer with a lengthier explanation. The sequence continued with the explainer providing further prompts as well as some didactic feedback.

In another extract from the same study, a different explainer assists learners at the Earthworm Exhibit. The teacher (T) also interjects.

L3: This question says: How do earthworms improve our soil? (Worksheet Question)
L1: That's where we are going now. Hullo. Can we ask you a few questions? How do earthworms improve our soil? (*worksheet question*)
E: Do you know what earthworms do when they go along
L(s): No [*Answering a question*]
E: No. Have you ever seen earthworms before?
L(s): Yah.
E: You know earthworms?
L(s): Yah.
T: Let me see [*The earthworms were under the soil and could not be seen*]
E: [*Lifts up a handful of soil with earthworms*]
L: Oooh it's disgusting! [*Displeasure*]
E: What's disgusting about it?
L: It's just that—[*sentence not completed*]
E: [*The exhibitor continues*] As they go along they make tunnels in the soil
L1: [*in low voice*]—Burrow in soil leaving tunnels [*Knowledge connection*] (Nyamupangedengu, 2010, p. 100).

Again, the explainer did not directly address learners' questions from the worksheet but, like a good teacher might, asked, "Do you know what earthworms do when they go along?" In this way the explainer tries to get the learners to answer the question themselves, although he also provides some didactic feedback, such as, "As they go along they make tunnels in the soil".

Soft scaffolding is a key skill that can be developed by educators in informal contexts. The most important issue is to take the visitor's question, and try and give her the skills to answer it herself, by prompting her to give further answers. If carried out successfully, the visitor can be led to the answer in a supportive manner, and yet the visitor herself has done most of the talking.

Conclusions: What Can Be Done to Improve Questioning Techniques in Informal Settings?

Science museums and hands-on galleries are increasingly popular places to visit. For example, each year record numbers of young people visit the science museum in London, coming from schools, youth clubs, scouts and other groups. Part of the appeal of the big national museums in London is the quality of what is on offer educationally. Since the publication of the Anderson report (Anderson/*A Common Wealth*, 1997), which criticised the quality of educational provision in the UK, the already very advanced design of exhibits and galleries and the extensive advice and assistance for accompanying adults have been further improved. These improvements have been made possible by extensive research of specific actions in museums as well as of best practice and findings of classroom research, some of which have been reported in this chapter. In Europe, the ICOM (International Council of Museums) has drawn up a set of, 'Curricula Guidelines for Museum Professional Development' (see: http://museumstudies.si.edu/ICOM-ICTOP/comp.htm). The guidelines detail what areas of knowledge and skills are needed by museum professionals. One of these areas, 'Public programming competencies: Knowledge of and skills in serving the museum's communities' stresses the importance of theoretical knowledge in communication, psychology and learning theory. Additionally, in the U.S., the National Research Council issued a report calling for an assessment of learning in informal environments, crucial for achieving and evaluating the museums' institutional goals but that also builds on relevant research (Bell, Lewenstein, Shouse & Feder, 2009). Bearing in mind the international consensus for improved knowledge of educational theory in these reports, we have shown in this chapter some of the research findings that should make communication more effective through improved questioning techniques.

Of course big national museums, like those in London, have an economy of scale and good research is affordable and available. Smaller institutions and one-off events often rely on volunteers and local goodwill. But in these situations it is still crucial and possible to plan for effective delivery of educational objectives that draw on best practice. For example, one of us had experience as a member of a local teacher advisory team which fundamentally improved success of a museum project. Previously, an exhibition on Earth and Space for primary school learners, at a small city museum, relied on lectures and slide shows delivered by university scholars. Teachers had complained that much of the material, though well presented, was above their learners' heads. The teacher advisory team changed the nature of the exhibition by introducing tasks that questioned and challenged learners at different stations around the museum, each staffed by teachers. The result was a throughput of 4,000 learners over a period of four weeks with high praise for the quality of educational outcomes and no complaints from teachers.

Relying on local educational expertise within or beyond the museum to improve questioning technique can be at an even smaller scale. For example, one of us, used experienced classroom teachers to listen to questions asked by museum docents at an archaeological museum event on building technologies. Most questions used by the docents were closed and directed at giving information, so the teachers used peer coaching at specific exhibits to show how questions could be improved to make them more challenging and productive. Whatever sources of training and support are available, it is important to realise that those who work in museums, staff and volunteers alike, should not be left in the dark when it comes to developing the expertise needed to raise standards of educational provision through improved communication.

> Education should meet the needs of present day society in all sectors and museums are an important piece of the global social mosaic. Museums have to aim at unlocking the full potential of stored knowledge and collective memory held in their collections in order to contribute to the sustainable development of their respective communities (Legget, 2011, p. 15).

We believe it is the responsibility of museums as institutions and employers to ensure that these aims are achievable. This can only come from a wider collaboration for research and training between educational practitioners in schools, universities and support services and those who work in the museum sector. It is important, given that institutions involved in formal science education do not always rely on interactive methods, to ensure that professional pedagogical practices resulting from such collaborations do not replicate the teaching methods and portrayals of science and scientists that have turned many young people against the subject. Keeping dialogue and questioning open and interactive should help secure positive outcomes for both formal and informal sectors.

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Part VI
Conclusion

Chapter 29
The Need and Timeliness of Preparing Informal Science Educators

Joy Kubarek

The National Academy of Sciences' seminal piece on learning science in informal settings, *Learning Science in Informal Environments: People, Places, and Pursuits* (National Research Council, NRC, 2009), laid the foundation for an evolution in the profession of informal science education. The report validated the importance of learning science outside of the traditional school setting and provided a voice for the work of informal science educators. Indeed, people only spend about 5% of their lives learning in the traditional school setting, leaving a massive opportunity to extend and enhance their learning beyond the classroom (Falk & Dierking, 2010). As the book calls out, "the responsibility, and even onus, of providing an education in science is no longer the exclusive preserve of the formal sector, but is more explicitly shared with resources in the community (NRC, 2009)." The range of informal science settings has also grown and diversified. A 2004 survey conducted by the Center for Informal Learning and Schools (CILS), identified 2,500 Informal Science Institutions (ISIs) in the United States alone, including museums, zoos, aquaria, and science and nature centers. Yes, learning science outside of school still occurs in these designed settings, but now there is a rise in learning science online, through television and through social science gatherings, such as science pubs and more. However, despite the report from the National Academy of Sciences, the professionals categorized as informal science educators continue to face pressure to make their work more systematic, to professionalize it, and to demonstrate impact through more robust, and valid, measures of education outcomes.

The role of the informal science educator was first conceived around the early part of the twentieth century and at this point in time it was primarily classroom teachers who were hired as ISI educators during the summer months (Hein, 2006).

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At this time, their role was more so that of an interpreter, sharing knowledge with visitors. Eventually this role would evolve and draw upon individuals from specific science disciplines as well as those with experience in traditional classrooms. This blended approach provided not only content knowledge, but knowledge of how to engage visitors and facilitate learning. In more recent years, museum studies programs have been established and a new breed of informal science educator has joined the workforce, those with more formal training in the work of museums though there is some contention over how well this serves the purpose of museum education as opposed to broader administrative responsibilities such as curatorship and conservation of objects (Tran, 2006, 2008). Most studies on the work of informal science educators portray them as a diverse group of individuals—some have formal and/or informal education experience, science and non-science degrees, education and non-education degrees and novices to advanced professionals (Astor-Jack, Bacerzak, & McCallie, 2007; Bailey, 2006; Dragotto, Minerva, & Nichols, 2006; Tran, 2008). This diversity of backgrounds may be advantageous for teaching an equally diverse range of visitors and program participants at ISIs. However, it can also be problematic as Tran (2008) indicates this lack of a shared professional experience has led to the lack of a shared language, differing perspectives on their roles as educators and perhaps most concerning, differences in pedagogy. For example, some informal science educators take on the role of facilitator, guiding learners through the process, tapping into their prior knowledge and interests and focusing on a more student-centered approach whereas others tend to be didactic in their approach, transferring their knowledge to the learner and missing opportunity to make relevant connections (Cox-Peterson, Marsh, Kisiel, & Melber, 2003; Flexer & Borun, 1984; Helling, Madgiarz, Long, Laughlin, & Kasscahu, 2008; Schatz, 2008; Tal & Morag, 2007; Tran, 2002). This variability in instruction may also be rooted in the lack of ongoing, shared professional training and education (Castle, 2006; Tran, 2002; Tran & King, 2007).

This handbook on preparing informal science educators addresses the need for formalizing the work of these professionals and is timely as it is right at the crux of the evolving nature and recognition of informal science education. The compilation of chapters takes the reader on a journey through informal science education, beginning at its roots including the current discussion of how to define it, branching out to specific approaches to designing programs, professional development of informal science educators and engaging in reflective practice, and finally opening up to the future of science communication as an extension of informal science education. The chapters have been written by many who are experienced in both the research and practice of informal science education, providing not only empirically supported work, but also legitimacy in understanding the context of informal science educators. Together, these chapters provide an essential handbook for both informal science educators and those that work to support them in their professional growth.

Defining ISE

This section lays the foundation for understanding why this focused look at the practice of informal science educators is an important one to begin with. Through the years there has been much debate over defining informal science education and delineating it from more ambiguous and antiquated terminology such as non-formal or out-of-school time learning. Professionalizing the work of informal science educators and coming to consensus on best practices to prepare them cannot happen without an understanding of the historical and present day discussion of what qualifies as informal science education. In this chapter, Katz provides not only this historical perspective, but a compelling argument for why the vernacular on informal science learning should change to continual science learning. Katz describes continual science learning as "making implicit the relationship of humans to the world, how we fit, how we adapt, and how we impact and sustain the life systems of which we are a part." The emphasis is on learning science all around us at any given time, not just in a set designed setting or program. Acknowledging that learning science is expansive and moves beyond the borders of schools, museums, and so forth is crucial to preparing others to effectively engage people in learning experiences. This perspective means that understanding teaching and learning of science is complex, far more complex than what most educators understand it to be. Katz states "future preparation for continual science learning may mean revising our vocabulary to expand and include in our vision those who do not now recognize the imperative, the opportunity, and their role in lifelong science education." While complex and perhaps overwhelming to digest, Katz proceeds to provide some concrete examples of how educators can think through transitional and transformational changes to the way we teach and learn about science. While these may just be suggestions at this point, they are a starting point for conversation around the changing nature of the work of informal science educators and the need to continue to work towards professionalizing it. Overall, this chapter tees up the rest of the handbook to dig into the nuances of what and how to best prepare informal science educators.

Professional Development

This section of the handbook illustrates the need and variety of professional development for informal science educators. For example, reflective practice is slowly becoming a mainstay of informal science educator practice. With informal science educators coming from a broad range of backgrounds, reflective practice serves as a tool to unite practitioners as a community and to engage in critical conversations about their work. As such, reflective practice benefits not only the individual but the immediate community of informal science educators as well.

Reflective practice must be understood by both what informal science educators reflect on and how they do so.

Patrick and King and Tran elaborate on what informal science educators should reflect on in their chapter about the nine dimensions of reflective practice and conceptual learning through reflection respectively. Patrick takes the nine dimensions of reflection and categorizes them in a fashion that resonates with some of the key components of informal science education practice. Patrick categorizes these dimensions into theory and research, teaching, and peers. Organizing the dimensions in this manner provides a schema from which informal science educators can operate and make the process of reflection more systematic and ingrained in their practice. It also aides in the professionalization of the practice in that it acknowledges the role, and importance, of theory and research in informing the work of informal science educators. Just as traditional classroom teachers are taught the fundamentals of learning theories and pedagogy, so must informal science educators. Patrick provides concrete examples of activities informal science educators can do in each of these categories of reflection. These activities range from reading literature related to practice, using different methods to evaluate teaching, engaging in discourse with peers about alternative perspectives on the practice, and so forth. These activities are tools for the informal science educator toolbox so they may take ownership of their own professional growth. Patrick also raises the point of reflection being not just about the past, but about the present and future. Patrick refers to reflection-on-action (the past), reflection-in-action (the present), and reflection-for-action (the future). This demonstrates how reflective practice is on-going and should be imbedded as part of an informal science educators' practice.

Patrick's description of the nine dimensions of reflective practice has some similarities to King and Tran's discussion of a conceptual framework for informal science educators. King and Tran posit that this framework coupled with a reflective process is necessary to hone informal science educators understanding and skills. The framework from King and Tran includes six components which primarily expand on the pedagogy of informal science educators. The six components are context, choice and interest, content, objects, how to support learning, and talk. These six components become the roots that anchor informal science educators in their practice. As King and Tran state, "in combining the above elements, we argue that the pedagogical practice of an informal educator thus involves mediating the interaction between the subject matter (embodied in the object, content and context of the informal institution) and the learner by providing opportunities for choice and control, and using talk within a frame bounded by an understanding of learning research." Similar to pedagogical content knowledge, this framework unites what informal science educators teach with how they teach it in a manner that may be most effective in accomplishing learning. This framework has the potential to become an anchor of informal science education preparation, providing a consistent conceptual framework from which to work. Coupled with a reflective process, informal science educators now have the tools to further develop and grow as practitioners.

The chapter on iterative implementation provides a concrete example of how reflective practice may be applied in practice and lead to tangible results. This chapter explores the challenge of shifting the mindset of docents at a natural history museum from one embedded in the notion that learning means knowledge transfer to one that acknowledges that learning is a process and should be guided rather than directed. The project used an iterative implementation process to engage skeptical docents in the development, implementation, and constant refinement of a new field trip program. The iterative process itself took on an inquiry-based approach relying on the central feature of providing the learner, in this case the docent, autonomy, engaging them in conversation and reflection, and allowing for deeper investigation of the challenge at hand (in this case, implementing a new field trip with new content that kept students actively engaged). The chapter provides ample quotes from docents actively reflecting on the process and applying these reflections to improving the overall field trip.

Yeh's chapter on personal epistemologies' influence on docents' instruction is a classic narrative on how one's beliefs shape their actions. Yeh's description of a case study of two docents illustrates the complexity of developing informal science educators. Informal science educators, be it paid programmatic staff, exhibit designers, or docents, come from diverse backgrounds. Their prior experiences and education shape their personal science epistemologies which in turn shapes how they enact teaching. Yeh describes personal epistemologies in two categories, the nature of knowledge and the nature of knowing. The case study is truly a tale of two cities—one docent deeply rooted in transforming knowledge from one individual to another, a knowledge dump of sorts that relies heavily on lecture-based strategies. The other docent relies on the process of discovery and making observations to guide how people learn, more of an inquiry-based approach. Understanding informal science educators' epistemologies and how this influences their instruction is important for anyone preparing these professionals. This may inform professional development opportunities for informal science educators, highlighting the array of pedagogical practices available and helping informal science educators reflect on where their beliefs are and how they want to be as instructors.

Finally, McLain's chapter on professional identity rounds out this section making a poignant statement about the professionalization of informal science education. McLain makes parallels to what has been studied about the professionalization of formal school teachers and the role professional development may play in this process. In particular, McLain urges the field to look at professional development through the lens of identity development, where the training is not only centered on building understanding of content knowledge and pedagogical content knowledge but rather weaving these understandings into the persona, the identity, of the informal science educator. McLain contends that this approach also better primes the informal science educator for continued growth and development beyond the immediate intervention or training. McLain elaborates on this through a description of the STEPS project, an NSF-supported initiative to cultivate a community of practice of informal science educators from an array of museums to go through professional development applying this identity development approach.

The description of this project and how it was enacted serves as a model for how those who develop and work with informal science educators may design and implement their own identity-centered professional development programs. As McLain concludes from the results of the STEP project: "The emergent professional development outcome categories [(1) Awareness, knowledge, and understanding; (2) Engagement, interest, and attitude; (3) Skills development and transfer] suggest a structure for both designing informal science educator professional development programs and for evaluating the results. Considered as a continuum of deepening impacts (from 1 to 3), these outcome categories could be used as pathways for intentionally enhancing educator professional identity." McLain concludes the chapter with recommendations for elements to incorporate into professional development for informal science educators. Indeed, professional development that considers identity construction is complex but in the end it is fruitful and what is needed on this path to professionalization of informal science educators.

Designing Programs

Designing programs is at the core of the work of informal science educators. The design process itself may be complex as illustrated in the conceptual framework shared by King and Tran in the section on reflective practice. Informal science educators must have an understanding of the content, the context, the audience, and instructional approaches. The challenge for informal science educators is the diverse audiences they serve. Be it through exhibits, multi-media or programs, informal science educators serve people of all ages, prior experiences, and backgrounds. In addition, Falk and Dierking's Contextual Model of Learning (2000) provides more detail on the contextual factors involved in museum-based experiences. The personal, social, and physical factors of a museum experience must be considered when designing a program. People come with different motivations, varied social groups, and may be heavily influenced by their physical surroundings. In short, the work of informal science educators designing programs is a complex, multi-faceted one with numerous inputs to consider. This section highlights some of the ways in which informal science educators design programs specific to certain audiences or contexts.

Gupta and Correa's entry on science identity development in youth details the design, and impact, of a program in which youth are developed as floor facilitators conducting science communication. The program places youth at the forefront of the visitor-museum interface and ultimately creates an opportunity for youth to develop their science identity through use of the museum structure and interactions with visitors. Gupta and Correa provide a narrative on their own personal experiences as "Explainers" in informal science institutions and then link it to current research on how to positively affect youth development. They reference three features of positive youth development, including sustained relationships between teens and adults (mentorship), building life skills, and opportunities for teens to apply those life skills as both participants and leaders. These are important design principles for informal science educators to consider when striving to accomplish positive youth development or science identity development with program participants. Understanding the nuances of the relationship between a youth and a mentor and subsequent activities to support skill development is key to be successful. An important take away from this entry is that there is a significant gap in research around this area of youth development from programs that put them in the role of facilitators and an integral part of the overall informal science institution. What has been researched is useful for informal science educators to apply to program design but more must be done to truly understand the significance of these types of programs and how to be the most effective in the design and implementation of them.

Toomey Zimmerman and Land touch upon a more recent, emergent need to be considered when designing programs—that of technology integration. In their chapter, Toomey Zimmerman and Land describe four design guidelines and key concepts to be considered when developing programs using mobile devices. These guidelines are: facilitate heads-up technology use that supports social interactions within informal spaces; augment the visitors' experiences with games, scientific narratives, and disciplinary-relevant aspects; incorporate activities that move the visit away from a passive consumption of facts towards the active generation and use of new knowledge; and revisit the learning experiences afterwards with the inclusion of bridges to home or community, use of social media, and connections to the same or other informal science education sites. Toomey Zimmerman and Land offer multiple case studies examining how these guidelines may be applied in practice. They provide practical examples to inspire informal science educators and demonstrate the need to be intentional when designing programs that are inclusive of such technologies.

Kim's chapter on designing astronomy workshops for youth also provides some concrete design principles or guidelines for informal science educators to consider when developing astronomy programs. Kim's work revealed four design principles to consider: developing observation-based inquiry, constructing multimodal modeling, generating argumentations using models, and remodeling through evaluation and reflection. Many of these design principles resonate with other entries in this handbook emphasizing the role of reflection in informal science educators' practice, of being iterative, and so forth. Kim's focus on an astronomy program is unique in its emphasis on "Multimodal Mediated Modeling Activities" as the primary instructional strategy for teaching astronomy to youth. Astronomy tends to be an abstract content area for teachers to understand and subsequently teach their students. These design principles give informal science educators a solid foundation from which to build from to be as effective as possible in implementing astronomy programs for youth. Oftentimes youth may get exposure to astronomy concepts primarily through informal venues such as science centers or planetariums.

Howitt, Blake, and Rennie provide another example of the attention informal science educators must pay towards program design for specific audiences. This chapter highlights the need for informal science educators to understand their audience and their needs and to apply this knowledge to the design process rather than leaving a program to be a one size fits all model. The audience in question in this chapter, early learners, is timely as more attention is paid towards engaging early childhood with science. Howitt, Blake, and Rennie describe five effective pedagogical approaches for early learners and science. These approaches include practices that are: (1) providing emotional support for young children to encourage exploration, (2) using modelling to demonstrate interactions for young children, (3) using open-ended questioning (where answers offered explanations or descriptions) to extend young children's thinking, (4) understanding the purpose of the active role of all adults, and (5) acknowledging young children's competence and capabilities. Their work has found that this process helps informal science educators develop science conversations with children to extend their current knowledge and ideas.

This chapter by Howitt, Blake, and Rennie is also significant in that it helps legitimize the power of play. Often times, particularly in children's museums, outsiders view and criticize the experience as strictly for fun and entertainment and many question whether play is in fact educational. As this chapter highlights, play is indeed an instructional approach that is effective for priming young children to learn. Further exploration of play as an instructional approach may help solidify it as early science learning pedagogy and become more mainstream in the preparation of informal science educators who may be working with this specific audience.

Tunnicliffe's study on gender differences in conversation amongst students at an exhibit highlights once again the importance of informal science educators understanding their audience. The conversation analysis demonstrated a marked difference in both the amount and nature of comments made by groups of boys versus groups of girls. The comments of boys were higher in number and more factual in nature. Boys tended to like to categorize the animals they saw on exhibit and describe features. Girls, on the other hand, were more emotional in their comments and made more descriptions of how they related to the animals. This is important for informal science educators to note when designing and implementing educational experiences. If boys gravitate toward categorizing objects and wanting to know more facts about them, an informal science educator may design a program that allows them to do this more. For girls, it may prompt an activity for storytelling or describing the objects in a different way.

Finally, this section on program design concludes with an entry from Jensen regarding the challenges of researching the long term impact of an informal science experience. While this chapter may not directly address program design, per se, it is important for informal science educators to recognize the challenging nature of their work. Indeed, it is possible, even probable, that a visit to an informal science institution has long term impact, but there is not valid, reliable evidence to fully support this yet. Jensen critiques the Falk and Needham (2011) study conducted at the California Science Center. The study attempted to assess the long term impact of the California Science Center on the general populous of the Los Angeles area. The study took on both an "inside-out" and "outside-in" approach, looking at both visitors and non-visitors to determine a correlation with gains in science knowledge and attitudes and visits to the science center. However, as Jensen points out, there were several sampling, research design, and statistical analysis challenges with the study that make the findings less appropriate to accept as evidence of long term impact. These challenges range from lack of a truly representative sample to an over reliance on self-report measures which inherently have several weaknesses making them less valid and reliable for assessing such constructs as knowledge gains. Jensen's critique acknowledges that the Falk and Needham study is worthy and important in the context of informal science education, it just affirms what was already known to be challenges with conducting long-term impact research of this nature. Informal science educators should be aware of the need for research like this and be ready and willing to assist researchers as needed.

Bridging the Gap Between Formal and Informal Educators

A hearty section covering a diverse range of approaches to preparing informal science educators, these chapters address the "how" of preparing these professionals. It also highlights the similarities as well as differences in the work of formal classroom teachers compared to informal science educators. The chapters read more like case studies bringing practical examples to the forefront of the conversation on how best to prepare informal science educators.

The chapter by Egg, Kapelari, and Dillon explores a common approach to learning and professional growth—communities of practice. In this instance, the community of practice includes both formal and informal science educators and the authors use a social network analysis to describe the relationships amongst the teachers and educators and how these relationships subsequently influence knowledge development and sharing. The study found that full participation or 'social embeddedness' of participants during a professional development program was a crucial factor for completing the course and sharing knowledge. Hubs, or groups, of teachers and educators, were also of importance in transferring knowledge to others and shifting individuals from weak links to strong links in the network. This chapter demonstrates that a community of practice may be a powerful method for professional development for informal science educators, and, in this case, it served as a mechanism to bridge the gap between formal classroom teachers and informal science educators.

Sanford and Sokol's chapter on informal science educator professional development once again highlights the links between formal and informal science education. First, Sanford and Sokol provide an example of how students can indeed make positive links between learning in an informal environment, in this case a zoo, and learning in the classroom. But more so, the chapter focuses on how elements of teacher professional development may inform a new framework for the professional development of informal science educators. A prevalent challenge in informal science education is the fact that educators come from a diverse range of backgrounds. They lack a consistent knowledge base and standard skillset so on the job training is necessary. However, most informal science institutions lack time or resources to adequately provide such opportunities. Sanford and Sokol provide a recommendation for how to balance different professional development activities and give examples of how this might look in practice for informal science educators.

Hestness, Riedinger, and McGinnis provide a robust chapter on multiple approaches to developing formal and informal science educators using informal science contexts. They approach the chapter from the standpoint of seeing synergies between preparation of both formal and informal science educators but also acknowledge the area of divergence as it pertains to informal science educators. In particular, some of these areas of divergence include the influence of prior teaching and learning experiences, the importance of modeling research-based teaching practices, promoting reflective practice, the value of communities of practice, and the unique aspects of informal science education contexts that matter for the preparation of informal science educators. Hestness, Riedinger, and McGinnis further explore these facets of preparing educators with informal science contexts through four approaches:

Approach 1: An informal science education internship experience for undergraduate elementary education majors preparing to teach in formal settings
Approach 2: An innovative science methods course for undergraduate elementary education majors preparing to teach in formal education contexts
Approach 3: A course on connecting formal and informal science education for graduate elementary education and environmental education students
Approach 4: A course on informal science education for graduate and undergraduate education and environmental science students

The chapter proceeds to provide a narrative of these different approaches and how they looked in practice. The authors discovered several important lessons learned which should be considered by others attempting to prepare informal science educators or even formal classroom teachers using informal science contexts. These lessons learned include challenging educators' prior beliefs and learning experiences; encouraging ongoing reflective practice; addressing the challenges that limited collaborations between formal and informal educators; identifying additional strategies to foster meaningful collaboration between formal and informal science educators; and developing a shared community of practice for science educators across settings. Many of these lessons align with the approaches recommended by authors in other chapters of this handbook, in particular those proposed by King and Tran, and Egg, Kapelari, and Dillon.

Matthews, Thompson, and Payne's chapter provides a personal narrative on the benefits of a formal science teacher education program promoting the development of informal science educators. The chapter flows as a personal reflection from a course instructor and two students who went on to become informal science educators though their course of study was to prepare them as formal classroom teachers. Both students identified common elements of their formal teacher education programs that have clearly and positively impacted their careers as informal science educators: experiences in the out-of-doors, experiences with children in the out-of-doors, inquiry-based instruction, opportunities to share their knowledge with others (children and adults), and the ability to locate resources and needed information. Another notion that resonated with the informal science educators was the need to begin with the end in mind. Regardless of context or audience, backward design is a fundamental approach necessary for any educator to understand and apply in practice. Though this chapter makes a compelling case for the commonalities of formal and informal science educator preparation, as Hestness, Riedinger, and McGinnis point out, there are still some areas of divergence that are necessary to address. For example, the audience that informal science educators work with is much broader and more diverse than that of a classroom teacher. Likewise, so may be the physical space where an informal science educator may do their instruction. As Patrick and King and Tran highlighted in their chapters, informal science educators must recognize the complexity of the audience and context and develop strategies to accommodate the diverse nature of both.

The chapter by Adams and Branco demonstrates how unique informal science settings such as urban parks are an important tool for teachers to use in their instruction. Parks may aid in developing students' sense of place while meeting science curriculum goals and standards. As Adams states "parks offer unique opportunities for authentic science learning in that people are able to interact with natural ecosystems and engage in authentic data collection practices, while enjoying being in the outdoors." However, as already mentioned by the previous authors in this book, there is a pedagogy that goes with using this setting and matching it with the audience, in this case classroom students from an urban area. Adams describes a six step process of making sense of place which is vital for both the teacher and the students to be successful in maximizing the learning potential. These steps include interacting in the place, establishing your identity with and within the place, realizing the resources at your disposal, creating new experiences and learning opportunities, and intensifying use of the place such as integrating it with activities back in the classroom. The chapter continues to describe examples of how the National Park Service implemented several initiatives to increase and enhance teacher and students use of urban parks to accomplish science learning. Some of these activities included engaging students alongside park scientists, teachers sharing ideas for how to use the park space and connect it to the classroom, and so forth. Teachers reflected on how the programs provided students with a "living vocabulary" and generated excitement and interest to continue learning about science. This chapter brings attention to an under-utilized asset at the disposal of many teachers, informal and formal alike. It provides yet another tool for informal science educators to consider when developing programs, in particular those intended to engage urban youth who may have difficulty accessing natural wild places.

The last chapters in this section illustrate the untapped potential for informal science education in some international locations. The chapter by Ruyani and

Matthews is a comparison of two vastly different geographical settings—in this case North Carolina and Bengkulu, India. While North Carolina is rich with both nature and informal science learning opportunities connecting to nature, Bengkulu has untapped potential for such opportunities. Bengkulu has similar conservation challenges as North Carolina, but informal science education has not infiltrated the country in the same way it has in North Carolina. The take away messages for informal science educators are to first, gain an understanding of the current landscape of informal science learning in their immediate community, and second, to realize that there are complexities in any community that may make it challenging to fully realize the potential. Working with the community to mitigate or overcome those challenges will be key to being successful.

Finally, Moormann's narrative on the Explorers of Nature program in Germany bridging museums and refugee families highlights the need for cultural inclusivity and sensitivity for today's informal science educators. The Explorers of Nature program addresses a unique and emerging challenge of how to utilize the resources and expertise of a museum as a social change agent for refugee populations. As described by Moormann, the Explorers of Nature program used a multi-disciplinary team of informal science educators, artists, refugee students, and social workers to develop a culturally relevant experience to introduce refugee children and families to German culture and language. The multi-disciplinary approach was key for the museum to provide a culturally appropriate experience for the refugee children and their families while exposing them to German nature, culture, and language by exploring the local environment. One way in which the program maintained this cultural sensitivity was to have the children and families create personal narratives reflecting on their experience in the program through photography and drawing rather than requiring written or oral narratives that may make them uncomfortable as they still learn the German language. Informal science educators interact with an increasingly more diverse population on a daily basis and also have great potential to be an anchor of a community, a place where new inhabitants of a community may turn to. Training informal science educators in culturally sensitive approaches, such as forming multi-disciplinary teams, will be even more important as communities continue to evolve.

Public Communication

Marking an upward trend of science communication efforts, this section highlights how communication has become a vehicle for learning about and engaging with science. Indeed, as earlier stated, informal science education has extended beyond traditional designed settings such as museums, zoos, aquariums and so forth. It has reached the expanses of multimedia, popular media, and more. Coupled with this reach is a heightened expectation for scientists to communicate their work and aid in educating the general public. Their work cannot exist in the proverbial vacuum. However, most scientists like the training and subsequent skills to be effective in their communication. Scientist communication training programs are on the rise though still in their infancy. As Baram-Tsabari and Lewenstein state in their chapter, "although much effort is being invested in science communication training, a conceptually-based list of specific learning goals has not yet been developed, and the existing training efforts are rarely accompanied by systematic evaluation of learning outcomes." In this chapter, they propose a list of core competencies for effective science communication by scientists in terms of skills, knowledge, and attitudes and assessment practices to measure the attainment of those goals. These competencies fall into three categories of learning goals: communication skills, views about science communication, and knowledge of the context in which science communication takes place. Together these form what could be considered an emergent idea that scientists should essentially have pedagogical content knowledge (PCK) just as formal and informal educators should. Scientists have the strength of the content knowledge, but then to understand how best to translate that knowledge in a manner that others will comprehend is another feat in and of itself.

The core competencies Baram-Tsabari and Lewenstein speak of comprise a framework from which science communication trainers can adopt and apply in a more structured and formal way than has been done to date. Doing this will also allow others to evaluate the effectiveness of science communication programs and continue to improve these programs. Indeed, one of the big ideas of this chapter is that to make progress in preparing scientists to become better science communicators we need to establish clear, theory-driven learning goals and develop shared pedagogies and assessment tools for achieving and evaluating them.

Xanthuoudaki and Miotto provide an interesting perspective on the complexities of informal science educators being part of a multi-faceted, diverse professional community. Their backgrounds, training, and even their roles within the informal setting vary from person to person and place to place. This presents a challenge when looking at how informal science educators evolve to be responsive to this new era of visitors and program participants. Visitors are eager to contribute directly to the informal science institution now, be it through user-generated content, social media, and so forth. Program participants are seeking out more experiences that hone their 21st century learning skills and prepare them to be active, literate, contributing members of society. This all requires informal science educators to shift from conduits of knowledge to be transferred to visitors to educators who facilitate reflective opportunities and are responsive to more interest-driven and even self-directed learning opportunities. The quote provided in this chapter of "museums are places for learning, not places for teaching" is a powerful one and elucidates this shift. Xanthuoudaki and Miotti further elaborate on this shift with a real-life example from the National Museum of Science and Technology—Leonardo DaVinci. The facilitators at MUST have undergone extensive training to ensure they are consistent in how they approach this new era of visitors at the museum. Imbedded in this is also an observation grid to monitor the facilitation and continuously improve upon their practices. Overall, this chapter adds a timely piece to this handbook in that it highlights the ever-changing nature of the work of informal science educators and concrete examples of those who train and prepare them may adapt their strategies as well.

The work of informal science educators may occur in smaller, more targeted programmatic experiences to large more general public facing experiences such as general museum visits with exhibits. Lederman and Holliday address what informal science educators need to know about the nature of science (NOS) and how informal science educators can effectively use informal environments to communicate NOS understanding to the public. This chapter emphasizes the potential for the general public to gain understanding about the NOS and scientific concepts through informal science settings, but points out a gap in many informal science educators' own comprehension of NOS and how best to teach it. Many informal science settings see hundreds of thousands of not millions of visitors each year. One of the big ideas from this chapter is that only informal science educators with both NOS content and pedagogical knowledge will have the capacity to augment exhibits and programs with NOS and contribute to the development of their visitors' scientific literacy. If the majority of informal science educators are lacking in NOS content and pedagogical knowledge, this is a significant missed opportunity to bolster millions' of people's scientific literacy. Lederman ad Holliday revisit what is already known about teachers' development of NOS and teaching NOS effectively in the classroom and encourage a closer look at how informal science educators can do the same.

Reiss' chapter tackles a current, complex topic which informal science educators are confronted with—how to teach about evolution. Science topics such as climate change, evolution, bioethics, and so forth are important for an individual to be scientifically literate, but these topics are often skirted around in terms of science communication because they are so complex and politically embedded. Reiss provides a comprehensive review of competing narratives on evolution and creationism, including some mainstream examples of how the topic could be introduced, such as with the film the *March of the Penguins*. Reiss proposes that informal science educators are in a unique position to facilitate learning about evolution because visitors tend to come with higher interest and motivation to learn as opposed to a classroom and they have more tangible examples to draw from. Ultimately Reiss' chapter is intended to highlight the importance of understanding controversial topics and reflect on how best to facilitate conversation and subsequent learning around such topics.

Stocklmayer and Rennie round out this section nicely with a look at the convergence, and in some cases divergence, of informal science education and science communication. Stocklmayer and Rennie provide a historical perspective on how science communication has evolved, including moving from a one-way transmission model to public understanding to the more current idea of public engagement which acknowledges non-scientists as part of the conversation and reflection of science, not just a recipient. They further elaborate on three modes of science communication: communication to the public, communication with the public (or knowledge sharing), and communication among the public (or knowledge building). Each has implications for informal science educators facilitating informal science learning experiences. Core to the role of informal science educators being effective at science communication is the need to spark curiosity to drive further investigation and learning. Stocklmayer and Rennie discuss the different types of curiosity that may be sparked and how each may or may not transition into further questioning by an individual. Their narrative culminates with a suggested framework for how informal science educators may be more effective science communicators. Overall, Stocklmayer and Rennie make a compelling case for why understanding science communication and focusing on skill development in this area is important in the preparation of informal science educators. This also signifies the evolving nature of work for informal science educators.

Patrick carries on the theme of public communication of science within a specific discipline—conservation. Patrick's chapter on "sense of conservation" speaks to the importance of informal science educators understanding who their audience is and what their prior experiences and knowledge may be. The study Patrick shares in this chapter found that middle school students' prior experiences with the local ecosystem shaped their current understanding and attitudes toward conservation and that in fact many of these experiences occurred outside of school. As Patrick states, "the multidimensional ways in which students learned about these organisms is important as practitioners define their pedagogical approaches to [conservation education]. The multi-purpose aspect of learning can be perplexing for practitioners wishing to develop [conservation education] programs that focus on local communities and shared community knowledge of the local flora and fauna. By not taking into account the shared community knowledge, [conservation education] programs and opportunities risk limiting their reach to those who already see conservation as important." When communicating about specific organisms or ecosystems, informal science educators should take into account the prior experiences and social interactions their audience may have had already. It would be a disservice to assume a specific audience already has a uniform, common understanding of one particular concept. This is certainly an added challenge for informal science educators as they consider their pedagogical approach to communicating science. The next chapter by Braund and Lelliott provides an approach that may aid in overcoming this challenge.

Braund and Lelliott conclude the section on science communication with a look at how informal science educators may use questioning to facilitate learning. The chapter dives deeper into what makes questioning effective and shares examples of how this may look in practice in informal settings. Much of the research on questioning has been conducted in the formal setting, in classrooms. Regardless, the power of effective questioning and sparking dialogue amongst learners is clear. Braund and Lelliott bridge what is known about effective questioning in classrooms to practical examples in informal settings, including labels on exhibits, use of objects, interactive exhibits, and worksheets or other guides. Questioning may also help an informal science educator better understand what their audience's current understanding and attitudes toward a topic may be. It may be a tool for overcoming the challenges highlighted by Patrick in the chapter about sense of conservation. It is important for informal science educators to understand best practices behind questioning and use of these tools or experiences to facilitate learning.

Conclusion

As this handbook demonstrates, preparing informal science educators is a complex, robust area of research and discussion at this time. From the changing nature of how we discuss informal science education to infusing technology and more sophisticated, systematic approaches to science communication, informal learning of science is transforming and so must the professionals who develop and implement these experiences. The sections of this handbook on professional development, bridging informal and formal educators, and communicating with the public provide a foundation from which informal science educators can build their professional knowledge and skills. Much like classroom teachers, informal science educators must have not only the content knowledge and pedagogy, but the pedagogical content knowledge. Informal science educators must understand where informal learning of science has come from and where it is headed. They must understand the diversity of their audience and couple this with the best teaching strategies and learning contexts for them. Informal science educators must be provided with the time, resources, and other support to reflect and continually hone their craft. This handbook covers all of these facets of being an effective informal science educator and as such will be another essential tool to which informal science educators refer.

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