Cheryl B. Leggon · Michael S. Gaines
Editors

STEM and Social Justice: Teaching and Learning in Diverse Settings

A Global Perspective

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ISBN 978-3-319-56296-4 ISBN 978-3-319-56297-1 (eBook)
DOI 10.1007/978-3-319-56297-1

Library of Congress Control Number: 2017943383

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Acknowledgements

Cheryl B. Leggon. I am grateful to Professor Willie Pearson, Jr., for his unwavering support and for generously sharing his expertise, experience, wisdom, and insight. Much appreciation and gratitude go to my son, Robert Leggon Gray, M.D., for his encouragement and for being a champion for social justice. Crucial to my work on this book was the Georgia Institute of Technology International Travel Award from the Ivan Allen College—special thanks to Dean Jacqueline Royster, Gregory Abrams, and Professor Kaye Husbands Fealing (Chair of the School of Public Policy). I would like to express my gratitude to those with whom we worked at Springer—especially Melissa James for her belief in this project from the beginning, and Brinda Megasyamalan for her professionalism and patience throughout the process. Much gratitude to our contributors for their excellent work, thoughtful insights, and prompt responses to our requests. Our contributors and supporters are responsible for the strengths of this volume; we take full responsibility for any flaws or faults.

Michael S. Gaines. I would like to acknowledge the initial support of the National Science Foundation for taking the Science Made Sensible Program from a dream to a reality, and the NSF international supplement that facilitated the lifelong relationships that I established with science educators in South Africa who are major contributors to this book. Also, I am grateful to Prof. William Green, Sr., Vice Provost Prof. Leonidas Bachas, Dean College of Arts and Science, and Prof. Angel Kaifer, Associate Dean of the College of Arts and Sciences for institutionalizing Science Made Sensible with University of Miami funds. Most of all, I am indebted to my late son, Nathan Gaines, who inspired me to make a difference in opening the eyes to science of those who otherwise may never have looked.

The original version of this book was revised

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Authors' Biography

Judy Brown led the Education Department of the Miami Museum of Science from 1987 to 2015 and currently serves as SVP, Emerita, for the Patricia and Phillip Frost Science Museum. She has played a leadership role nationally in broadening participation of underserved groups in STEM and has received many prestigious awards. In 1995 she received the National Science Teachers of America (NSTA) Informal Science Educator of the Year Award as well as the Educator of the Year from the Miami Chapter of Phi Delta Kappa. In 2005, she received the Eleanor Roosevelt Award from the American Association for University Women (AAUW) for her work in encouraging girls to pursue science and technology-related career pathways. She is a recipient of the 2005 Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring, the United States' highest honor for mentoring, and in 2014 received the Roy Shafer Leading Edge award from the Association of Science and Technology Centers in recognition of extraordinary accomplishments that significantly advanced the mission of science-technology centers and museums nationally. Her interests continue to lie primarily in mitigation of the impact of poverty on children and youths' opportunity to learn, with concentration on early childhood, science education, and equity and diversity program development in formal and informal education settings.

Myra Burnett, PhD served as the interim provost and vice president for academic affairs at Spelman College from 2014 to 2017. She was a member of the External Advisory Board for the National Experiment in Undergraduate Science Education (Project NEXUS) of the Howard Hughes Medical Institute, which produced a paper on innovative methods for increasing the numbers of underrepresented minority students in science and technology fields. Other professional service has included membership on several regional and national advisory committees, such as a three-year term on the Advisory Committee for the Education and Human Resources Directorate, National Science Foundation, and participation in an Expert Panel for a joint committee of the National Institute of General Medical Sciences and Howard Hughes Medical Institute. A graduate of Harvard University, she received a master's degree in social psychology from Stanford University and completed her doctorate in clinical psychology at Duke University.

Jennifer M. Case is a professor in the Department of Chemical Engineering at the University of Cape Town, with a special responsibility for academic development. She lectures and convenes courses in the first and second years of the chemical engineering program, and her research on the student experience of learning has been widely published. In 2006 she was awarded the President's Award from the National Research Foundation, in 2007 the UCT Distinguished Teachers' Award, and in 2013 the HELTASA-CHE national award for teaching excellence. In 2011 she was a Mandela Mellon fellow at Harvard University. She was the founding president of the South African Society for Engineering Education and is a coordinating editor for the international journal *Higher Education* and a co-editor for the Routledge/SRHE series Research into Higher Education.

Zaramasina Clark was a senior mentor and Te Rōpū Āwhina whānau member from 2012 when she began her postgraduate studies at Victoria University of Wellington (VUW). Between 2013 and 2015 she coordinated the Āwhina Post-Graduate Seminar (APGS) Series, an integral part of Āwhina which supported and developed research skills in postgraduate whānau members. The APGS Series also contributed to the Āwhina kaupapa by exposing undergraduates to the postgraduate research environment, thus easing the undergraduate to postgraduate transition. Ms. Clark is of Tongan and New Zealand European descent but was born in Fiji. After completing a Bachelor of Science degree at the University of Auckland, she completed a Master of Biomedical Sciences degree at VUW, where she is currently a PhD candidate. Her research is focused on investigating the factors within the mammalian ovarian follicle that influence oocyte competency (i.e., the ability of an oocyte to form a viable embryo following fertilization).

Karen E. Clay currently serves as the Assistant Director for Study Abroad at Spelman College. In addition, she serves as Manager of the Spelman Global STEM Program and is responsible for increasing the number of undergraduate African American women in science, technology, engineering and mathematics (STEM) who travel abroad to conduct research. The United States Department of Education has recognised the G-STEM Program as a model for Historically Black Colleges and Universities in the areas of women in STEM and undergraduate research. Her on-going research interests include Brazil and Haiti, South-South development cooperation, emerging donor relations and US-Latin American relations. She is the first native born African American woman to earn a PhD in International Relations from Florida International University. Also, she earned degrees as Specialist in International Education from New York University, and the Master of Public Administration and the Bachelor of Arts in Political Science from Texas A & M University.

Brandon I. Collier-Reed is an associate professor in the Department of Mechanical Engineering and Deputy Dean: Undergraduate Education in the Faculty of Engineering and the Built Environment at the University of Cape Town. He is currently the President of the South African Society of Engineering Education and a registered Professional Mechanical Engineer with the Engineering Council of South Africa. He is a Fellow of the South African Institution of Mechanical Engineering and a past Director of the Centre for Research in Engineering Education. His research looks at understanding how the student experience is impacted by the use of technology in teaching and learning. He also has an interest in the nature of technology and the technological literacy of adolescents.

Dr. Michael S. Gaines is Professor of Biology, Assistant Provost for Undergraduate Research, and Director of Pre-Health Advising and Mentoring at the University of Miami (UM). Gaines earned a B.S. degree at Tulane University and his master's and Ph.D. degrees at Indiana University. His research is on the effects of grazing and burning on microbial diversity in Kruger National Park in South Africa. Gaines is director of UM's HHMI Undergraduate Education Program. The major goal of the program is to increase the number of underrepresented students in research careers. He also directs an NIGMS Bridge Program between UM and Miami Dade College (MDC) and an NSF S-STEM Program. Both of these programs aim to increase the number of MDC students who are underrepresented in the sciences transferring to research universities and completing baccalaureate degrees. In addition, Gaines serves as campus coordinator for the NSF Florida–Georgia Louis Stokes Alliance for Minority Participation and the Leadership Alliance Programs. These programs provide research experiences for underrepresented students in STEM. He also directs an NIGMS Initiative for Maximizing Student Development, which is a research training program that supports graduate students from underrepresented groups pursuing PhDs. Gaines directs the Science Made Sensible Program which partners UM pre-service teachers with Miami-Dade County in-service middle school teachers to develop science curricula in their classrooms. Gaines teaches undergraduate courses in general biology and bioethics.

Cássia de Brito Galvão, PhD is a professor in the Environmental and Health Sciences Program at Spelman College (Atlanta, GA, USA). She has served in the field of environmental geotechnology for more than 20 years in the roles of teacher, researcher, consultant and community outreach. She has authored more than one hundred publications, including books, book chapters and peer-reviewed articles. Currently, she serves as treasurer of the International Society of Environmental Geotechnology (ISEG), USA, a multidisciplinary professional geotechnical organisation of technical and policy experts from Europe, North and South America, and Asia who work on various aspects of sustainable development, and that has generated international research partnerships and regional development policy initiatives. Her main research areas are geotechnical, chemical and mineralogical properties of soils; thermodynamics of contaminant interactions with soils and clean-up techniques;

recycling of waste materials; waste disposition; mining waste disposition; rain-induced landslides; erosion control; streambank erosion control; bioengineering techniques applied to erosion control; and modelling with Global Information Systems (GIS).

Jane Indorf is Educator Assistant Professor of Biology at the University of Miami (UM). She earned her B.A. degree in biology (ecology and conservation biology) at Boston University and Ph.D. degree in biology (molecular ecology and evolution) at UM. Indorf's research interests are in biology education, molecular ecology, and evolution. Her current research focuses on the use of case studies to teach undergraduate students core science competencies. She also conducts research on the effectiveness of authentic research experiences in introductory biology and chemistry laboratory courses for improving undergraduate student learning and retention in science. Indorf works closely with UM's Howard Hughes Medical Institute (HHMI) Undergraduate Science Education program and educational partnership with Miami Dade College. She did her postdoctoral training in science education working with UM's HHMI National Experiment in Undergraduate Science Education program. As a postdoc, she coordinated the Science Made Sensible program as it was being institutionalized at UM. During graduate school, Indorf spent two years as a National Science Foundation GK-12 Science Made Sensible graduate fellow teaching inquiry-based science labs to Miami-Dade County inner city middle school students.

Cheryl B. Leggon, PhD is an associate professor in the School of Public Policy at the Georgia Institute of Technology. Dr. Leggon's research underscores the criticality of disaggregating data by race/ethnicity and gender to develop policy, programs, and practices that enhance the quality of the United States' science and engineering work forces. She was elected a Fellow of the American Association for the Advancement of Science (AAAS), and of Sigma Xi. In 2013, Dr. Leggon was appointed to the Human Resources Expert Panel (HREP), National Center for Science and Engineering Statistics (NCSES) of the National Science Foundation. Her most recent publications include "Advancing Policies for Progress" (with Connie L. McNeely and Jung Won) in Advancing Women in Science: An International Perspective, Willie Pearson, Jr., Connie L. McNeely, and Lisa Frehill editors, 2015. New York: Springer. Before coming to Georgia Tech in 2002, she was Director of Women's Studies and Associate Professor of Sociology at Wake Forest University, and prior to that a Staff Officer in the Office of Scientific and Engineering Personnel, National Research Council, National Academies. Leggon earned a BA in sociology from Barnard College, Columbia University, and a PhD in sociology from the University of Chicago.

Anthony Lelliott is Professor of Science and Technology Education at the Marang Centre for Mathematics and Science Education at the University of the Witwatersrand (Wits) in Johannesburg, South Africa. 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, biotechnology, and astronomy education. He supervises PhD, masters, and Honors students and teaches on various courses in science education at undergraduate and postgraduate levels. He has worked in teacher education since 1987 and in 1995 joined Wits where he has held various leadership positions. He completed BSc Hons and MSc degrees at the University of Durham, UK, and holds a PhD from the University of the Witwatersrand.

Kai McCormack, PhD is an associate professor in the Psychology Department at Spelman College. Dr. McCormack currently serves as the co-director of G-STEM, an NSF-funded program which provides mentored international research experiences to students in the STEM disciplines. She has worked with existing study abroad providers in the expansion of their offerings to include research experiences, particularly ones tailored to undergraduate STEM majors. She also has worked to create new international research experiences for undergraduates, by working closely with both Spelman and non-Spelman faculty. She currently runs a primate behavior research course, in which students gain observational research experience on the green monkeys of Barbados. In addition to her interest in the advancement of African-American women in the STEM disciplines, Dr. McCormack's research examines the effect that the mother-infant relationship has on rhesus monkey outcomes. Dr. McCormack earned a PhD in psychology from the University of Georgia, and a BA in psychology from Claremont McKenna College.

Sonja Miller holds a Master of Science degree from the University of Otago, New Zealand (NZ), and a PhD in marine biology from Victoria University of Wellington (NZ). After completing her master's degree, Sonja worked for a range of government organizations and research institutes involved with marine conservation or fisheries. Sonja was a Te Rōpū Āwhina whānau member from 2004 when she came to Victoria University of Wellington (VUW) to do her doctoral studies. After finishing her PhD, she completed a 3-year Foundation for Research, Science and Technology (FRST) Te Tipu Pūtaiao Postdoctoral Fellowship at VUW. The fellowship and two subsequent projects used the successful Āwhina whānau model to build Māori and Pacific marine science capability through research in areas of interest to, and in partnership with, Māori and Pacific communities. She has been a member of the Āwhina Research Team since 2012 and, prior to leaving Victoria University at the end of 2015, worked closely with the Deputy Dean (Equity) in the Faculties of Science, Engineering, Architecture and Design at VUW doing the hands-on, day in, day out work of building STEM capability in Āwhina whānau members.

Ulrich Oberprieler is Manager of the Department "*Conservation Education & Public Engagement in Science*" at the National Zoological Gardens (NZG) in Pretoria, a facility of the South African National Research Foundation (NRF). As such he is leading science engagement programs at the National Zoo and heading the "NZG Academy." In addition to his management responsibilities, Ulrich specializes in offering courses and lectures on environmental topics. Public presentations on birds (especially raptors), mammals, snakes, ecology, and the environment are offered regularly. He is also involved in various initiatives to create awareness about current conservation and poaching crises in South Africa. Ulrich specializes as a science communication practitioner – translating scientific information into forms which are understandable and of general to public target audiences. His education programs, books, lectures, and papers have reached thousands of people.

Hazel Phillips is an indigenous woman of Ngāti Mutunga descent. She gained her PhD in education at the University of Canterbury, New Zealand. Prior to her current position as an independent researcher she was a Senior Lecturer in He Parekereke, Faculty of Education at Victoria University of Wellington. Her background in Māori education and indigenous epistemologies and research methodologies has led her to be involved in a diverse range of research projects over the past 20 years. Hazel's passion remains within Māori communities and the transformative potential they contain. As a member of Te Rōpū Āwhina for 6 years, Hazel contributed her qualitative research expertise to Āwhina research in determining and advancing Māori and Pacific student success in STEM disciplines.

Dr. Tiffany B. Plantan received a B.S. in environmental science from the University of Tampa before receiving a Ph.D. degree in biology from the University of Miami (UM). Her research interests are ecology and conservation biology. Tiffany's dissertation examined the feeding behavior of oxpeckers (*Buphagus* spp.) in relation to ungulates in sub-Saharan Africa. As a postdoctoral fellow funded by the National Institute of General Medical Sciences, Tiffany coordinated the Bridge to the Baccalaureate program, which is a partnership between Miami Dade College and UM. This program aims to increase the number of students from underrepresented groups pursuing and entering careers in science, technology, engineering, and math (STEM). Tiffany then held appointments of adjunct assistant professor in the Department of Biology and Assistant Director of Pre-Health Advising and Mentoring at UM where she mentored students interested in pursuing careers in the health sector. She also continued to coordinate the Bridge program, as well as a National Science Foundation scholarship program for community college transfer students to UM who are interested in STEM careers. Currently, Tiffany is Director of Education in UM's Graduate School where she implements, interprets, and enforces policies and procedures related to graduate programs in 11 schools and colleges.

Ken Richardson did his master's degree in physics at the University of Auckland, New Zealand (NZ), and his PhD in high energy astrophysics at the University of Durham, England. Since then he worked in a wide variety of research areas—from gamma ray astronomy and cosmic ray astrophysics to fisheries and remote sensing—focusing mainly on modeling and analysis. Over the last decade he developed an interest in longitudinal methods and causal inference while at the University of Otago, Wellington, NZ. He has had a close involvement with Te Rōpū Āwhina over many years, contributing particularly to the development of the Āwhina Research Team whose goal is to develop a robust evidence base for the impact of Te Rōpū Āwhina on Māori and Pacific success in STEM disciplines at Victoria University of Wellington, NZ.

Liz Richardson did her BSc in cell biology at the University of Auckland, New Zealand, and her Diploma in Teaching at Auckland Teachers' College. She has had a longstanding commitment to empowering Māori and Pacific and other low socio-economic communities through education using a holistic whānau and community approach. As a secondary school science teacher and in senior positions at the University of Waikato and Victoria University of Wellington, Liz developed successful models to increase the participation and success of pupils from these backgrounds. In her role as Deputy Dean (Equity) in the Faculties of Science, Engineering and Architecture and Design (SEAD) at Victoria University, Liz developed and led Te Rōpū Āwhina. This kaupapa-based whānau contributed to community development and leadership through the production of Māori and Pacific SEAD professionals. During its 16 years of existence Āwhina oversaw significant absolute and relative increases in Māori-Pacific undergraduate and postgraduate degree completions, and Māori-Pacific undergraduate and postgraduate completion rates. These on-campus successes were crucial to building a strong and active relationship between Āwhina and local and regional communities. Liz was awarded the Queens Service Medal in 2010 for her (and Āwhina's) contribution to Māori and Pacific education. She retired from Victoria University in December 2015.

Amy Rubinson former director of the Museum of Science's Upward Bound Math and Science Center, is a practitioner who has worked extensively in both the formal and informal sectors. She earned her PhD in education from Colorado State University. Her research is related to understanding factors that contribute to academic outcomes for underrepresented students who participated in an out-of-school time STEM college readiness program. She is also interested in students' persistence in STEM fields throughout post-secondary education and professionally. She is a life-long learner who consistently seeks the opportunity to grow from her professional settings and share her knowledge with others.

Andrew Tarr currently works as a business analyst in the Information Technology unit at Victoria University of Wellington, New Zealand, where he has had wide-ranging responsibility for institutional reporting. Andrew has been part of the Āwhina research team since 2010 where one of his main contributions has been the provision of data from the VUW student system. Andrew has had experience in teaching and research in STEM subjects as a postgraduate student and retains a strong interest in teaching and learning in the tertiary sector, particularly improving education for indigenous students. Andrew has an MA in philosophy from the University of Western Ontario, Canada, and a BSc(Hons) in chemistry and a BA in philosophy from the University of Canterbury, New Zealand.

Dr. Dimeji Togunde is the Associate Provost for Global Education and Professor of International Studies at Spelman College, where he leads the College's comprehensive internationalisation agenda. He has been responsible for the implementation of the College's strategic plan (2010–2017) and its Quality Enhancement Plan (QEP), known as Spelman Going Global! which was well received with an accolade from the Southern Association of Colleges and Schools (SACSCOC) in its response to the Fifth-Year report. Dr. Togunde oversees the Office of Study Abroad and International Exchange, Cultural Orientation Program, International Affairs Center, International Student Services, Global-STEM Program, and all faculty-led study abroad programmes. Under his leadership, Spelman's success in global education was recognised with the 2017 Senator Paul Simon spotlight award on internationalisation from the National Association of International Educators (NAFSA). He received his PhD in Development Sociology from Cornell University.

Elize Venter grew up in Bloemfontein in the Free State where she completed her high school career at Oranje Hoër Meisieskool. She completed a Bachelor of Science degree and a teacher's diploma at the University of the Free State. She started her career as a Life Sciences teacher. She later completed a master's degree in environmental education at the University of South Africa. She was employed at the National Zoological gardens of South Africa as curriculum developer from 2009 to 2015. During this time she completed a Doctor's degree in didactics, also at the University of South Africa. She currently holds a position at the Tshwane University of Technology. Elize has two children, Izaan and Ian. She is passionate about conservation of wild animals and their habitats and has a specific interest in the evaluation of conservation education programs.

Rian de Villiers has been lecturing at the University of Pretoria since 2002. He holds a PhD, MSc, BSc(Hons), and a Higher Education Diploma (HED). Currently he is an associate professor in the Department of Science, Mathematics and Technology Education in the Faculty of Education. He teaches pre-service life sciences and natural sciences teachers. Rian is a South African National Research Foundation (NRF)–rated researcher and he was involved in various international collaborative research projects from 2002 to 2014. His expertise is in the fields of inter- and intra-continental teacher migration, teacher training in life sciences education, controversial topics in life sciences, and community-based service learning. His topical work on teacher migration has been some of the most quoted studies in the Faculty of Education. He was awarded one of the most prestigious grants of its kind in the world—the Commonwealth Academic Fellowship—to study at King's College, University of London.

Te Rōpū Āwhina Whānau was a comprehensive on-campus whānau (family) for students studying degrees and majors in the STEM disciplines at Victoria University of Wellington, New Zealand, between 1999 and December 2015. The Āwhina kaupapa (goal) was to produce STEM professionals who will contribute to Māori and Pacific and other minority communities' development and leadership. Āwhina whānau included all those who agreed with its kaupapa and whānau values, and contributed to its success, both off and on campus.

Chapter 1
Introduction and Overview: STEM and Social Justice: Teaching and Learning in Diverse Settings

Cheryl B. Leggon and Michael S. Gaines

Abstract Over the last half-century, there have been many dramatic social, historical, cultural, demographic, and political changes worldwide. National boundaries have dissolved or shifted to the extent that society is conceptualized not only on a national level, but also on an international one. The global economy is based on information, invention, and innovation deriving from science and technology. Competing successfully in today's global economy necessitates developing a well-educated and well-trained science, technology, engineering, and mathematics (STEM) workforce. In the global knowledge-based economy, the most important resources are human resources. Bringing together people with a variety of perspectives to address problems results in better solutions and enhances both innovation and creativity (Medin, Lee, and Bang, 2014; Phillips, 2014).

Keywords STEM • Social justice • Race • Ethnicity • Gender

Over the last half-century, there have been many dramatic social, historical, cultural, demographic, and political changes worldwide. National boundaries have dissolved or shifted to the extent that society is conceptualized not only on a national level, but also on an international one. The global economy is based on information, invention, and innovation deriving from science and technology. Competing successfully in today's global economy necessitates developing a well-educated and well-trained science, technology, engineering, and mathematics (STEM) workforce. In the global knowledge-based economy, the most important resources are human resources. Bringing together people with a variety of perspectives to address problems results in better solutions and enhances both innovation and creativity (Medin, Lee, and Bang, 2014; Phillips, 2014).

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C.B. Leggon, M.S. Gaines (eds.), *STEM and Social Justice: Teaching and Learning in Diverse Settings*, DOI 10.1007/978-3-319-56297-1_1

No nation can afford literally or figuratively to squander its human resources. A nation—whether developed or developing—must foster, nurture, and enhance the talents of every citizen. Continuing to exclude certain groups from access to quality education increases their under-participation in STEM fields and both reflects and reinforces social injustice. Therefore, increasing and enhancing the participation of groups that are traditionally underrepresented in STEM is not only a matter of economic competitiveness but also a matter of social justice.

Although "social justice" is defined in a variety of ways, most definitions include the notion of fair access and equitable distribution of social resources. Our conceptualization of education for social justice is more comprehensive than focusing on education as the means to economic revitalization. Traditional STEM education pedagogy and practices extinguish curiosity and creativity, and impede critical thinking—the very skills needed in the global economy. Education practices that encourage and support active participation and engagement from STEM students significantly enhance learning, and prepare students not only for jobs but also to be global citizens. Effective development and efficient utilization of human resources require innovative programs and practices.

The conceptualization for this volume developed over the past several years during various international conferences—starting in Havana, Cuba in 2006, and continuing at meetings in Japan (2014), South Africa (2013 and 2015), and New Zealand (2015). At first, the focus of this volume was on selected innovative programs designed to augment the STEM workforce through increasing and enhancing the participation of underrepresented groups. As this volume developed, however, our perspective broadened to include STEM teaching and learning not only for economic development, but also for individual empowerment.

The programs and initiatives included in this volume span the STEM career pathway—primary, secondary, and tertiary education—and professional development and socialization—in the United States, South Africa, and New Zealand. Similarities as well as differences between and among programs across nations were systematically analyzed for lessons learned. Through participating in these programs, students saw not only the contributions that they could make to STEM, but also the contributions that they could make through STEM to society in general, and to their race/ethnic community, in particular. In turn, this provided a meaningful context within which participants came to view STEM not as something that is "mystical" and beyond their grasp, but something that can enhance their lives as well as their quest for social justice. Developing, nurturing, and enhancing interest in STEM among underrepresented groups translates into improved academic performance, increased career options, enhanced empowerment and social justice.

One distinguishing feature of this volume is that the contributors to the volume are or have been actively involved in these programs as policymakers, researchers, teachers, administrators, and evaluators. For example, Leggon was part of the external evaluation team for projects that Gaines directed at the University of Miami (The Leadership Alliance and Science Made Sensible) and the external evaluator for G-STEM at Spelman College. Including contributions from an evaluator is rare because evaluation data are usually proprietary. Another distinguishing feature of this volume is that it includes programs in formal settings, informal settings, and combinations thereof.

It is our sincere hope that this volume will accomplish three primary objectives:

1. To disseminate information about these initiatives to a broader audience.
2. To inform programs, policy, and practices.
3. To provide a starting point for future research and research-based initiatives.

1.1 Part I: Teaching and Learning STEM in Formal Settings

Formal settings include schools at the elementary, secondary, and tertiary levels, as well as undergraduate and graduate levels. This section discusses three program initiatives: Science Made Sensible (SMS) 1 and 2; Awhina; and Enhancing Global Research and Education (G-STEM). These initiatives share the same overarching goal: to increase and enhance the participation in science, technology, engineering, and mathematics of groups that are usually underrepresented and underserved by traditional formal institutions.

1.1.1 Science Made Sensible 1 and 2

In their chapter, *Tiffany Plattan, Jane Indorf, Rian deVilliers*, *and Michael Gaines* discuss the genesis and evolution of Science Made Sensible (SMS), a program, initially funded by the National Science Foundation (NSF). SMS began in 2007 as a partnership between the University of Miami (UM), Florida, USA and a consortium of public middle schools (grades 6–8) in Miami. The program was developed to address the interrelated problems of scientists' failure to communicate simply, school teachers' lack of grounding in science, and the decline of science and math scores, as well as learner interest in science and math, between the 4th and 12th grade. UM graduate students in science, technology, engineering, and math (STEM) disciplines worked with middle school science teachers to engage learners in science through the use of inquiry-based, hands-on activities. Lessons learned from the first iteration informed the next iteration—*Science Made Sensible 2*. Due to its success in Miami, in 2009 the Science Made Sensible Program was exported to South Africa with additional funding from the National Science Foundation. In this iteration, Miami middle school science teachers and UM graduate students in STEM worked with science teachers and learners at several middle schools in Pretoria, South Africa. The goals of SMS in South Africa included sharing information about each country's educational system, discussing pedagogical techniques used in the classroom, and developing inquiry-based natural science lesson plans that could be used in both Miami and Pretoria classrooms.

1.1.2 Awhina

In their chapter, *Liz Richardson, Zaaramasina Clark, Sonja Miller, Hazel Phillips, Ken Richardson, and Andrew Tarr* discuss Awhina—a model for building post-secondary STEM capability. The purpose of Awhina is to "produce Maori and Pacific scientists, technologists, engineers, architects and designers who will contribute to Māori and Pacific community development and leadership." Established in 1999, Te Rōpū Āwhina Whānau (Āwhina) at Victoria University of Wellington (VUW) has substantially increased numbers of Māori (indigenous New Zealanders) and Pacific undergraduate and postgraduate students in the science, technology, engineering, and mathematics (STEM) disciplines. Āwhina includes concepts and ideas to enhance indigenous and minority student success in tertiary institutions. It is important to note that strengthening the STEM capability of Māori and Pacific students and the communities from which they come is critical to the wellbeing of all New Zealanders.

1.1.3 Enhancing Global Research and Education (G-STEM)

Kai McCormack, Dimeji Togunde, Cheryl B. Leggon, Trezinha Cassia de Brito Galvao, Karen Clay, and Myra Burnett present an innovative initiative—Enhancing Global Research and Education (G-STEM), at Spelman College. Spelman College, an historically Black college and a global leader in the education of women of African descent, has made strategic and focused efforts to increase the international experiences of all students. G-STEM was created to address the specific challenges related to international experiences for STEM students by providing women of African descent majoring in STEM with formally mentored international research experiences so that they complete their undergraduate STEM major with transformative worldviews. This chapter reviews the development of the G-STEM program, highlighting successful international research partnership typologies, recruitment and retention practices of underrepresented students, student experiences and outcomes, and the barriers to STEM student participation in international research experiences.

Despite the commonality of overall goals and objectives, these programs differ in terms of: demographic characteristics of underrepresented and underserved groups; level of focus in the STEM education pathway; and geographic location (Table 1.1).

Table 1.1 Goals and objectives of STEM initiatives

	SMS 1	SMS 2	Awhina	G-STEM
Focal population(s)	Hispanics, Haitians, and African Americans	Black South Africans	Maori and Pacific	African American women
Education level	Grades 6–8	Grades 6 and 7	Undergraduate/ tertiary	Undergraduate/ tertiary
Geography	Miami, Florida (United States)	Miami, Florida and Pretoria, South Africa	Wellington, New Zealand	Atlanta, Georgia United States

1.2 Part II: Teaching and Learning STEM in Informal Settings

Informal settings include zoos and botanical gardens, science centers and museums, nature centers, visitor centers, public science events, and after school programs. In an interesting 2010 paper appropriately titled "The 95% Percent Solution: School is not where most Americans learn most of their science," Falk and Dierking present a compelling argument that to improve literacy in STEM it will be necessary to develop engaging programs not just in the classroom where lifelong learners spend only 5% of their life time but also outside of school. The learning that occurs during the other 95% of the time becomes particularly critical in closing the STEM achievement gap between underserved groups and the rest of the population thereby directly addressing social justice.

Anthony Lelliott in his chapter "*Recent Research on Science Communication and Engagement in Informal Settings in South Africa*" gives an overview of informal science education from an historical perspective. Lelliott traces science communication contextually from the days of apartheid where the "expert" scientist imparts wisdom to the public in the role of an authority figure, to the post-apartheid philosophy of *ubuntu* which emphasizes equity through human connectedness and sharing. Over time science communication has moved from the "expert model" during apartheid to a "participatory conversation model" guided by *ubuntu* where there is a dialogue between the scientist and the public. Lelliott presents results evaluating learning across a broad array of informal science education venues. He concludes from these studies that learning does occur in informal settings but in some studies it is not the same type of learning that occurs in the classroom.

Elize Venter and Ulrich Oberprier in their chapter on *Zoo Programs in South Africa* describe a range of educational programs offered at the National Zoological Gardens (NZG) in Pretoria. One of the strategic objectives of the NZG is "to provide a high-quality impact platform for science advancement and public engagement in conservation, biodiversity and environmental sustainability." Under the umbrella of the NZG Academy there are five different programs: (1) Program for Educational Support, (2) Program for Science Careers, (3) Program for Public Engagement in Conservation, (4) Program for Research Capacity Development, and (5) Program for Staff Development. Two of these programs deserve special mention at this point for their uniqueness. The student activities in the educational support program are closely aligned with the public school curriculum (Curriculum Assessment Policy Statements). In this case, formal learning in the classroom is reinforced by informal learning at the zoo. It also provides teacher training. The research capacity program enables students to do research. Because the NZG has a statutory mandate from South Africa's National Research Foundation, the zoo can provide undergraduates and post-graduates research experiences related to conservation. The best way to get excited about science as a career is by doing science and becoming a discoverer of knowledge.

Judy Brown and Amy Robinson in their chapter *Science Museums, Science Education and Social Justice* present the Frost Science Museum's Integrated Marine

Program and Computer Training (IMPACT) in Miami, FL as a case study. What makes Miami a pivotal city in tying informal science engagement to social justice is the diversity of the population. Over 85% of students enrolled in Miami-Dade County Public Schools are from underrepresented groups. Almost 20% are classified as limited English proficient, and 72% qualify for free or reduced price lunch. The IMPACT program recruits students from Haitian and Hispanic backgrounds in 9–12 grades. This program has an academic year and intense summer component. During the 28 Saturday sessions during the academic year, students learn life skills, attend STEM-themed classes, and explore the Museum's hands-on exhibits. The 6-week summer component is run in collaboration with the University of Miami Rosenstiel School of Marine and Atmospheric Science and is hosted on the marine school campus. The cornerstone of the program is that all students participate in a marine research project. The outcome data for IMPACT are impressive. The high school graduation rate for IMPACT participants is an incredible 98% compared to 56% for the general population. IMPACT clearly demonstrates that informal science education programs when done well can make a real difference that carries over to success in the classroom.

1.3 Part III: Role of Professional Societies

In *Critical Contemporary Questions for Engineering Education in an Unequal Society: Deliberations for the South African Society for Engineering Education (SASEE), Brandon I. Collier-Reed and Jennifer M. Case* focus on the role of professional societies and organizations to address inequality, educational attainment, and social justice. Through analyses of 125 papers presented at three biennial SASEE conferences, the authors discuss the criticality of teaching and training teachers to teach students to develop skills "to help them as engineers play a role in shaping and contributing to the development and success of a community" including: community-based outreach as a component of engineering education; and sustainability, citizenship, and ethics in mainstream engineering curriculum. SASEE workshops and biennial conferences "have made some contribution toward ensuring that all engineering educators are able to critically engage with the needs of students; particularly those most at risk."

1.4 Part IV: Lessons Learned Across Settings and the Way Forward

In *Lessons Learned Across Settings, and the Way Forward, Leggon and Gaines* summarize lessons learned across formal and informal settings and nations—South Africa, New Zealand, and the United States. This section identifies design principles that the initiatives discussed in previous chapters have in common, and summarizes lessons learned in terms of what programs, policies, and practices are effective or at least promising. These lessons are discussed to catalyze thinking and provide direction and strategies to develop, sustain, and institutionalize innovative programs and practices addressing STEM teaching and learning as issues of individual empowerment and social justice.

References

Falk, J. H., & Dierking, L. D. (2010). The 95% percent solution: School is not where most Americans learn most of their science. *American Scientist, 98*, 486–493.

Medin, D., Lee, C. D., & Bang, M. (2014). Diversity in science: Where are the data? *Scientific American*, October 1, 2014:221–222.

Phillips, K. (2014). How diversity makes us smarter. *Scientific American*, October 1, 2014:225.

Part I
Teaching and Learning STEM in Formal Settings

Chapter 2
Science Made Sensible

Tiffany B. Plantan, Jane Indorf, Rian de Villiers, and Michael S. Gaines

Abstract The Science Made Sensible (SMS) program, initially funded by the National Science Foundation (NSF), began in 2007 as a partnership between the University of Miami (UM), Florida, USA and a consortium of public middle schools (grades 6–8) in Miami. The program was developed to address the interrelated problems of scientists' failure to communicate simply, school teachers' lack of grounding in science, and the decline of science and math scores, as well as learner interest in science and math, between the 4th and 12th grade. UM graduate students in STEM (science, technology, engineering, mathematics) disciplines worked with middle school science teachers to engage learners in science through the use of inquiry-based, hands-on activities. In 2009 the SMS program was exported to South Africa with additional NSF funding. The goals of SMS in South Africa included sharing information about each country's educational system, discussing pedagogical techniques used in the classroom, and developing inquiry-based natural science lesson plans that could be used in both Miami and Pretoria classrooms. Miami middle school science teachers and UM graduate students in STEM worked with science teachers and learners at several middle schools in Pretoria, South Africa. Following completion of NSF funding, the SMS program was institutionalized and has since undergone modification to include undergraduate students. This chapter covers the conception, implementation, assessment, and evolution of SMS.

Keywords Formal learning • Hands-on learning • Inquiry-based learning • Pedagogy • Science education • Science Made Sensible • Student-centered learning

2.1 Introduction

Perhaps Albert Einstein put it best when he stated "the fundamental ideas of science are essentially simple and may, as a rule, be expressed in a language comprehensible to everyone" (Einstein & Infeld, 1966). But this is seldom honored. Scientific

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C.B. Leggon, M.S. Gaines (eds.), *STEM and Social Justice: Teaching and Learning in Diverse Settings*, DOI 10.1007/978-3-319-56297-1_2

concepts sometimes are made much more complicated and confusing than necessary due to some educators not relating to their audience and/or falling back on excessive technical jargon.

There is consensus that graduate programs fail to prepare future scientists to communicate clearly (Trautmann & Krasny, 2006; Bettinger, Long, & Taylor, 2016). We train graduate students how to do scientific research—not how to talk about it. They learn to teach through pure empiricism, as they teach a laboratory course or first present research at a professional meeting.

Ignorance can be a serious constraint upon effective teaching. Numerous studies of middle school teachers (Kennedy, 1998; Garet, Porter, Desimone, Burman, & Yoon, 2001; Desimone, Porter, Garet, Yoon, & Birman, 2002) emphasize that teachers' limited content knowledge accounts for superficial curriculum coverage and a focus on memorization rather than inquiry learning. Such teaching does not engage learners.

It is during middle school, when instruction is often rote and poorly presented, that learner interest and achievement in science begin a steady decline (Osborne, Simon, & Collins, 2003). This has elicited worldwide concern that not enough schoolchildren and young adults are entering the science, technology, engineering, and mathematics (STEM) disciplines (Gallant, 2010). Among those who do pursue such tracks, diversity is lacking. Therefore, globally, educators are faced with the challenge of making science sensible and attractive, piquing young learners' interest in STEM education early in life so that they then consider it as a career path. Amplifying this challenge is the fact that learners from underrepresented groups in the inner city historically have been excluded from access to a quality education (Clark, 2014).

So how does one make science sensible? Young learners often have a preconceived notion of what a scientist is, does, and looks like. Science needs to be made accessible and misconceptions need to be corrected so that learners can not only begin to understand science, but also to see themselves as scientists.

Research reveals a connection between having positive experiences with science and the development of interest in science (Bulunuz & Jarrett, 2010). There is much to be said for incorporating hands-on, inquiry-based learning activities in the science curriculum. Many researchers including Benford and Lawson (2001), Gerber, Cavallo, and Marek (2001), and Zimmerman (2000) reported that inquiry-based instruction can promote scientific reasoning abilities. When learners see and experience science first-hand, they are more likely to understand and retain the concepts being taught. By engaging learners in the practices of science, we can help them begin to understand what science is and how scientific knowledge develops and advances (National Research Council, 2011).

In this chapter, we present the Science Made Sensible (SMS) program as an example of formal learning, a program with the purpose of making science sensible by transforming students from passive to active learners using an inquiry-based approach. In our program, graduate and undergraduate students, referred to as "resident scientists," collaborated with K-12 public school science teachers in Miami, Florida, USA and Pretoria, South Africa to incorporate student-centered learning into the curriculum. We emphasized hypothesis testing, measurement, data collection, and quantitative analyses.

2.2 The Original Miami Model: Design and Implementation

From 1999 to 2011, the National Science Foundation (NSF) Graduate Teaching Fellows in K-12 Education (GK-12) Program funded over 300 projects at different universities throughout the USA (Ufnar, Kuner, & Shepherd, 2012). Over 10,000 STEM graduate students were supported by this program, impacting thousands of schools, their teachers, and learners (Mervis, 2011). Science Made Sensible (SMS) is one such project.

SMS is based on a hands-on/minds-on learning model (Haury & Rillero, 1994). Its basic premise is that when learners are physically involved in science they are more likely to be mentally engaged. Inquiry-based learning refers to the pedagogical approach that uses the general processes of scientific inquiry as its teaching and learning methodology (Ketpichainarong, Panijpan, & Ruenwongsa, 2010). Not only does it promote science content, it also promotes learners' habits of mind, creative thinking, problem-solving ability, science process skills, and understanding of the nature of science (Hofstein & Lunetta, 2003). Kubicek (2005) emphasized that inquiry-based learning should include the basic skills to conduct a scientific investigation as well as an understanding of how scientists do their work.

In 2007, SMS began as a partnership between the University of Miami (UM), Florida, USA and Miami-Dade County Public Schools (M-DCPS). M-DCPS is the nation's fourth largest school system, with 347,000 learners enrolled in 392 schools, which includes 57 middle schools (grades 6–8) and 66 high schools (grades 9–12). The diverse K-12 learner population reflects Miami's role as a "Gateway to the Americas" with 69.2% of learners being Hispanic, 21.8% Black Non-Hispanic, 7.3% White Non-Hispanic, and 1.8% other, which includes Native American, Alaskan Native, Asian, Pacific Islander, and Multiracial. M-DCPS learners speak 56 different languages (primarily Spanish, Haitian Creole, and English) and come from 160 different countries. Almost 20% of M-DCPS learners are classified as limited English proficient, and 72% qualify for free or reduced price lunch. Approximately 50% of high school seniors who go on to college attend Miami Dade College, a local community college, which graduates the highest percentage of underrepresented minorities with associate degrees of any two-year institution in the nation (Miami Dade Country Public Schools, 2016).

The SMS program was designed to address the interrelated problems of scientists' failure to communicate sensibly, school teachers' lack of grounding in science, and the decline between grades 4 and 8 in science and mathematics achievement scores in the USA (Gonzales et al., 2008). These problems are recognized, but they are often considered independent issues and, consequently, are addressed separately. With SMS, we consider these problems systematically and synergistically.

In the beginning years of the program, SMS paired UM graduate students in the STEM disciplines (SMS fellows), serving in the role of "resident scientists," with local inner city middle school science teachers. The aim of the program was to (1) improve the communication and teaching skills of graduate students, (2) enhance the professional development of middle school teachers, and (3) advance scientific curiosity and learning among middle school learners.

SMS graduate fellows worked in a total of 12 poor-performing middle schools in inner city Miami. By working with an SMS fellow in their classrooms, learners were exposed to innovative exercises and science experiments that stimulated their interest and engagement in class, and improved their academic performance; we hope that this will lead to an increased likelihood of these learners pursuing an education in science at the tertiary level.

Each academic year, from 2007–2008 through 2012–2013, from 7 to 11 UM graduate students and a matching number of Miami-Dade County middle school science teachers from multiple schools were selected to participate in the program after submitting an application and being interviewed by the program director, Prof. Michael Gaines, and the program coordinator. Prior to the start of the school year, those selected to participate engaged in a two-week summer institute at UM. Each day, the institute focused on a different topic, including classroom management, written and oral communication skills, cooperative learning, team building, metacognition, directed discussion and effective questioning, promoting and assessing critical thinking, problem- and case-based learning, and formative and summative assessment. SMS fellows and teachers collaborated to develop both scientific teaching skills and inquiry-based lesson plans that met Miami-Dade County's Next Generation Sunshine State Standards. At the beginning of the institute, each SMS fellow was paired with one teacher to collaborate with during the academic year at one Miami middle school.

Each SMS fellow worked with his/her teacher partner for 10 h per week over one continuous academic year in grade 6, 7, or 8 science classrooms. They focused on making the science education experience interesting and exciting for middle school learners, implementing the lesson plans and activities developed during the summer institute. When possible, they integrated the disciplines of mathematics, biology, chemistry, and physics in the lessons. They also assisted learners with science fair projects and helped them to prepare for state standardized testing. For example, in a given class period, the SMS fellow/teacher team would introduce a science topic to the learners by engaging them through the use of a PowerPoint lecture, educational video clip, or a demonstration lab. Then to aid learners in grasping the topic, the SMS team would invite them to participate in an inquiry-based lesson plan. In one such lesson plan on the scientific method, learners were given a container of crickets to observe and then read a comic strip about crickets which led to a question about what type of food crickets prefer. With the teacher and resident scientist facilitating, learners worked together as a class to decide how they would set up an experiment to study cricket food preference (given orange slices and granola bars as the food items). Learners had to identify the independent variables, dependent variables, and then develop a hypothesis. Then in small groups, learners carried out the experiment, collecting data, and graphing their results (Lesson created by SMS fellow S. Bignami, in 2011). Through this activity, learners applied their understanding of the scientific method to a real-world question.

To date, more than 100 original lesson plans have been created and disseminated through the SMS program. Supplies needed to implement lesson plans were purchased and stored at UM in a room easily accessible by the SMS team. Unused and leftover supplies were returned to this supply depot for future use.

Another aspect of SMS was the annual development of a communal science project across participating SMS schools. Learners from each school worked together to collect data on a selected research topic. One of these projects, called "Dig-it," involved learners in a research project about soil and plant growth. Learners collected soil at their homes or in their neighborhoods, brought the samples to class and measured pH, nitrogen, phosphorus, and potash levels. They then hypothesized about the effects of these variables on plant growth, planted seeds in their soil samples, and measured plant growth in height daily over a two-week period. Through these communal projects, learners practiced their scientific research skills and got experience in scientific responsibility, cooperation, and collaboration. Additionally, each SMS fellow incorporated his or her dissertation research into classroom activities throughout the school year. The learners were excited to experience first-hand research by a real "resident scientist." This debunked misconceptions about all scientists being old white men wearing lab coats. Through SMS, learners interacted with scientists of all ethnicities, ages, and genders.

Throughout the academic year, the program director met with the SMS fellows biweekly to discuss relevant topics and issues, and to check in with fellows about progress in their classrooms and the status of the partnerships with their teachers. Twice a semester, the SMS fellows, teachers, and program director met for a workshop at UM, which served as a forum for discussing challenges and best practices in terms of communication and teaching.

At the end of each academic year, the fellow and teacher participants were invited to attend a capstone event at UM hosted by the SMS program director. University and school district administrators, as well as the SMS fellows' research mentors, also attended the event. Learners from all participant schools were invited to enter an essay contest explaining how the resident scientist working with their teacher made science more sensible. One winner from each school was selected to attend the capstone with his/her family members. At the capstone, the year's activities were highlighted, SMS fellows and teachers presented their most engaging lesson plans, and learners read their winning essays out loud to the audience describing the positive impact that the SMS program had on their understanding of and interest in science.

2.3 Institutionalization and Evolution of the Miami Model

The NSF ended its GK-12 education program in 2011, though it continued to fund programs that were already in progress. During the 2013–2014 academic year, SMS transitioned from NSF funding to become institutionalized at UM. With this institutionalization came program changes, the major change being that instead of graduate students in STEM going into the public school science classrooms, undergraduates in STEM assumed the role of resident scientist. The impact of this current model is broader than that of the original model. Institutionalization has allowed for expansion to include high school teachers and learners. The goals of the institutionalized model reflect this expansion and mirror the original SMS program objectives. The current goals are to: (1) improve communication, teaching, and mentoring skills of UM science students; (2) enhance the professional development of middle school and high school teachers; and (3) advance the scientific curiosity and learning of middle school and high school learners.

The program is now structured around a tiered-mentoring multigenerational model; graduate students mentor advanced undergraduate students who in turn mentor middle and high school learners. Also, middle school teachers interact with high school teachers, and graduate students and undergraduates work with the teachers to develop inquiry-based lesson plans. Undergraduates and graduate students are selected to participate after submitting an application, which includes a short essay on why they would like to join SMS, and interviewing with the program director and program coordinator. Twelve STEM undergraduates and six STEM graduate students participate each year. Each undergraduate student is paired with a middle school or high school science teacher from one of the three middle schools or three high schools selected by the M-DCPS district.

The undergraduate "resident scientists" go into middle school and high school science classrooms for 6 h per week, bringing learners inquiry-based, hands-on activities. Undergraduates receive six course credits in biology and/or chemistry during their two-semester full academic year commitment. They are required to commit to the full academic year to provide the learners with continuity, stability, and time to build a positive rapport. The graduate students mentor two undergraduates each, meeting with them biweekly to assist in lesson plan development. The graduate students visit their undergraduates' classrooms once each semester. The program director meets with the undergraduate and graduate students biweekly during the fall and spring semesters. As in the original SMS model the teachers, graduate students, and undergraduates all attend four weekend workshops during the academic year to discuss challenges and best practices for communication and teaching.

2.4 Effectiveness and Challenges of SMS in Miami

To evaluate the SMS program's success in meeting its goals and objectives, we used a mixed methods approach with confidential surveys administered to participants and focus group interviews conducted by an external evaluator towards the end of each academic year. The same surveys also were given to non-SMS program participants for comparison. This evaluation approach has been effective in gathering feedback on the effects of the program on all groups. Based on 5 years of data from the original model and 2 years of data from the current model, we are able to summarize the outcome of our program thus far and gauge the extent to which we have accomplished our goals.

Quantitative and qualitative data support the success of the original SMS model in attaining the program's three goals to: (1) improve the communication and teaching skills of graduate students; (2) enhance the professional development of middle school teachers; and (3) advance the scientific curiosity and learning of middle school learners. SMS graduate student fellows became more confident about explaining their research to a lay audience. All but one of the 46 fellows (98%) strongly agreed/agreed that after participating in SMS they felt adequately prepared to explain their research to non-scientists. SMS fellows also reported feeling better prepared to talk about their field of study to the general public (100% strongly agreed/agreed). SMS teachers benefited, too. Almost twice as many SMS teachers reported feeling confident in their ability to implement lab activities that reinforce lessons on almost anything in the curriculum compared to teachers who did not participate in SMS (82% SMS teachers vs. 47% non-SMS teachers). Additionally, SMS teachers reported feeling more confident lecturing about science (97%) than non-SMS teachers (84%). Each year we had teachers and schools asking us to continue working with them the following year, which is a testament to the positive impact of SMS.

The greatest impact of SMS has been on the learners. Over 2000 learners from the poorest-performing schools in Miami's inner city participated in SMS between 2007 and 2013. The majority of these learners (84%) reported that they really understood the science taught in their class. Most learners (85%) strongly agreed/agreed that they did many science labs, and 78% strongly agreed/agreed that they learned how to apply science outside of school. The learners' excitement about having a resident scientist in the classroom is captured in their evaluations of the program: 84% strongly agreed/agreed that having a scientist in the classroom helped them to understand science, and 88% strongly agreed/agreed agreed that they would like a scientist to work in their future science classes (Fig. 2.1).

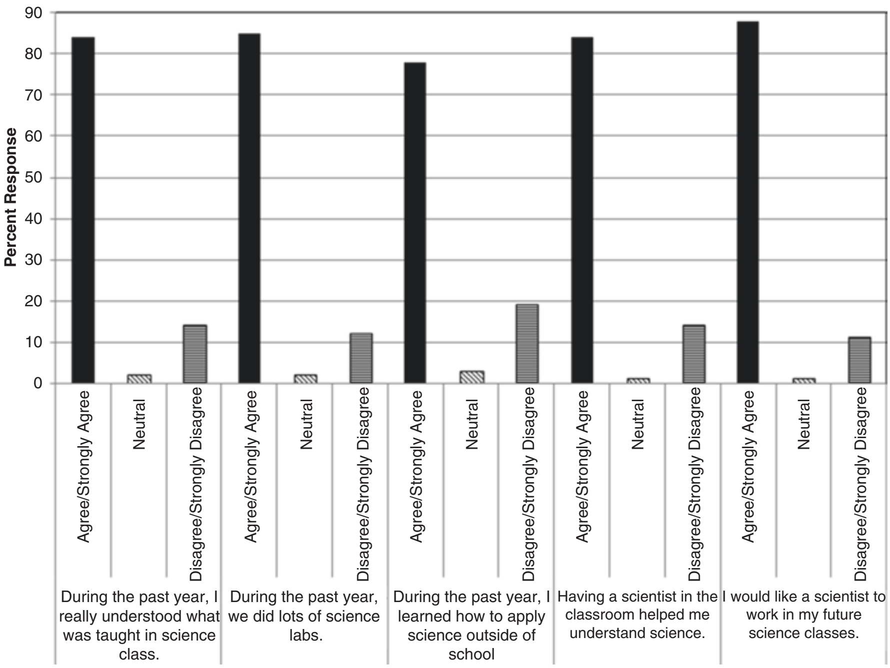

Fig. 2.1 Learner responses to five program evaluation statements for years 2007–2012 when graduate student "resident scientists" worked in public middle school science classrooms in Miami ($n = 2079$)

Evaluation of the first 2 years of the current institutionalized model reveals similarities and differences compared to the original model. The institutionalized SMS model gives graduate students experience with mentorship and hones their communication skills, although they do not get the same level of practice with communicating science to a lay audience. This is reflected in the fellows' survey responses. All but one (91%) of the graduate fellows felt that SMS positively affected their communication skills, and 73% strongly agreed/agreed that as a result of being an SMS fellow, they gained confidence in making conference or seminar presentations. Seventy-three percent said SMS improved their graduate education. Most undergraduates who have participated in SMS also reported that the program has positively affected their verbal and/or written communication skills. One hundred percent strongly agreed/agreed that SMS helped them to gain confidence in making presentations. All but one student, who was neutral, said that SMS improved their undergraduate education. As expected under the new program structure, the SMS undergraduates, who are now the resident scientists in the classrooms, reported greater benefits from the program than did the graduate fellows, who now participate in a smaller capacity as mentors.

The high school and middle school teachers who responded to an evaluation regarding their participation in our new SMS model reported high satisfaction with the program. All but one of the middle school teachers who responded to the survey also participated in the old model and have been a part of the SMS program for multiple years. All of the high school teachers strongly agreed/agreed, and all of the middle school teachers strongly agreed that they would recommend SMS to other science teachers. All but one high school teacher, who was neutral, strongly agreed/agreed that they gained confidence in incorporating hands-on activities and quantitative exercises into the science curriculum; all of the middle school teachers strongly agreed. The self-reported benefits of the program to the alumni middle school teachers may be greater than for the new teachers since the alumni teachers have had multiple years to work on their professional development through the SMS program.

The majority of middle school (90%) and high school (70%) learners strongly agreed/agreed that having a scientist in the classroom helped them to understand what was taught in their science class (Fig. 2.2). Compared to the original SMS model, a lower percentage of learners strongly agreed/agreed that they participated in many science labs over the past year with a resident scientist in the classroom (72% of middle school learners compared to 45% of high school learners). This may be in part due to scheduling: the undergraduate resident scientists have less flexible schedules than the graduate student fellows did and are required to spend less time in the classroom compared to the SMS graduate fellows who participated in the original SMS model. The majority of middle school (64%) and high school learners (55%) strongly agreed/agreed that they learned how to apply science outside of school; this is less than the percentage of middle school learners (78%) who strongly agreed/agreed under the original model. The graduate fellow resident scientists under the old SMS model came into the science classrooms with more experience in both teaching and science in general than did the undergraduate resident scientists in the new SMS model. The graduate fellows are more effective in the classroom in terms of teaching and learning science than the undergraduate students are.

Similar to the original model, 92% of middle school and 81% of high school learners strongly agreed/agreed that having a scientist in the classroom helped them to understand science. This consistency with both SMS models illustrates that learners like having a resident scientist—regardless of whether he/she is a graduate student or undergraduate student—in their classroom, and respond well to having a role model regularly present in the class. More middle school learners (84%) than high school learners (75%) strongly agreed/agreed that they would like to have a scientist work in their future science classes (Fig. 2.2). The middle school learners seem to benefit more than the high school learners based on their self-evaluation of SMS. This may reflect the power and effectiveness of early intervention. High school learners, having gone through more schooling than middle school learners, are perhaps more set in their ways of learning and are used to the traditional high school science classroom where they are passive rather than active participants in their education. High school learners may not be as open to learning from a resident scientist as middle school learners are, and find engaging in hands-on learning difficult. This is a style unfamiliar to the older high school learners who may be uncomfortable with new ways of learning compared to the middle school learners.

Focus group interviews conducted with both original model and institutionalized new model resident scientists and teachers revealed similar challenges faced in the classroom. Learner behavioral issues sometimes detracted from the resident scientists'

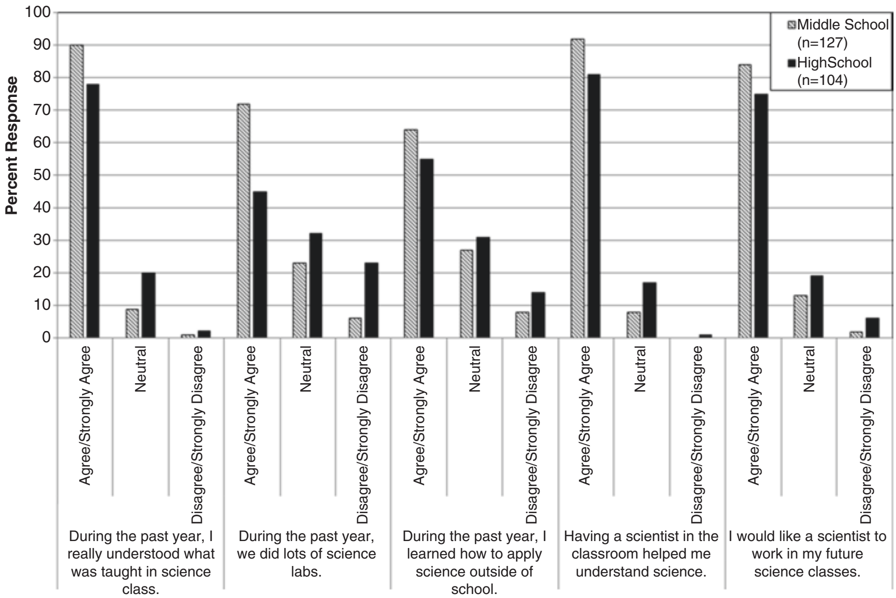

Fig. 2.2 Learner responses to five program evaluation statements for the 2014–2015 and 2015–2016 academic years when undergraduate student "resident scientists" worked in public middle school (n = 127) and high school (n = 104) science classrooms in Miami

and teachers' ability to effectively implement the inquiry-based lesson plans they developed. They also found at times that it was difficult to implement their inquiry-based lesson plans within a structured curriculum and while working around a heavy testing schedule. Large classes at some schools made it challenging to engage learners especially those with different educational backgrounds and levels of preparation.

Despite the challenges, SMS is successfully enhancing the education of middle school learners and high school learners. They are exposed to more hands-on lab activities and benefit from having a resident scientist role model in their science classroom. High school learners especially become more excited and more interested in attending college by having an undergraduate resident scientist in their class. During a focus group interview, one high school teacher remarked that before the resident scientist was coming to her/his classroom there was no discussion of college and science. Once the resident scientist began coming into the class, the learners began talking frequently about college and science. Upon hearing about the success of the SMS program, other M-DCPS schools have inquired about participating in the program. The word is out; this model makes a difference in the science classroom.

2.5 The Original South Africa Model: Design and Implementation

Due to the success of our SMS program in Miami, we extended the program internationally. In spring 2009, we were awarded an international supplement grant to our NSF GK-12 SMS program. This supplement allowed us to involve select graduate fellows and teachers in teaching activities in South Africa. Our overarching goals were to learn about South Africa's educational system, develop lesson plans in collaboration with Pretoria middle school teachers, and share effective pedagogical techniques used in the classroom.

We chose South Africa because of its environmental and social parallels with South Florida. The problems in many South African schools mirror the problems in Miami's inner city schools. First, there are achievement gaps among learners from different ethnic groups, and between groups of different socio-economic status (Frempong, Reddy, & Kanjee, 2011; National Research Council, 2011). These problems, coupled with a lack of teachers' content knowledge in the basic sciences and inadequate educational resources for underserved populations in some public schools of both countries, could eventually result in shortages of scientists, technologists, engineers, and mathematicians. Second, in both countries, there is an achievement gap—specifically, a disparity in test scores and persistence rates (Clark, 2014)—between different ethnic groups. According to the 2014 National Science Foundation Science and Engineering Indicators report (National Science Board, 2014), White learners in grades 4 and 8 in the USA performed approximately 12% higher on the National Assessment of Educational Progress test in mathematics and science than did their Black counterparts. In comparison, data from the National School Effectiveness Study that randomly tracked a national cohort of learners for 3 years, beginning in grade 3 in 2007, shows that mean literacy scores for learners in former Black African schools are less than half of those for learners in historically White schools (Taylor and Muller in Clark, 2014). The educational divide in both countries, coupled with language barriers (three languages in Miami, and 11 languages in South Africa), inadequate teacher training, and lack of educational resources, could eventually result in shortages of individuals in STEM fields in both the USA and South Africa.

To initiate the SMS South Africa program, we first connected with the University of Pretoria (UP), South Africa. Prof. Rian de Villiers, a staff member in the UP Department of Science, Mathematics and Technology Education, arranged for our SMS team to work in the 6th and 7th grade classrooms of middle schools in the Pretoria area. Prof. de Villiers liaised with the Pretoria schools each year to determine which science teachers would participate in SMS.

During the pilot year and all subsequent years, our application to enter schools and interact with teachers and learners in Pretoria was approved by officials in Gauteng Province in which Pretoria is located.

To protect the privacy of participants, the participating middle schools are referred to as Schools A, B, C, and D. The language of instruction at all schools is English. School A is located in a densely populated township, which is generally associated with a peri-urban area (suburb), where residents belong mainly to a low-income group. Schools B, C, and D are urban schools and former Model C schools situated in a middle class area (according to apartheid policy, a Model C school was designated for White learners).

At School A, staff and learners are Black and Zulu-speaking. Class sizes are large with up to 40 learners in a class. In the natural sciences classes, learners do not sit at desks, but rather stand at desks all day long. At School B, approximately half of the staff is White but 99% of learners are Black and Zulu or Sotho-speaking. The average class size is 35 learners per class. The natural sciences classrooms are well resourced. At School C, the staff is predominantly White and only a few teachers are Black or mixed race. More than 95% of the learners in this school are Black, and speak Sotho, Zulu, or Xhosa. The class sizes are relatively small with no more than 30 learners in a class. At School D, 98% of staff is White and all learners are Black and Sotho-speaking; classes can accommodate 30 learners.

Graduate fellows and middle school teachers who participated in SMS in Miami were invited to apply to participate in SMS in South Africa. Interested individuals submitted an application and were interviewed by the SMS program director and program coordinator. Prior to departure for South Africa, selected fellows attended an orientation session at UM led by the program director, and were instructed to adhere to UM travel procedures for students.

The program director appointed teacher–fellow teams to a Pretoria school (predetermined by Prof. de Villiers). Selected participants on both continents were then connected by email, so that they could discuss the curriculum that would be covered during the program and begin lesson planning. Supplies for the program were either purchased on site in South Africa, or were purchased in Miami and brought to South Africa by the SMS team.

Four SMS graduate fellows, two SMS Miami science teachers, and the SMS director piloted the international program. After participating in an orientation session upon arrival in South Africa led by a South African faculty member and a meet-and-greet session between Miami and South Africa participants, the team spent a week working with teachers and learners at two middle schools in Pretoria. Participants were divided into teams, each consisting of two Miami graduate fellows, one Miami science teacher, and one Pretoria science teacher. The international SMS teams collaborated to create and implement lesson plans that related to the science topics being taught in the classroom.

As a result of the positive response to SMS in South Africa, we were approved by NSF to continue the program for two additional years. In August 2010 and 2011, we expanded our program to include three middle schools and we lengthened the number of days spent in the schools to 2 weeks.

2.6 Institutionalization and Evolution of the South Africa Model

The SMS South Africa program was supported with NSF funding from 2009 through 2012. Starting in 2013, the program was institutionalized and fully supported by UM funds. As a result, the program was slightly modified to mirror the institutionalized SMS program in Miami. Also, we addressed the main concern from the original South Africa model, which was that program participants wanted increased classroom/lesson plan preparation, as well as to increase the amount of time spent in the school classrooms.

UM graduate students in STEM no longer participate in SMS South Africa. Instead, four undergraduate students from UM's School of Education and Human Development are selected to participate in the program. These undergraduate students plan to enter teaching careers following completion of their undergraduate degree. Student teacher participants are selected by the program director and program coordinator at the end of the fall academic semester of their junior year; they then enroll in a three-credit course at UM during the spring semester. The course prepares them for the upcoming summer experience in South Africa, and they develop and solidify lesson plans that they will later implement in the Pretoria schools. Following completion of the course, the four students, accompanied by the program director, travel to South Africa for 3 weeks to teach science. As in the original model, an onsite orientation and meet-and-greet session in Pretoria occur shortly after the team arrives in South Africa. We continue to partner with the same middle schools as we did since the start of the program in 2009.

2.7 Effectiveness and Challenges of SMS in South Africa

Reflecting on the SMS South Africa program revealed several similarities and differences between South African and American learners. Although these are generalizations based on our limited experience working with the education systems of a few schools in Pretoria and Miami, we feel they are worth mentioning nonetheless.

The Pretoria schools operate on a traditional bell-and-block schedule, similar to the Miami schools. The number of school days per year in Miami and Pretoria are comparable. We learned that all teachers in Pretoria must be certified to teach science, as is the case in Miami. The Pretoria science curriculum is continuously updated as in Miami, and the themes and topics are taught uniformly within a specified time frame. The South African counterpart to the Miami-Dade County Sunshine State Standards is the South African Curriculum Assessment and Policy Statements.

Language barriers in the classroom are a problem common to both Pretoria and Miami—although it is more prevalent in the former. South Africa has 11 recognized languages, whereas in Miami there are 3 languages commonly encountered in the classroom (English, Spanish, and Creole). In addition, there is a continuous influx of people to South Africa from neighboring countries, which increases the language diversity and can make course instruction challenging.

However, there was a notable difference in the teacher–learner relationship; this relationship was much more formal in the Pretoria schools than what we had experienced in Miami schools. The Pretoria learners whom we met were very respectful in the way that they addressed all authority figures in the classroom. The Miami learners in SMS tend to be more informal in the way they interacted with their teachers and other authority figures. The teacher-to-learner ratio appears to be an increasing problem in the Pretoria schools. There were 35–40 learners per class during our visit. Despite the large class sizes, discipline did not appear to be an issue. This was not the case in some schools we worked with in Miami, where the average class size is 25. We were extremely impressed with the Pretoria learners' respect for educators and intense enthusiasm for their education.

Another difference was the sense of community. There was a strong sense of community in the Pretoria schools that is not always apparent in the Miami schools. This sense of community was facilitated in part by daily morning meetings of all teachers and school-wide assemblies in the courtyard, which often included singing and dancing. The substitute for such daily meetings in the Miami schools we work in is done over an intercom system or television broadcast as learners sit in their classrooms.

Finally, in the Pretoria schools there seemed to be a great deal of flexibility in how and when the curriculum was delivered to the learners. There appeared to be fewer concepts that needed to be covered, yet these concepts were able to be covered in greater depth. The Miami-Dade County school system has a pacing guide that specifies when and for how long certain concepts should be taught. The pacing guide system is beneficial in that it keeps all teachers on a similar timeline. Yet within this pacing guide there are often many concepts that must be taught in a short period of time. Therefore, the teacher is not able to go into great depth on each concept and there may not be sufficient time for all concepts to be covered.

At the end of each international experience, evaluations were administered to both the Miami and Pretoria participants (teachers, graduate/undergraduate students, and learners). The results of these evaluations reveal the following.

The Miami SMS teachers and graduate fellows developed an appreciation for the common challenges of teaching in Miami and Pretoria. All of the Pretoria teachers strongly agreed that having the SMS team in their classrooms was a positive experience, and that they could introduce the SMS activities into their classrooms. They each felt that their learners benefited from the visit and that they personally benefited from the visit. Furthermore, they each said they were willing to welcome a visit by the SMS team in the future. As for the SMS team, generally participants agreed that their teaching experience in South Africa was a positive experience, and they left with a better appreciation for the common teaching challenges in the city centers of Pretoria and Miami.

Learner responses to surveys administered in years 2011 and 2012 are in Fig. 2.3 (original SMS South Africa model with UM graduate students as the "resident scientists"). Results mirror those of evaluation data collected in years 2014 and 2015 in Fig. 2.4 (institutionalized SMS South Africa model with UM undergraduate students as the "resident scientists"). At least 85% of learners agreed/strongly agreed with each evaluation statement indicating high overall satisfaction with the SMS South Africa program.

The main improvement proposed by all program participants in the original model of SMS South Africa was to increase classroom/lesson plan preparation, as well as to expand our time in the schools to increase the learner, teacher, and institutional impact of the SMS program. These changes have been incorporated into the new SMS South Africa program that is now institutionalized at UM. We now spend almost 3 weeks in the classrooms.

2.8 Lessons Learned and Moving Forward

With this chapter, we present an example of one approach to increasing learner interest and achievement in STEM education at the middle school and high school levels. The ultimate goal is for these young learners, mostly individuals from groups traditionally underrepresented in STEM, to consider a career in science as a viable option—thus diversifying the STEM workforce. At the same time, we sought to increase the communication and mentorship skills of STEM graduate students and the pedagogical skills of undergraduate students and middle school science teachers, which in turn impact learner interest and achievement.

In order to appeal to young learners, we attempted to reduce repetition, memorization, and monotony in the classroom, and shift science education instruction from a passive to an active learning experience. We put "resident scientists" in middle school and high school classrooms to give learners a first-hand perspective of what scientists look like and do. We wanted learners to relate to these scientists and see a career in science as a feasible and achievable goal for themselves and their peers.

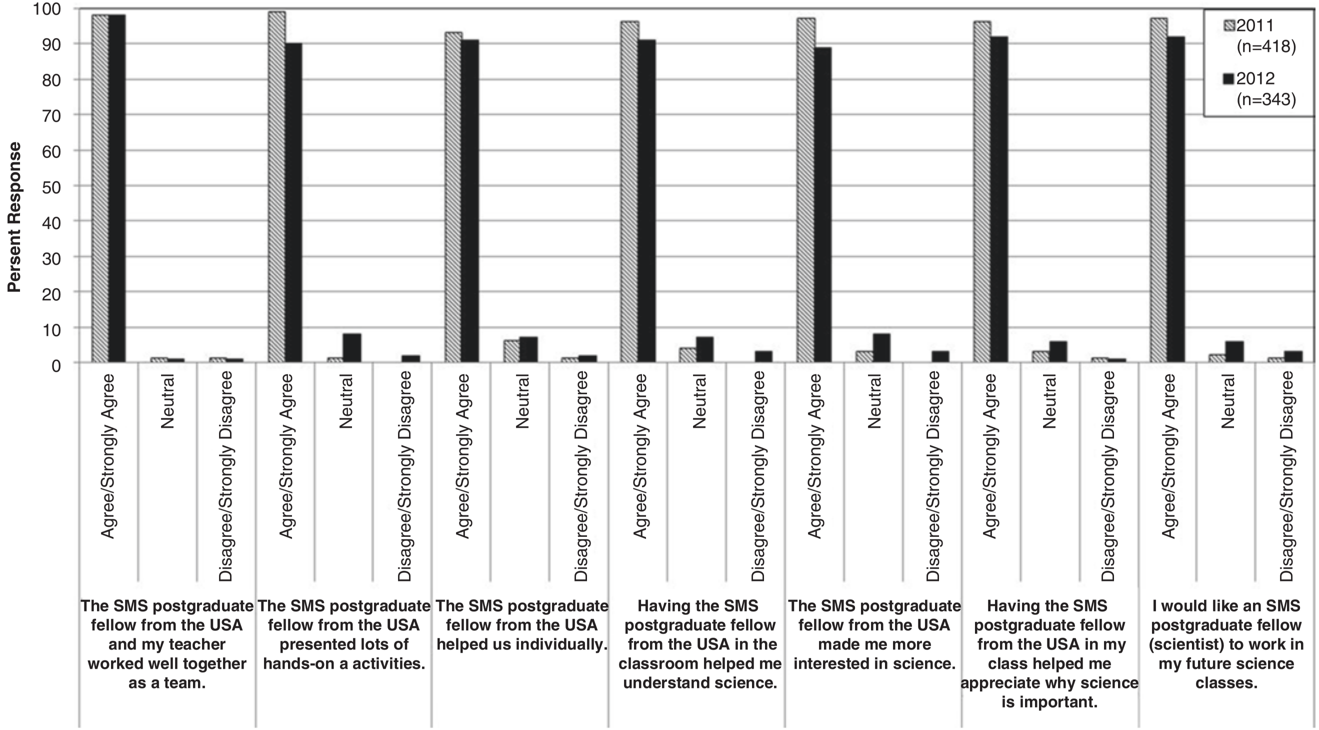

Fig. 2.3 Learner responses to 7 program evaluation statements when graduate students worked in middle school science classrooms in Pretoria. Responses from 2011 include learners at Schools A, B, and C ($n = 418$). Responses from 2012 include learners at Schools A and B ($n = 343$)

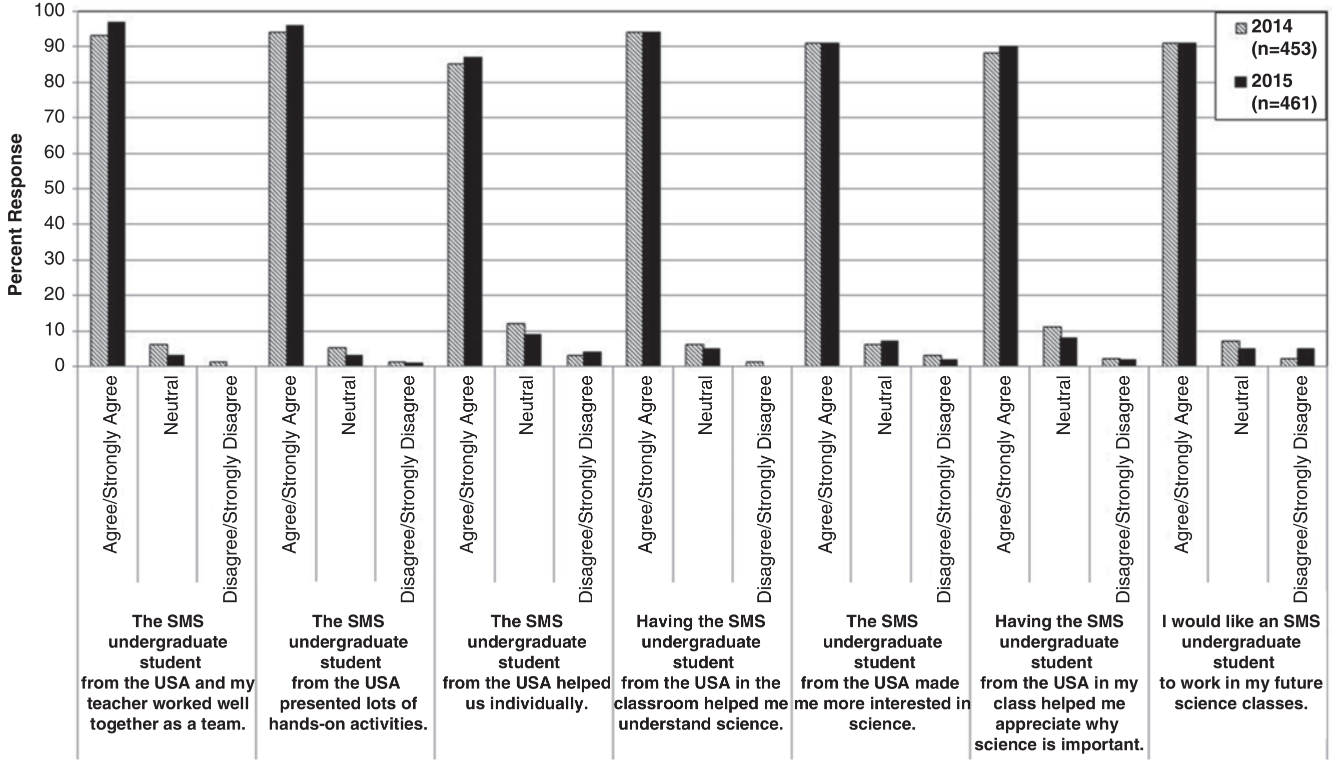

Fig. 2.4 Learner responses to 7 program evaluation statements when undergraduate students worked in middle school science classrooms in Pretoria in 2014 and 2015. Responses include learners at Schools A, B, C, and D

We are not naïve to the fact that the majority of learners touched by SMS will not enter STEM careers. However, we are optimistic that their experience will lead them to become socially responsible citizens who feel prepared to confront environmental and economic societal issues and become empowered to be informed decision makers.

What has been absent from our program since its inception are data on the education and career paths pursued by learner participants. Impeding this tracking process are several factors, including learners who move, and the school system not being able to provide the necessary data.

From our experience with the SMS program both nationally and internationally, the most critical factor in making a partnership successful, whether that partnership be between a public school district and a private university, or between two school systems on different continents, is strong communication. Program goals, objectives, and intended deliverables need to be clearly outlined and communicated to all stakeholders (participants, administrators, government officials, and to an extent the local community) at the outset. Additionally, there needs to be trust between parties, and all partners and participants must see the benefits of the partnership and feel valued. Long-term planning is a pre-requisite to launching and sustaining such programs, which is why it is most beneficial to have designated personnel committed to the cause. As with any new initiative, there is the unforeseen and the unplanned. Flexibility and adaptability are thus required to achieve success. When working to sustain a program with institutional funds following completion of a grant funding period, dissemination of program activities is key. In that regard, program leaders are encouraged to share program design, successes, challenges, outcomes and results through published peer-reviewed papers, and presentations and conferences at the local, national, and international levels.

References

Benford, R., & Lawson, A. E. (2001). *Relationships between effective inquiry use and the development of scientific reasoning skills in college biology labs* (Arizona State University, Tempe, AZ, 2001). Educational Resources Information Center (ERIC) Accession No. ED456157.

Bettinger, E., Long, B., & Taylor, E. (2016). When inputs are outputs: The case of graduate student instructors. *Economics of Education Review, 52*, 63–76.

Bulunuz, M., & Jarrett, O. S. (2010). Developing an interest in science: Background experiences of pre-service elementary teachers. *International Journal of Environmental and Science Education, 5*(1), 65–84.

Clark, J. V. (2014). *Closing the achievement gap from an international perspective: Transforming STEM for effective education*. London: Springer.

Desimone, L. M., Porter, A. C., Garet, M. S., Yoon, K. S., & Birman, B. F. (2002). Effects of professional development on teachers' instruction: Results from a three-year longitudinal study. *Educational Evaluation & Policy Analysis, 24*(2), 81–112.

Einstein, A., & Infeld, L. (1966). *The evolution of physics: From early concepts to relativity and quanta*. New York: Touchstone Books.

Frempong, G., Reddy, V., & Kanjee, A. (2011). Exploring equity and quality education in south africa using multilevel models. *Compare, 41*(6), 819–835. doi:10.1080/03057925.2011.607488.

Gallant, D. J. (2010). *Science, technology, engineering, and mathematics (STEM) education*. New York: McGraw-Hill Education [Online]. Available: https://www.mheonline.com/research/assets/products/555d6702c950ecb7/stem_education.pdf.

Garet, M. S., Porter, A. C., Desimone, L., Burman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal, 38*(4), 915–945.

Gerber, B. L., Cavallo, A. M., & Marek, E. A. (2001). Relationships among informal learning environments, teaching procedures and scientific reasoning ability. *International Journal of Science Education, 23*(5), 535–549.

Gonzales, P., Williams, T., Jocelyn, L., Roey, S., Kastberg, D., & Brenwald, S. (2008). *Highlights from TIMSS 2007: Mathematics and science achievement of U.S. fourth- and eighth-grade students in an international context* (NCES 2009–001Revised). Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education.

Haury, D., & Rillero, P. (1994). *Perspectives of hands-on science teaching*. Columbus, OH: The ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

Hofstein, A., & Lunetta, V. (2003). The laboratory in science education: Foundations for the twenty-first century. *Science Education, 88*(1), 28–54.

Kennedy, M. (1998). *Form and substance in in service teacher education* (Research Monograph No. 13). Madison, WI: University of Wisconsin, National Institute for Science Education.

Ketpichainarong, W., Panijpan, B., & Ruenwongsa, P. (2010). Enhanced learning of biotechnology students by an inquiry-based cellulose laboratory. *International Journal of Environmental and Science Education, 5*(2), 169–187.

Kubicek, J. P. (2005). Inquiry-based learning, the nature of science, and computer technology: New possibilities in science education. *Canadian Journal of Learning and Technology, 31*(1), 51.

Mervis, J. (2011). Outrage greets NSF decision to end STEM fellows program. *Science, 331*(6021), 1127.

Miami-Dade County Public Schools (2016). *Statistical Highlights 2015–2016*. [Online] Available: http://oada.dadeschools.net/.

National Research Council (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics*. Committee on Highly Successful Science Programs for K-12 Science Education. Board on Science Education and Board on Testing and Assessment, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

National Science Board. (2014). *Science and engineering indicators 2014*. Arlington VA: National Science Foundation (NSB 14-01).

Osborne, J. A., Simon, S. B., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049–1079.

Trautmann, N., & Krasny, M. (2006). Integrating teaching and research: A new model for graduate education? *Bioscience, 56*(2), 159–165.

Ufnar, J. A., Kuner, S., & Shepherd, V. L. (2012). Moving beyond GK-12. *CBE-Life Science Education, 11*, 239–247.

Zimmerman, C. (2000). The development of scientific reasoning skills. *Developmental Review, 20*, 99–149.

Chapter 3
Te Rōpū Āwhina: A Model for Building Post-Secondary Māori and Pacific STEM Capability in Aotearoa/New Zealand

Liz Richardson, Zaramasina Clark, Sonja Miller, Hazel Phillips, Ken Richardson, Andrew Tarr, and Te Rōpū Āwhina Whānau

Abstract Between 1999 and 2015, Te Rōpū Āwhina Whānau (Āwhina) at Victoria University of Wellington (VUW) substantially increased numbers of Māori (indigenous New Zealanders) and Pacific undergraduate and postgraduate students in the STEM disciplines. Underpinning Āwhina's success was its kaupapa and the creation of an inclusive whānau (family) environment that normalised high expectations, aspirations and achievements, collective success and reciprocity. The kaupapa (goal) of Āwhina was to produce Māori and Pacific STEM professionals who would contribute to Māori and Pacific community development and leadership. Importantly, the Āwhina kaupapa enabled non-Māori and non-Pacific students to contribute as whānau members.

Āwhina included concepts and ideas suggested for indigenous and minority student success in tertiary institutions. Given expected demographic changes over the coming decades, the future wellbeing of all New Zealanders will depend on the success of Māori, Pacific and other minority groups. Central to that is strengthening the STEM capability of Māori and Pacific students and the communities they come from.

In this chapter, we describe what Āwhina was, what it did and why. We provide evidence that Āwhina had a positive influence on Māori and Pacific success in STEM disciplines at VUW, and demonstrate that Āwhina almost closed the equity outcome gap in metrics such as degree completion rates. We also document Āwhina's history, including its struggle for survival, factors that threatened its successful continuation, and ways to mitigate those threats.

Keywords Māori • Pacific • Whānau (family) • Minorities • Tertiary success • STEM • Underrepresented • Mentoring • Evidence-base • Culture change

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C.B. Leggon, M.S. Gaines (eds.), *STEM and Social Justice: Teaching and Learning in Diverse Settings*, DOI 10.1007/978-3-319-56297-1_3

3.1 Introduction

The population of Aotearoa/New Zealand is small (4.6 million (Statistics New Zealand, 2014, 2015b)), and increasingly diverse. Most of New Zealand's population (74%) are European, with Māori (the indigenous people of New Zealand, 14.9%), Asian (New Zealanders of Asian descent, 11.8%), and Pacific (New Zealanders descended from the indigenous peoples of Pacific Nations, 7.4%) comprising most of the remainder[1] (Statistics New Zealand, 2014). However, Māori and Pacific populations are expected to grow more rapidly than the European population with projected increases of 3.9%, 3.1%, and a decrease of 9.0%, respectively, between 2013 and 2038 (Statistics New Zealand, 2015a). Both Māori and Pacific people do not fare well in metrics of inequality when compared with New Zealand's European population for indicators such as smoking, obesity, unemployment, median weekly income and income distribution, access to the internet in the home, and proportion holding a Bachelor's degree or higher (Marriott & Sim, 2014). According to the 2015 OECD economic survey for New Zealand, Māori, Pacific, and low-income households are worse off than others for income, housing, health, and education outcomes (Carey, 2015).

Over a third of students currently in compulsory schooling identify as Māori or Pacific (Ministry of Education, 2015d), and these proportions are expected to increase over the next two decades (Statistics New Zealand, 2015a). However, outcomes in secondary (Ministry of Education, 2015a) and tertiary (Juhong & Maloney, 2006; Scott, 2005) education are not consistent with population demographics. For example, in compulsory schooling in 2014, the percentage of school leavers meeting university entrance requirements was only 14.5% for Māori students and 20.4% for Pacific students compared with 43.6% of European and 64.1% of Asian students (Ministry of Education, 2015c). At tertiary level Māori and Pacific students have attrition rates for Bachelors degrees of 43% and 48%, respectively, whereas New Zealand European or Asian students have attrition rates of 27% and 23%, respectively (Ministry of Education, 2014a). Relative to the total population, lower proportions of Māori and Pacific students complete undergraduate degrees, and the situation is worse at postgraduate level. These disparities exist to an even greater extent in science, technology, engineering, and mathematics (STEM) subjects, especially at postgraduate level (Ministry of Education, 2014b; Wilson et al., 2011).

Victoria University of Wellington (VUW), one of eight universities in New Zealand, is located in New Zealand's capital city, Wellington. Within its wider boundaries, the city has a population of around 470,000 people of which 8% are Pacific and 13% Māori (Statistics New Zealand, 2013). Approximately 19,000 students attend VUW, 80% of whom are European, 10% Māori, 5% Pacific, 13% Asian, with 5% identifying as 'other'[1] (Tertiary Education Commission, 2015). The university has

[1] Non-exclusive ethnic categories.

nine faculties, including science, engineering, architecture, and design, referred to hereafter as the SEAD faculties, which cover STEM and STEM-related disciplines. Non-SEAD faculties include Law, Humanities and Social Sciences, Education, and Business.

Between 1999 and 2015 Te Rōpū Āwhina Whānau (Āwhina) in the SEAD faculties at VUW addressed disparities in tertiary STEM and STEM-related outcomes for Māori and Pacific students. After the retirement of the SEAD Deputy Dean Equity in December 2015, a fundamental change to SEAD equity programmes was instituted by senior VUW managers. To ensure the lessons of Āwhina's achievements are not lost this chapter tells the story of Āwhina, where it came from, what it was, what it did and why, and summarises some evidence of its impact on SEAD disparities at VUW. The chapter concludes with an exploration of factors that inhibit broader uptake of promising initiatives like Āwhina by tertiary institutions and which may also undermine their long-term sustainability, and suggests ways to mitigate these threats.

'Māori' is a collective term given to the indigenous people of New Zealand. Historically, Māori comprised numerous hapū and iwi (sub-tribes and tribes), each with their own identity reflected in their knowledge systems, dialects, values, and practices but the primary social unit underpinning Māori identity was, and remains, whānau (family). The term Māori was in use prior to the arrival of European colonisers, but its use today to collectively refer to the whānau, hapū, and iwi of the indigenous people of Aotearoa is a post-colonial construct (Wilson et al., 2011).

Beginning in earnest in the early eighteenth century, Aotearoa was colonised by European settlers, becoming a British Colony through the signing of the Treaty of Waitangi in 1840 between the British Crown and some (though not all) Māori chiefs throughout the country. The Treaty established protocols for Māori and Pākehā ('Pākehā' refers to all people of European descent) to live by. Importantly, it also established a set of rights for Māori that included self-determination and equality. However, despite the Treaty Māori were marginalised by colonisation, losing their ability to determine their own future. State-provided education was a primary tool for assimilation into the colonising culture. By the 1960s assimilationist policies, institutional racism, classroom bias, and Māori disengagement had generated glaring social disparities (Bishop & Glynn, 2003; Titus, 2001). More recently, education has been seen by Māori as a way to realise their aspirations and 'tino rangatiratanga' or self-determination; that is, to be Māori as defined by Māori (Penetito, 2004). This has led to the establishment of kaupapa Māori (by Māori, for Māori) initiatives, including Māori-medium schooling and Māori tertiary institutions or wānanga (Wilson et al., 2011).

The multiethnic, heterogeneous Pacific population in New Zealand has grown since the 1940s due to immigration policies designed to meet demands for unskilled labour (Ongley & Pearson, 1995). In the 2013 New Zealand census (Statistics New Zealand, 2014), the Pacific group included people from Samoa, the Cook Islands, Tonga, Niue, Tokelau, Fiji, Kiribati, Nauru, Papua New Guinea, Solomon Islands, and Vanuatu. The four largest groups of Pacific peoples living in New Zealand are Samoan, Cook Islands, Tongan, and Niuean, with almost 2 in every 3 Pacific people born in New Zealand (Statistics New Zealand, 2014). In this chapter we use the term Pacific to refer to New Zealanders of Pacific origin, even though the term does not reflect the ethnic diversity within Pacific communities (Coxon, Anae, Mara, Wendt-Samu, & Finau, 2002; Ferguson, Gorinski, Samu, & Mara, 2008; Penn, 2010).

Over the last three decades neoliberal ideas, increasingly adopted by successive governments in New Zealand, Australia, Canada, the UK, and the USA, have substantially impacted policy agendas (Boston & Eichbaum, 2014; Roberts, 2007). Competition became the norm for individuals, state-owned enterprises, and public institutions, including compulsory education and funding for tertiary education and science. 'User-pays' policies were also applied to many areas including health and education (Roberts, 2007). However, the economic dividends hoped for by the government following the neoliberal reforms did not eventuate, generating instead greater income inequality and poverty. New Zealand's GINI coefficient (a common measure of inequality) has increased over the last 30 years to rank among the highest in the OECD (Boston & Eichbaum, 2014).

According to the 2015 OECD economic survey for New Zealand, equity in educational outcomes is weak, the level of income inequality is well above the OECD average, and the jobless poverty rate is high. In terms of New Zealanders' knowledge and skills, although the proportion of people with Bachelor's degrees or higher is increasing for all ethnic groups, the proportion for both Māori and Pacific is still 40% and 50% lower, respectively, than that of European New Zealanders (Marriott & Sim, 2014). Similarly, although the tertiary participation rates for all ethnic groups are increasing (Marriott & Sim, 2014), for Māori and Pacific the increase is mainly in non-degree qualifications (Ministry of Education, 2015b). Moreover, a key metric of educational success is qualification completion, rather than participation, yet greater proportions of Māori and Pacific students enrolled in Bachelor degrees do not complete relative to all students (Ministry of Education, 2014a). If the nation is to develop a highly skilled workforce to support predicted increases in employment in high knowledge areas this situation must change (McKinley, Gan, Jones, & Buntting, 2014).

There is also global recognition of the importance of diversifying the STEM workforce, with diversity acknowledged as bringing new perspectives to STEM fields (Committee on Underrepresented Groups and the Expansion of the Science and Engineering Workforce, 2011; O'Brien, Scheffer, van Nes, & van der Lee, 2015; Robinson & Dechant, 1997). For example, even though minorities are the fastest growing portion of the population in the USA they are underrepresented in STEM disciplines (Leggon & Pearson, 2009).

3.2 Āwhina: Capability-Building for Success

The outcomes achieved by Te Rōpū (the group) Āwhina (to support) whānau (family)[2] in the SEAD faculties at VUW are the result of a whakapapa (ancestry) of successful initiatives for underrepresented students established by the lead author Liz Richardson over several decades at secondary level in New Zealand and Britain. These included tertiary programmes at Waikato University (supported by Science Faculty Dean, Professor Ken McKay) and between 1999 and 2015 at VUW as the Deputy Dean (Equity) in the SEAD Faculties. The VUW position coincided with the appointment of Pro Vice Chancellor and Dean of Science and Architecture and Design, Professor Peter Englert who appointed Ms. Richardson to a senior SEAD role and tasked the SEAD Management Team to develop a strategic goal of producing Māori and Pacific scientists and engineers. Throughout his time at VUW Professor Englert supported and defended Āwhina and fought tenaciously for equitable outcomes for students. Āwhina was the first faculty-based mentoring programme established and funded by the SEAD faculties. Āwhina started with 16 senior Māori and/or Pacific students who asked their parents/kaumatua for a programme name and waiata (song, and a traditional means of Māori cultural expression).[3] In this case, the waiata was written to reflect the Āwhina kaupapa (goal). Another student provided a poutama (stepped pattern of knowledge and whakapapa (genealogy/ancestry)) logo. The SEAD Deputy Dean (Equity) played a leading role in the growth and development of the whānau until retiring on 21 December 2015, the day Te Rōpū Āwhina ended.

Āwhina was an on- and off-campus whānau (family) with a kaupapa of producing Māori and Pacific graduates in the SEAD disciplines who would become leaders in their communities. As Āwhina was kaupapa-, rather than whakapapa-based, Āwhina members could be of any ethnicity.

Underpinning the kaupapa of Āwhina were whānau values of high expectations, achievements, and aspirations; working and celebrating success collectively; and reciprocity through putting back into Āwhina and into the communities it represented. In short, Āwhina changed the culture of SEAD Faculties to enable Māori and Pacific students to succeed in SEAD disciplines at tertiary level.

Āwhina was resourced by the SEAD Faculties and embodied many of the concepts and ideas suggested for indigenous and minority student tertiary success (BEST, 2004; Hrabowski, 2014; Leggon & Pearson, 2009; Linn, Palmer, Baranger, Gerard, & Stone, 2015; Maton, Hrabowski, & Pollard, 2011; Tsui, 2007). For example, its leader was committed to long-term improvement of Māori and Pacific success in STEM disciplines with a position of influence in the SEAD faculties (Committee on Underrepresented Groups and the Expansion of the Science and Engineering Workforce, 2011; Guillory & Wolverton, 2008; Leggon, 2015; Maton et al., 2011).

[2] In other words, the SEAD supportive family.

[3] Hence the name 'Āwhina' and the Āwhina waiata were kaupapa-based and belonged *only* to Te Rōpū Āwhina whānau.

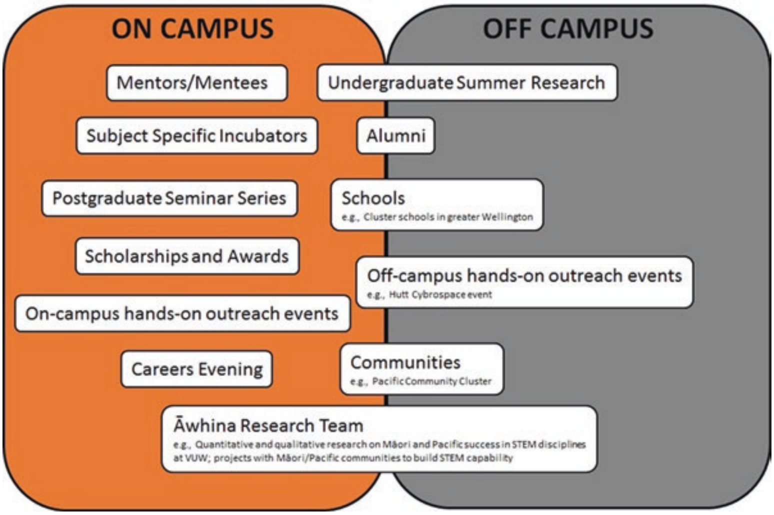

Fig. 3.1 Diagram showing the range of Āwhina activities

Other key aspects of Āwhina included a supportive on-campus whānau environment with a strong kaupapa; high expectations around grades and degree completions; aspiration for postgraduate study; collective success and reciprocity; community connectedness; peer support and mentoring; a (small) budget to cover staff costs, Āwhina events and outreach, scholarships, and casual and fixed-term staff; outreach; academic tutoring; dedicated Āwhina staff; and robust evidence to evaluate success. Importantly, Āwhina also had extensive interactions with, and strong 'buy-in' from, SEAD staff. Such staff were instrumental in assisting, influencing, funding and/or supervising Āwhina summer researchers, providing references for employment/scholarships, assisting with scholarship applications, and helping students facing personal, financial, or academic challenges. Staff also attended Āwhina events, helped with outreach, and donated texts to the Āwhina library. The broad scope of Āwhina's activities and relationships is shown in (Fig. 3.1).

3.2.1 On-Campus Whānau

Āwhina's backbone was the on-campus mentor–mentee relationship. Both mentors and mentees (as well as their whānau) were supported by senior student and staff mentors, career and community mentors. In turn, Āwhina on-campus mentors worked with their 1st year and 2nd year mentees to build the academic momentum required to succeed, and to train their mentees to become mentors.

Mentors were high achievers in their subject areas, and often but not always, final year undergraduates or postgraduates. Mentors in their second year of study also worked with 1st year mentees to fill gaps in subject areas where there were few mentors at 3rd year or postgraduate level, e.g., mathematics, engineering, computer science, biomedical science. The primary role of mentors was to be a first stop for academic help in their subject specialty areas, to assist mentees with the transition from high school to university, and to academically strengthen first and second year mentees.

Prior to the second trimester ending, new mentors were identified (1) by asking mentors to recommend mentees who would be good mentors, and (2) from mentee's first trimester grades (B+ grade or higher). Before the end of the academic year, prospective mentors were invited to have a kanohi ki te kanohi (face to face) discussion about becoming a mentor. This discussion was followed up just before the start of the first trimester of the following year to assess mentor commitment. All mentors were then invited to a meeting at the start of trimester 1 to welcome them for the year and prepare/brief them for their mentoring role. This meeting was also the first opportunity during the year for the mentors to come together as a whānau and for those who were new to get to know other mentors.

Potential mentees were given information kanohi ki te kanohi about Āwhina and where they could sign up. These notifications took place a number of times through the year, but the most crucial times were during orientation week, i.e., the week prior to the start of the academic year. During orientation most students were already on campus preparing for another year of study. A range of orientation sessions were held during this week, and senior Āwhina mentors spoke at selected sessions to let new SEAD first year students know about Āwhina, e.g., the SEAD new student orientation sessions, the new Pacific students session at the Pacific Orientation, and the new Māori students session at the Māori orientation. Core first year courses were also targeted by Senior Āwhina mentors who let all students know about Āwhina, its kaupapa and whānau values, what Āwhina did, and if students were interested, where they could find out more and sign up. Signing up to Āwhina required explicit agreement with its kaupapa and whānau values.

Once mentees joined Āwhina they were assigned a mentor in the same degree major by the Āwhina Office Team. Most returning mentors continued working with their existing mentees but would also take on new mentees where possible. Mentors made initial contact with their mentees to meet up kanohi ki te kanohi, and decide on a time to meet in the whānau rooms for regular study sessions. In addition, mentors were also asked to run a 1 h whānau room session during the week to help mentees and other whānau members with specific papers. Mentors and mentees were encouraged to work in the Āwhina whānau rooms when not in class, and to work with others doing similar papers. All whānau members were also reminded that the whānau rooms were 'business spaces' where they could ask for help from other whānau members and help others.

Mentors played a key role in transitioning mentees into the university environment, with mentors more likely to come from backgrounds similar to their mentees, giving them an understanding of, and ability to cope with, the unique pressures faced by Māori and Pacific and other minority students. The mentor/mentee relationship was often long-term. For example, mentees would ask their mentors for advice before and after completing their degrees. Mentors helped ensure mentees had a suitable degree programme and had considered postgraduate study. Senior mentors were expected to ‘step-up’ and take on responsibilities for the running of Āwhina such as monitoring whānau room compliance, helping to organise outreach or special events, and co-ordinating mentors. Depending on levels of responsibilities, individual mentors received a modest stipend or award. In line with the Āwhina kaupapa, the expectations on mentors were high, with mentors expected to be positive role models at all times, to support one another, and to show leadership. These leadership experiences within Āwhina prepared them for leadership roles in the workplace, and in their communities.

3.2.2 Āwhina Incubators

Another important aspect of the on-campus Āwhina Whānau developed after 2012 were Āwhina Incubators, led by senior Āwhina mentors or SEAD academic staff. These were small Āwhina whānau groups in the same degree programme but at different levels who worked together to improve whānau outcomes. Incubators met for sessions lasting between 1 and 2 h on a weekly basis and for revision sessions in Trimesters 1 and 2 exam study breaks. Throughout 2015 Āwhina incubators existed for: biology, biomedical science, biotechnology, chemistry, computer science, engineering, environmental science, geology and geography, marine biology, maths, statistics, and psychology and were well attended.

3.2.3 Āwhina Whānau Rooms

Although all students were invited to be part of Āwhina, only those who signed up to Āwhina and its kaupapa and whānau values could access the Āwhina whānau rooms. Āwhina had four whānau rooms funded by SEAD and physically located within SEAD schools and faculties to bring together and normalise the relationship between Āwhina whānau members, staff, and other students. The rooms provided secure 24/7 accessible study spaces for mentors to work with their mentees, and for whānau members to work in groups or study individually. Computer workstations were available in each room, along with printing facilities. Whānau rooms were dedicated study spaces with strict rules for activities that could occur, and an expectation that the whānau would abide by those rules. Large notice boards inside the room displayed Āwhina undergraduate and postgraduate students’ posters of presentations at national and international conferences. The outside wall of the whānau room added another dimension by providing up to date information about Āwhina to whānau and passers-by.

3.2.4 Āwhina Budget

Āwhina had a modest budget that covered the salary and operational costs of 1–2 (1999–2010) or 2.6 (2011–2015) full-time permanent staff to provide the continuity required in a capability-building area. The leadership role was at a senior and influential level (Deputy Dean) within SEAD, providing the autonomy necessary to sustain a culture of success for minority and indigenous students.

The Āwhina budget also covered Āwhina Awards and Scholarships, casual staff, conference travel to present, and Āwhina functions. Costs associated with the whānau rooms were covered by the eight SEAD schools in the three faculties.

3.2.5 Āwhina Scholarships and Awards

A portion of the Āwhina budget was used to support Āwhina whānau members with awards and scholarships. Āwhina Awards helped Āwhina mentors and mentees complete degree programmes, while the main objective of Āwhina postgraduate awards was to increase progression to, and completion of postgraduate studies. Both Āwhina Awards and Āwhina Postgraduate Awards acknowledged whānau members who made significant contributions to Māori and Pacific development and leadership through their work with Āwhina whānau members and their communities. Āwhina Scholarships helped postgraduate Āwhina whānau with their studies, assisting with activities such as attending conferences to present their research, travel for field work, and other research costs. Āwhina whānau who received scholarships were exceptional mentors and role models that demonstrated a commitment to the Āwhina kaupapa such as contributing to Āwhina outreach, mentoring and supporting other whānau members, and attending Āwhina events. The Āwhina budget also supported Āwhina Summer Research Scholarships which exposed undergraduate 2nd and 3rd year students to the research environment by providing a stipend for 10 weeks of research over the university summer break. Through Summer Research Scholarships, students established relationships with supervisors who often became their postgraduate supervisors. Āwhina fully funded or co-funded (50:50) the Summer Research Scholarships with SEAD Schools.

3.2.6 Āwhina Library and Study Resources

The Āwhina library included a small, well-stocked collection of current prescribed course textbooks, many donated by SEAD staff, or koha (gifted) by Āwhina graduates. Other resources for whānau members included scientific calculators to use and past exam papers for revision. Previous Āwhina Summer Scholarship reports were also available for borrowing.

3.2.7 *Āwhina Website*

The Āwhina website established in 2000 brought together on-campus whānau activities and outreach, and off-campus outreach events, kept whānau updated and raised the profile of Āwhina in the community. Significantly, the website engaged directly with Āwhina students and their communities, low decile secondary schools, pupils, parents, and supporters. The website was created and maintained by Āwhina staff and mentors despite pressure to adopt a corporate approach.

3.2.8 *Āwhina Resources*

Āwhina whānau members also produced a number of outreach and on-campus resources to support secondary school pupils, parents, and teachers including: 'Te Whata Kura Ahupūngao', bi-lingual (Māori and English) multimedia online Physics Resources; three inspirational booklets (Cybrospace Journeys to Success, Cybrospace Journeys to Success Reloaded, and Cybrospace Journeys to Success Revolutions) that profiled emerging Māori scientists, engineers, architects, and designers and provided useful tips for tertiary study; the 'STEP into STEAD' (STEAD = SEAD + Technology) DVD where mentors 'busted myths' around what it takes and who succeeds in SEAD subjects and created the 'If we can do it so can you!' challenge to rangatahi (youth). Over 20,000 booklets were distributed to school pupils and teachers, communities, marae, supporters, and Āwhina whānau members. These resources were funded by Te Puni Kōkiri (Ministry of Māori Development); The Māori Education Trust; and Professor Sir Paul Callaghan, Professor of Physical Sciences and founding director of the MacDiarmid Institute for Advanced Materials and Nanotechnology at VUW. We acknowledge their generosity and significant contributions to building future leaders.

3.2.9 *Āwhina Postgraduate Seminars*

From 2003 onwards Āwhina Postgraduate Seminars (APGS) became the vehicle to support rapidly increasing numbers of postgraduate whānau members, providing a regular forum for presenting their research to the whānau. Presentations covered a broad range of SEAD disciplines including transport and open space planning (geography), development of 5G wireless technologies (engineering), pain experience (psychology), Von Staudt Calculus & Rank 3 matroids (maths), the development of Church Pacific Architecture in New Zealand (architecture), chemical defence in plants (chemistry), and many more.

The APGS was open to all whānau members. Final year undergraduates were encouraged to attend as this helped to reduce barriers to postgraduate study by exposing whānau members to the postgraduate environment. Āwhina students were also encouraged to do research of relevance to them and their communities.

3.2.10 Āwhina Birthdays

Āwhina Birthdays were the largest and most popular event in the annual calendar, and, along with Career Evenings, were compulsory for all whānau members. Birthdays evenings began with a whakatau (informal Māori greeting) and singing of the Āwhina waiata. An Āwhina mentor Master of Ceremonies (MC) ensured the event kept to time and introduced guest speakers (often alumni, but not always). The focus of the evening was to strengthen Āwhina whānau connections, acknowledge Āwhina whānau successes, and have some fun. This was achieved by bringing together food, entertainment from mentors and mentees (in which everyone participated), guest speakers, and presentations from Summer Research students. The event ended with a photograph for the Āwhina website.

3.2.11 Āwhina Alumni

Many Āwhina alumni kept in contact after leaving VUW, creating opportunities in the workplace for student internships, employment, and scholarships. Local alumni participated in annual careers evenings, sharing their knowledge and experiences of the job market, workplace, career development, and networking.

3.2.12 Āwhina Careers Evenings

Annual Āwhina Careers evenings began in 2009 and were popular with current whānau members, alumni, communities, and supporters. Victoria University Careers staff were staunch supporters of Āwhina, attending all Āwhina careers events, sharing their knowledge and alumni contacts, and assisting mentors to prepare for interviews. As with Birthdays, Careers evenings began with a whakatau and singing the Āwhina waiata. An Āwhina mentor MC introduced guest speakers. This was followed by supper and a 90-min expo that gave students an opportunity to question a wide range of employers (private and public sector, and entrepreneurs). Students often secured internships, summer scholarships, and positions from these events. Presenters received a kete (bag) containing koha and Cybrospace booklets. The event ended with a photograph of everyone who attended. Many who attended supported the Āwhina kaupapa and encouraged colleagues to participate in further annual events. Their commitment helped to develop an excellent Āwhina Careers database.

3.2.13 Āwhina Outreach

Āwhina outreach activities were important to the academic success of Māori and Pacific pupils. They provided pathways for secondary school students into STEM disciplines, and opportunities for Āwhina mentors to gain teaching experience and put back to their communities. Outreach activities happened both on- and off-campus and required significant effort, often involving a large team of mentors and staff to create, pack, and transport the resources before events, run events, and then transport, unpack, and store the resources after events. The Āwhina kaupapa of 'giving back' was central to Āwhina whānau outreach success as was the 'if we can do it so can you!' message.

3.2.13.1 On-Campus Outreach

These events brought rangatahi from intermediate and secondary schools on to campus where they met and worked with mentors and staff and were exposed to the tertiary SEAD environment, opening up options for tertiary STEM studies.

A good example of a large on-campus event was the all-day *Te Rōpū Āwhina hands-on 'Cybrospace'* event at VUW sponsored by Te Puni Kōkiri. Approximately 750 rangatahi (years 7–13, aged 11–18) and whānau from 32 North Island secondary and intermediate schools attended the event. Participants explored a range of exciting and challenging activities in architecture, biological sciences, marine sciences, chemistry, computer science, design, earth sciences, engineering, physics, and psychology at three of the university campuses. Students were transported by bus between campuses and spent 45 min on each of the activities.

Smaller outreach events on campus were the yearly *Cluster Schools on campus Rangatahi in Cybrospace* events where approximately 120 students from Āwhina Cluster Schools came on to campus to take part in all day hands-on SEAD activities with Āwhina mentors and SEAD staff in the second trimester break (in the 3rd school term). These involved 6 groups of up to 20 students rotating around 6 different SEAD activities, spending 30 min at each. In 2015 the activities included developing game strategies (mathematics), a virtual reality experience with the Oculus Rift (engineering), learning how to track wildlife (biology), examining the UV blocking properties of sunscreen (physics/chemistry), viewing features of rock-forming minerals in section under the microscope (geology), and the 'egg drop challenge' where students designed a structure to protect an egg from breaking when dropped from 5 m (architecture and design).

Summer Cybrospace Wānanga were residential 3–4 day events for a maximum of 40 years 12 and 13 (16–18 years old) students from regional schools to participate in hands-on activities equivalent to 1st year university study in SEAD laboratories prepared and run by SEAD staff and senior Āwhina mentors. Notices were sent to Principals with a request to forward information to senior staff. Rangatahi were selected by their teachers. Parental permission was required along with a template completed by them and returned to the Āwhina Office. Āwhina and iwi covered all costs. Subject disciplines included: physics, chemistry, biology, mathematics, statistics, architecture, design, psychology, marine biology, engineering, computer science, geography, geology, and environmental science. Specific activities included participation in a laboratory class where sea urchins were spawned, gametes fertilised, and developmental stages observed. This was followed by a field trip to look for invertebrate egg masses on the rocky shore. Another activity involved designing a pendant using digital technology (2D computer aided design software), which was then laser cut from acrylic. Students formed design teams to create pre-specified structures from supplied materials. Of the rangatahi who participated in Summer Cybrospace Wānanga, 40% enrolled in university study, with over 60% of these students enrolling at VUW.

3.2.13.2 Off-Campus Outreach

Off-campus community outreach took place when Te Rōpū Āwhina was invited to be part of community events to encourage the transition to higher education, and inspire rangatahi to consider careers in STEM disciplines. Events happened anywhere from the beach to the marae (meeting ground). Examples included Āwhina involvement in the 'Te Tai Timu Trust: Turning the Tide' wānanga (learning/lesson) held in Hawkes Bay. Te Tai Timu Trust runs programmes to motivate rangatahi to become future rangatira (leaders). Between 50 and 70 tamariki (children) and rangatahi aged 7–16, travelled from all over the country to participate in a 5 day wānanga, develop water safety skills, and become kaitiaki (guardians) of the ocean. Āwhina mentors ran biology activities such as DNA extractions and marine-related hands-on science. Āwhina also supported the Wairarapa Rural Education Activities Program (REAP), a programme that facilitates workshops highlighting career opportunities to Wairarapa (a region of New Zealand) school students. Teams of Āwhina mentors from the schools of Architecture and Design, Chemistry, Physics, and Biology ran hands-on activities relevant to their areas of expertise. Architecture and Design mentors worked with students to build cantilevered structures that support a small weight, and students also took part in the 'egg drop' challenge. The chemistry activity involved making flubber (a stretchy substance introducing some properties of polymers and non-Newtonian fluids), while students extracted DNA from fruit for the biology activity. For physics, students learnt about waves. Another large event held in Auckland City, involved Te Puni Kōkiri, Ngāti Whatua (iwi Māori holding manawhenua (territorial rights) in the Auckland area), and Āwhina in an 'Atamira: Māori in the City' expo celebrating Māori creativity and enterprise that was attended by over 100,000 people. Āwhina mentors and SEAD staff focused on, and developed, hands-on SEAD activities as part of the expo.

Āwhina ran its own regular well-attended outreach events off-campus in local communities (*'Cybrospace' events*), the main focus being to expose young people to opportunities in SEAD disciplines. Between 500 to over 1000 school students attended on the day, and as usual the key message was: 'If we can do it, so can you!' For example, the successful *Hutt Cybrospace* full-day event in early 2015 involved over 550 years 9 and 10 students (13–14 year olds) and was partially funded by Hutt City Council. A similar event held in 2010 sponsored by Ngāti Toa (one of the iwi Māori holding manawhenua in the Wellington region) and Te Puni Kōkiri attracted almost 1100 (mainly Māori and Pacific) rangatahi. The event involved SEAD activities created and run by Āwhina mentors and SEAD staff and a harakeke (flax) activity run by pupils from an Āwhina Cluster school.

Āwhina also designed and delivered the *Māori whānau in Science Day* which was held on 22 September 2008 at the Banquet Hall in the Beehive (New Zealand Parliament) in Wellington. Funded by Te Puni Kōkiri and timed to coincide with the launch by the Minister of Māori Affairs of the first Cybrospace Journeys to Success booklet, it attracted over 250 rangatahi Māori and whānau, the Prime Minister, and other Members of Parliament. The event was expo style with small groups of students rotating through physics, chemistry, architecture, design, biology, geology, psychology, maths, computer science, engineering, and mechatronics activities. Other events run by Te Rōpū Āwhina in partnership with communities included a science wānanga for whānau at the opening of Pukemokimoki marae. Excitement for science was generated by concentrating on themes relevant to Māori communities including sessions on DNA/whakapapa and the marine environment.

3.2.14 Āwhina Cluster Schools

Given disparities in educational outcomes evident in compulsory secondary schooling (Ministry of Education, 2015a), particularly for science and mathematics at year 9 (i.e., 13–14 year olds) (Chamberlain & Caygill, 2013), Āwhina developed the first local Āwhina Cluster School in 2009, with four cluster secondary schools established in the greater Wellington area by 2015. Selection of Cluster schools was based on two criteria: (1) commitment by the school (Principal, science teachers) to work with their Māori and Pacific students and Āwhina, and (2) schools were low to mid-decile (high to mid deprivation), and drew students from areas of high deprivation.

The primary focus of the Āwhina Cluster Schools was on academic success at secondary level which was achieved by one or more teachers who took responsibility for the Āwhina cluster and worked with a select group of students on a regular basis (either weekly or fortnightly). Cluster students were also Āwhina whānau members. At the start of each year a launch was held at the school, typically in the early evening to enable the maximum number of school students and their whānau to attend. Cluster launches involved the School Principal (or delegate), the (school) staff responsible for the Āwhina cluster, and welcomed students and their parents, outlining the importance of STEM-related disciplines for future post-secondary study and careers, and encouraging students to persist with STEM subjects and make the most of being part of the Āwhina Cluster. Āwhina mentors and staff also introduced themselves, talked about their own journeys to success in their specific STEM areas, and stressed the 'If we can do it, so can you!' message. Throughout the year cluster school students worked with their teachers and Āwhina mentors on top of their normal science classes. Students came onto campus for the annual *Cluster Schools Rangatahi in Cybrospace* events toward the end of the VUW teaching year.

3.2.15 Pacific Community Cluster

In 2010 Āwhina encouraged and supported the development of a Pacific Community Cluster. Āwhina mentors worked with years 11–13 (15–18 years old) Pacific students every second Saturday during the second university trimester corresponding to the third and fourth school terms (the New Zealand school year has four terms). Students in years 11–13 were targeted by the cluster as this is when students undergo formal national assessment in New Zealand's education system.

3.2.16 The Āwhina Research Team

The Āwhina Research Team (ART) mentored emerging Māori and Pacific researchers to develop partnerships with their communities through relevant research. In 2014 the ART, in partnership with iwi, secured external funding for 2 projects to build iwi and hapū marine and freshwater science capability. The ART published quantitative and qualitative research contributing to a robust evidence-base (Richardson et al., 2014; Richardson et al., 2017; Wilson et al., 2011), some of which will be summarised later. The ART disseminated Āwhina results through international and national publications and presentations, and community meetings. For example, in 2014 ART members presented in Japan as part of an indigenous panel in a human rights themed session on indigenous youth at the 18th ISA World Congress of Sociology—'Facing an unequal world—Challenges for global sociology'. In 2015, ART members also presented at the 17th Biennial International Study Association of Teachers and Teaching Conference (ISATT) conference in Auckland, New Zealand.

Other publications are in preparation, including results from postgraduate Māori–Pacific, undergraduate Māori, and undergraduate Pacific completion rate analyses.

3.2.17 Āwhina Biennial Survey

Survey questionnaires have been distributed to Āwhina students biennially since 1999 with the last survey carried out in 2013. Students were informed of the Āwhina Biennial surveys by word of mouth, email, and notices placed in the Āwhina whānau rooms on campus. The surveys were voluntary, anonymous, and conducted online, comprising open and closed questions. Students responded to questions about their lives both inside and outside university, and the impact of university on their lives now, and into the future. Survey sections included demographic information, academic interest, financial issues, learning support, Āwhina, off-campus resources and activities, and future educational goals. The results of the biennial survey were one component of the evidence-base of Āwhina, and helped to inform practice.

3.2.18 Āwhina Koha

All whānau members contributed in some way to the success of the whānau. Āwhina staff, students, and community members, and Āwhina Research Team members provided koha (gifted time) to develop and run Āwhina events, undertake research relevant to Āwhina, mentor, support, and advocate for whānau members.

3.3 Successes of Āwhina Whānau Members

Robust evaluation is a central component of the Āwhina kaupapa for at least three reasons. First, resources are scarce in a small country like NZ, and it is important that equity initiatives show they are effective in reducing disparities. Unfortunately, while significant public equity funding has been allocated to NZ universities, there is little published evidence of effect. Second, even initiatives with robust evidence of success, or at least of promise, can be improved. Third, successful equity programmes need to be sustained over a long period to achieve and then maintain equitable outcomes. Evidence suggests that this requires strong commitment at both programmatic and institutional level, and this can change over time as staff leave or retire.

Starting with only 16 mentors and 99 mentees in 1999, by 2015 Āwhina had 116 mentors and 229 mentees. Since Āwhina began there have been significant absolute and relative increases in Māori–Pacific (MP) undergraduate and postgraduate degree completions (Richardson et al., 2014). For example, up to 2015 Āwhina had almost 1200 Māori–Pacific degree completions, including 33 PhDs, 9 Postdoctoral fellows, and 9 science/maths/computer science teachers. Āwhina graduates also work in many areas, e.g., the Tertiary Education Commission and New Zealand Qualifications Authority, with 4 employed by their iwi, including one Chief Executive. Āwhina has secured $8.4 million of nationally and internationally contested scholarships for its whānau members.

Āwhina has almost closed the equity outcome gap according to a recent analysis from the ART seeking evidence of an Āwhina effect (Richardson et al., 2017). The analysis used a completion rate metric, based on completions and durations of study derived from a long-term audited VUW post-1991 student record dataset for undergraduate qualifications expected to take about 3 years, e.g., a bachelor's degree. Completion rates were defined as aggregated completions divided by aggregated study time for all students (successful or not) in several strata including ethnicity, faculty group, and (16) 5-year blocks starting from 1995. Medians and credible intervals (uncertainties) were computed from posterior Bayesian completion rate estimates in each stratum then standardised to remove variations in study time across faculty group, ethnicity, and year block.

Completion rate dynamics were probably impacted by several factors but, focusing on just the dynamics of disparity, SEAD MP and non-MP posterior completion rates tracked upwards and converged, consistent with an Āwhina effect. In contrast non-SEAD MP and non-MP posterior completion rates increased before 2007 then declined, but overall there was little change in the ethnic disparity gap.

A similar analysis of postgraduate qualifications expected to take about 2 years shows a trend of decreasing completion rate disparities in the SEAD faculties, but increasing disparities in the non-SEAD faculties (Richardson et al., 2017). Figures 3.2 and 3.3 provide results for an important subset of such qualifications: the Master of Science (MSc) and Master of Arts (MA) degrees. SEAD MP and non-MP MSc completion rates tracked upwards and converged (Fig. 3.2a), consistent with an Āwhina effect and a reduction in disparities (Fig. 3.2b). In the non-SEAD faculties, non-MP MA completion rates increased steadily but MP rates declined after 2004 (Fig. 3.3a), leading to an increase in completion rate disparities during that period.

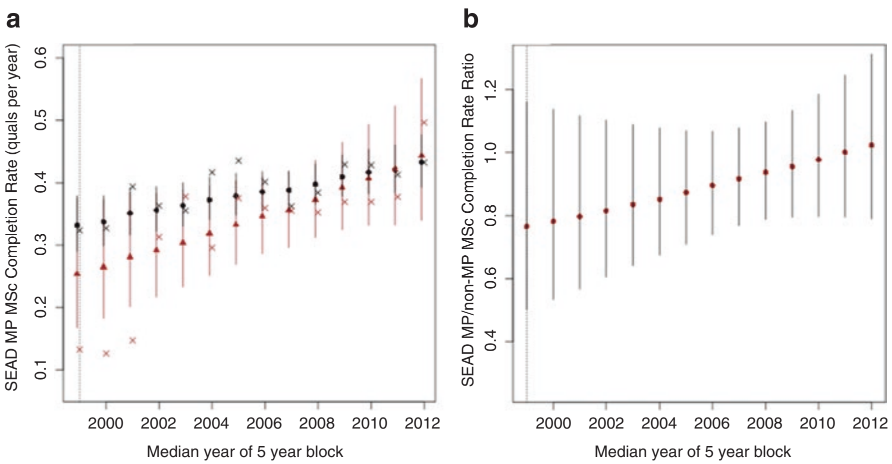

Fig. 3.2 (**a**) Bayesian completion rate estimates for MSc postgraduate degrees in the SEAD faculties for combined Māori–Pacific (MP) students (*triangles*), and all other students (*circles*). The *dotted vertical line* denotes the start of Āwhina. Crosses show empirical completion rates. (**b**) MP-to-non-MP rate ratios

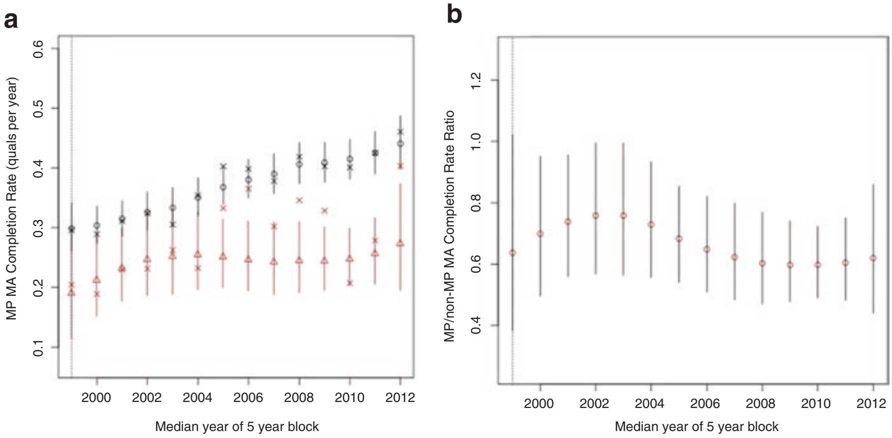

Fig. 3.3 (**a**) Bayesian completion rate estimates for MA postgraduate degrees in the non-SEAD faculties for combined Māori–Pacific (MP) students (*triangles*), and all other students (*circles*). The *dotted vertical line* denotes the start of Āwhina. Crosses show empirical completion rates. (**b**) MP-to-non-MP rate ratios

3.4 Lessons from the Āwhina Experience

Āwhina was one of a handful of initiatives worldwide with robust evidence of success. Key Āwhina characteristics included its kaupapa and strong whānau values, calibre and commitment of staff, broad autonomy to decide/implement the kaupapa (i.e., change the institutional culture), close connections with communities, seniority and permanence of leadership role, stable, and adequate resourcing, and a robust evidence-base. Academic and cultural support was embedded in culturally relevant practices and principles of Māori and Pacific communities, placing value on positive indigenous identities, relationships based on the notion of whānau, and reciprocity. Āwhina shared important characteristics with similar successful initiatives elsewhere, for example, the University of Maryland Baltimore County's (UMBC) Meyerhoff Scholars Program, the Leadership Alliance, and the National Consortium for Graduate Degrees for Minorities in Science and Engineering ('GEM'), where key elements for success include strengthening knowledge and skills, the provision of financial, academic, professional, and social support, network facilitation and professional socialisation, and bridge experiences to transition from one level of educational or professional achievement to another (Leggon & Pearson, 2009).

Diversification of the STEM workforce is critical to NZ's future social, environmental, and economic wellbeing, and there is good evidence from Āwhina and elsewhere about how to achieve that goal. Why then are similar programmes not ubiquitous within NZ, and their long-term sustainability a matter of community, institutional, and national concern? Put another way, given there are promising solutions to address ethnic disparities in tertiary success, and tools for evaluating their success, continued tolerance of disparities reveals something important about the nature of NZ institutions. To suggest possible future areas for investigation and debate, we turn first to international evidence, in particular from the USA. The USA faces similar issues with regard to diversifying the STEM workforce where at a national level there is recognition of the benefits and importance of diversity for business, government, and academia which underpins efforts to increase underrepresented minorities in STEM (Committee on Equal Opportunities in Science and Engineering, 2013; Committee on Underrepresented Groups and the Expansion of the Science and Engineering Workforce, 2011; Maton, Pollard, McDougall Weise, & Hrabowski, 2012; National Science and Technology Council, 2000).

An informative example is provided by UMBC, a majority European-American institution, which has created an environment of inclusivity, excellence, and success for students of all backgrounds. According to Hrabowski (2014), the key to UMBC's success is that each staff member takes responsibility for solving the problem of minority group underrepresentation. Evaluation evidence on the effects of the Meyerhoff Programme at UMBC led to significant gains in governmental and private foundation resources for successful equity initiatives. At the time, few intervention and student enhancement programmes were rigorously evaluated. Ultimately, the success of the Meyerhoff Programme attracted significant national attention as a proving ground for developing talented minority STEM students for graduate/medical school. Interestingly, the success of majority student STEM majors also increased, as did the success of students having higher test scores and high school grade point averages. In short, the Meyerhoff Programme transformed the institution. UMBC is now nationally recognised as an example of inclusivity for all students. This would not have happened without the evidence of the Meyerhoff Programme's effectiveness, and the influence of Freeman Hrabowski (W. Pearson Jr., personal communication, 14 October, 2015). Institutional change is therefore possible, and it is clear at a national level that robust evaluation is an important element in making such change possible. At an institutional and programmatic level there is also evidence that (1) the leader of an equity initiative must be demonstrably committed to the long-term reduction of disparities in STEM disciplines, and have a position of influence in the institution, and (2) the institution must have strong, high level commitment to the equity initiative over the long-term (Allen-Ramdial & Campbell, 2014; Committee on Underrepresented Groups and the Expansion of the Science and Engineering Workforce, 2011). However, key challenges remain around the elimination of institutional barriers. For institutions to be truly committed to equitable outcomes and success for all students, the institutional culture and climate needs to reflect the diversity of individuals making up the student body (Committee on Underrepresented Groups and the Expansion of the Science and Engineering Workforce, 2011; Whittaker & Montgomery, 2012). Long-term assessment of programme effectiveness is another area in need of further attention, requiring longitudinal data (Leggon & Pearson, 2009). Thus, while there is no doubt much work is still to be done in the USA to eliminate STEM disparities in post-secondary education and the workforce, there appears to be a growing understanding of how that can be achieved. As in this country, progress toward that goal probably depends at least in part on how tertiary institutions respond to that evidence, and the development of policy tools to accelerate their response. Some features of US universities such as tenure may be helpful in that regard. However, tenure has been increasingly undermined in the USA as increasing proportions of new faculty are employed on short-term contracts with no tenure-track (Head, 2011). Still, tenure provides faculty with the freedom and autonomy necessary to pursue work in areas of significance and interest to them. As such, tenure plays an important role in some successful US STEM initiatives for under-represented minority students (M Gaines, pers. comm., 27 January 2016).

Even though lessons from Āwhina are broadly consistent with those from successful US programmes, the situation in NZ is much less clear. At a national level, there is public recognition of the importance of MP success in tertiary STEM disciplines (Chauvel & Rean, 2012; Tertiary Education Commission, 2012), but little from business (Sutton, 2014). In addition, apart from Āwhina, there are no NZ examples of properly evaluated tertiary equity initiatives, and there are no examples of culture change at institutional level. This situation is likely to persist in the medium term if, as seems likely, equity initiatives cease to be effective within the SEAD faculties at VUW.

Undoubtedly there are powerful barriers to eliminating tertiary STEM disparities. First, the commitment of tertiary sector leaders to removing tertiary disparities is open to question: while most universities (and the TEC) have long had equity objectives enshrined in strategic documents (Ministry of Education, 2002), and section 181 of the Education Act 1989 places particular emphasis on University Councils having a duty to maximise the education potential of groups in those communities that are underrepresented among its student body, the sector appears to be unresponsive to national or international evidence, and/or unwilling to make the necessary changes. Second, the impact of the neoliberal experiment in NZ after the 1970s has fundamentally changed the nature of universities (Shore & Davidson, 2014) and may have rendered them less responsive to equity issues, as has been suggested in Australia (Schofield, O'Brien, & Gilroy, 2013). Indeed, it would be surprising if NZ universities reversed the national trend toward increasing inequality in areas important to the wellbeing of Māori and Pacific without fundamental changes to the culture of those institutions. One consequence of the neoliberal experiment is that university staff are increasingly on short, fixed-term contracts with no certainty of employment (Tertiary Education Union, 2015), leading to a growing 'underclass' of academics, i.e., in precarious employment (Nadolny & Ryan, 2015). However, evidence from successful initiatives makes it clear that stability of programme leadership and staffing is necessary to build the body of knowledge required for success. Third, the performance-based research fund (PBRF), which concentrates on Western research priorities (Broughton et al., 2015), marginalises research that is of primary relevance to NZ (Curtis, 2015), tangata whenua (Roa, Beggs, Williams, & Moller, 2009), and Pacific communities. The PBRF, established in 2002, assesses and funds tertiary education organisations based on their research performance to 'ensure that excellent research in the tertiary education sector is encouraged and rewarded' (Ministry of Education, 2013). Not surprisingly, therefore, the Āwhina Research Team has been unable to secure NZ funding to undertake research in programme evaluation. Furthermore, the PBRF diverts attention away from activities such as mentoring and teaching that are key elements of Āwhina's success (Boston, Mischewski, & Smyth, 2005).

Given that promising initiatives and methods for their evaluation exist (e.g., Te Rōpū Āwhina, at least until 2015), policy responses at a national level can be devised. For example: (1) significant financial penalties for institutions that fail to reduce disparities; (2) provision of long-term external funding for equity initiatives *having robust evidence of success*; (3) institutions required to evaluate success of equity initiatives using best practice methods and metrics, peer reviewed by external experts; (4) dedicated funding for research aimed at improving equity initiatives and methods of evaluation; (5) public funding for international conferences tasked with sharing experiences and lessons from promising programmes, methods of evaluation, and training of future leaders; (6) a permanent panel of national and international experts to investigate and monitor the provision and maintenance of effective equity initiatives, methods for their evaluation, commissioning of relevant research, and training of future leaders.

Undoubtedly, these policies require significant changes to tertiary institutions and other key actors in the tertiary sector. Such changes are long overdue. In regard to diversification of the STEM workforce, it is time the interests of the country, and in particular of its Māori and Pacific communities, take precedence over entrenched sectoral interests, particularly when everyone benefits as a result. We hope that the lessons from the Āwhina experience summarised here will contribute to that change, and help train the next generation of leaders who accept the responsibility of ensuring that it happens.

Acknowledgments Te Rōpū Āwhina Whānau would like to acknowledge Professor Ken McKay, previous Dean of Science at Waikato University (1992–1997) and Professor Peter Englert, previous Dean of Science and Pro Vice Chancellor of the Faculties of Science and Architecture and Design (1999–2002) who were committed to building an equitable society in Aotearoa; the late Sir Paul Callaghan (1947–2012) who stood up for Āwhina as he did for the MacDiarmid Institute for Advanced Materials and Nanotechnology; community supporters and sponsors; SEAD staff and those Management Team members who supported the Āwhina kaupapa and success for minority groups; Āwhina would not have been successful without the strong commitment of all these people as well as Āwhina whānau members from 1999 until 2015. We acknowledge and thank you all for your significant contributions to helping Āwhina to show what was possible with a collective effort and robust evidence-base. We would also like to thank Willie Pearson for helpful comments and support.

References

Allen-Ramdial, S.-A. A., & Campbell, A. G. (2014). Reimagining the pipeline: Advancing STEM diversity, persistence, and success. *Bioscience, 64*(7), 612–618.

BEST. (2004). *A bridge for all: Higher education design principles to broaden participation in science, technology, engineering and mathematics*. San Diego, CA: BEST-Building Engineering and Science Talent.

Bishop, R., & Glynn, T. (2003). *Culture counts: Changing power relations in education*. London: Zed Books.
Boston, J., & Eichbaum, C. (2014). New Zealand's Neoliberal reforms: Half a revolution. *Governance, 27*(3), 373–376.
Boston, J., Mischewski, B., & Smyth, R. (2005). Performance-based research fund: Implications for research in the social sciences and social policy. *Social Policy Journal of New Zealand, 24*(1), 55–84.
Broughton, D., Te Aitanga-a-Hauiti, T., Porou, N., McBreen, K., Waitaha, K. M., & Tahu, N. (2015). Mātauranga Māori, tino rangatiratanga and the future of New Zealand science. *Journal of the Royal Society of New Zealand, 45*(2), 83–88.
Carey, D. (2015). *Making New Zealand's economic growth more inclusive* (OECD Economics Department Working Papers). Paris: OECD Publishing.
Chamberlain, M., & Caygill, R. (2013). *Key findings from New Zealand's participation in the progress in international reading literacy study (PIRLS) and trends in international mathematics and science study (TIMSS) in 2010/11*. Wellington: Ministry of Education.
Chauvel, F., & Rean, J. (2012). *Doing better for Maori in tertiary settings: Review of the literature*. Tertiary Education Commission. http://maori-lit-review-2013.publications.tec.govt.nz/uploads/TEC-Doing-Better-For-Maori.pdf. Accessed 26 January 2016.
Committee on Equal Opportunities in Science and Engineering (2013). *Broadening participation in America's STEM workforce* (2011–2012 CEOSE Biennial Report to Congress). Arlington, VA: National Science Foundation.
Committee on Underrepresented Groups and the Expansion of the Science and Engineering Workforce. (2011). *Expanding underrepresented minority participation: America's science and technology talent at the crossroads*. Washington, DC: National Academies Press.
Coxon, E., Anae, M., Mara, D., Wendt-Samu, T., & Finau, C. (2002). *Literature review on Pacific education issues: Final report*. Wellington: Ministry of Education.
Curtis, B. (2015). The performance-based research fund, gender and a cultural cringe. *Globalisation, Societies and Education*. doi:10.1080/14767724.2014.996856.
Ferguson, P. B., Gorinski, R., Samu, T. W., & Mara, D. L. (2008). *Literature review on the experiences of Pasifika learners in the classroom*. Wellington: Ministry of Education.
Guillory, R. M., & Wolverton, M. (2008). It's about family: Native American student persistence in higher education. *The Journal of Higher Education, 79*(1), 58–87.
Head, S. (2011). The grim threat to British universities. *The New York Review of Books, 58*(1).
Hrabowski III, F. A. (2014). Institutional change in higher education: Innovation and collaboration. *Peabody Journal of Education, 89*(3), 291–304.
Juhong, B., & Maloney, T. (2006). Ethnicity and academic success at university. *New Zealand Economic Papers, 40*(2), 181–218.
Leggon, C. (2015). African American engineering deans in majority-serving institutions. In J. Slaughter, Y. Tao, & W. Pearson, Jr. (Eds.), *Changing the face of engineering: The African American experience*. Baltimore, MD: The Johns Hopkins University Press.
Leggon, C., & Pearson Jr, W. (2009). Assessing programs to improve minority participation in the STEM fields: What we know and what we need to know In R. G. Ehrenberg & C. V. Kuh (Eds.), *Doctoral education and the faculty of the future* (pp. 160–172). Ithaca: Cornell University Press.
Linn, M., Palmer, E., Baranger, A., Gerard, E., & Stone, E. (2015). Undergraduate research experiences: Impacts and opportunities. *Science, 347*(6222), 1261757.
Marriott, L., & Sim, D. (2014). *Indicators of inequality for Māori and Pacific people*. Wellington: Victoria University Business School.
Maton, K., Hrabowski, F., & Pollard, S. (2011). African American males in the Meyerhoff Scholars Program: outcomes and processes. In H. T. Frierson, & W. F. Tate (Eds.) *Beyond stock stories and folktales: African Americans' paths to STEM fields, Vol. 12* (pp. 47–70). Bingley: Emerald Group Publishing Limited.

Maton, K. I., Pollard, S. A., McDougall Weise, T. V., & Hrabowski, F. A. (2012). Meyerhoff scholars program: A strengths-based, institution-wide approach to increasing diversity in science, technology, engineering, and mathematics. *Mount Sinai Journal of Medicine: A Journal of Translational and Personalized Medicine, 79*(5), 610–623.

McKinley, E., Gan, M., Jones, A., & Buntting, C. (2014). Towards inclusive STEM education for all students. In S. Freeman, S. Marginson, & R. Tyler (Eds.), *The age of STEM: Educational policy and practice across the world in science, technology, engineering and mathematics* (pp. 201–204). Oxon: Routledge.

Ministry of Education. (2002). *Tertiary Education Strategy 2002/2007*. Wellington: Ministry of Education.

Ministry of Education. (2013). *A history and overview of the PBRF*. Wellington: Ministry of Education.

Ministry of Education. (2014a). *Attrition and retention*. https://www.educationcounts.govt.nz/__data/assets/excel_doc/0009/16299/Attrition-rates.xlsx. Accessed 10 Nov 2015.

Ministry of Education. (2014b). *Gaining qualifications*. https://www.educationcounts.govt.nz/__data/assets/excel_doc/0010/16300/Gaining-qualifications.xlsx. Accessed 10 Nov 2015.

Ministry of Education. (2015a). *New Zealand education profile 2013–2014*. https://www.educationcounts.govt.nz/__data/assets/pdf_file/0005/176585/New-Zealand-Education-Profile-2014.pdf. Accessed 21 Jan 2016.

Ministry of Education. (2015b). *Profile & trends. New Zealand's annual tertiary education enrolments 2014*. Wellington: Ministry of Education. https://www.educationcounts.govt.nz/__data/assets/pdf_file/0006/164364/Profile-and-Trends-2014-NZs-Annual-Tertiary-Education-Enrolments-Part-1.pdf. Accessed 8 Dec 2015.

Ministry of Education (2015c). *School leavers with NCEA level 3 or above: University entrance award*. https://www.educationcounts.govt.nz/indicators/main/education-and-learning-outcomes/1891. Accessed 2 Feb 2016.

Ministry of Education (2015d). *School rolls: Roll by FYL & ethnicity 2006–2015*. http://www.educationcounts.govt.nz/statistics/schooling/student-numbers/6028. Accessed 11 Nov 2015.

Nadolny, A., & Ryan, S. (2015). McUniversities revisited: A comparison of university and McDonald's casual employee experiences in Australia. *Studies in Higher Education, 40*(1), 142–157.

National Science and Technology Council. (2000). *Ensuring a strong US scientific, technical, and engineering workforce in the 21st century*. Washington, DC: Executive Office of the President of the United States.

O'Brien, K. R., Scheffer, M., van Nes, E. H., & van der Lee, R. (2015). How to break the cycle of low workforce diversity: A model for change. *PloS One, 10*(7). doi:10.1371/journal.pone.0133208.

Ongley, P., & Pearson, D. (1995). Post-1945 international migration: New Zealand, Australia and Canada compared. *International Migration Review, 29*(3), 765–793.

Penetito, W. (2004). Research and context for a theory of Māori schooling. In F. E. Jandt (Ed.), *Intercultural communication: A global reader* (pp. 173–188). Thousand Oaks: Sage.

Penn, R. (2010). *Manumalo: A study of factors which facilitate success for New Zealand-born Samoan students at university*. Masters thesis, Auckland University of Technology.

Richardson, K., Tarr, A., Miller, S., Sibanda, N., Richardson, L., Mikaere, K., et al. (2014). Āwhina reloaded: Updated results from a programme for Māori and Pacific tertiary graduate and postgraduate success in science, engineering, and architecture and design. In H. T. Frierson (Series Ed.), F. Cram, H. Phillips, P. Sauni, & C. Tuagalu (Vol. Eds.), *Māori and Pasifika higher education horizons: Vol. 15. Diversity in higher education* (pp. 179–200). Bingley: Emerald Press.

Richardson, K., Clark, Z., Miller, S., Pearson Jr, W., & Richardson, L. (2017). Āwhina revolution: A hierarchical Bayesian analysis of undergraduate and postgraduate completion rates from a programme for Māori and Pacific tertiary graduate success in STEM disciplines (submitted).

Roa, T., Beggs, J. R., Williams, J., & Moller, H. (2009). New Zealand's performance based research funding (PBRF) model undermines Maori research. *Journal of the Royal Society of New Zealand, 39*(4), 233–238.

Roberts, P. (2007). Neoliberalism, performativity and research. *International Review of Education, 53*(4), 349–365.
Robinson, G., & Dechant, K. (1997). Building a business case for diversity. *The Academy of Management Executive, 11*(3), 21–31.
Schofield, T., O'Brien, R., & Gilroy, J. (2013). Indigenous higher education: Overcoming barriers to participation in research higher degree programs. *Australian Aboriginal Studies, 2*, 13–28.
Scott, D. (2005). Retention, completion and progression in tertiary education in New Zealand. *Journal of Higher Education Policy and Management, 27*(1), 3–17.
Shore, C., & Davidson, M. (2014). Beyond collusion and resistance: Academic–management relations within the neoliberal university. *Learning and Teaching, 7*(1), 12–28.
Statistics New Zealand (2013). *2013 Census QuickStats about a place: Wellington region*. http://www.stats.govt.nz/Census/2013-census/profile-and-summary-reports/quickstats-about-a-place.aspx?request_value=14322&tabname=. Accessed 8 Dec 2015.
Statistics New Zealand (2014). *2013 Census QuickStats about culture and identity*. http://www.stats.govt.nz/Census/2013-census/profile-and-summary-reports/quickstats-culture-identity/ethnic-groups-NZ.aspx. Accessed 24 Aug, 2015.
Statistics New Zealand (2015a). *National ethnic population projections: 2013(base)–2038*. http://www.stats.govt.nz/browse_for_stats/population/estimates_and_projections/NationalEthnicPopulationProjections_HOTP2013-38/Commentary.aspx#fastest. Accessed 24 Aug 2015.
Statistics New Zealand (2015b). *Population clock*. http://www.stats.govt.nz/tools_and_services/population_clock.aspx. Accessed 8 Dec 2015.
Sutton, A. (2014). *A business lens on STEM. Exploring Auckland business investment in the science, technology, engineering and maths skills pipeline. A scoping document*. COMET Auckland. http://www.cometauckland.org.nz/webfiles/CometNZ/webpages/images/43744/Image_075_STEM_Stocktake_reportV2-75401.pdf. Accessed 26 Jan 2016.
Tertiary Education Commission. (2012). *Tertiary Education Commission Pasifika framework 2013–2017*. Retrieved 28 Jan 2016, from http://www.tec.govt.nz/assets/Forms-templates-and-guides/TEC-Pasifika-Framework.pdf
Tertiary Education Commission. (2015). *The performance of tertiary education organisations. 2014*. Victoria University of Wellington. http://www.tec.govt.nz/assets/EPI-reports-2014/EPI-Victoria-University-of-Wellington-2014.pdf. Accessed 8 Dec 2015.
Tertiary Education Union. (2015). *Casual and insecure work*. http://teu.ac.nz/portfolio/casual-insecure-work/. Accessed 16 Nov 2015.
Titus, D. (2001). *High stakes down under for indigenous peoples: Learning from Maori education in New Zealand; An outsiders perspective.* Paper presented at the Annual Meeting of the National Association for Multicultural Education, Las Vegas, NV, November 7–11, 2001.
Tsui, L. (2007). Effective strategies to increase diversity in STEM fields: A review of the research literature. *The Journal of Negro Education, 76*(4), 555–581.
Whittaker, J. A., & Montgomery, B. L. (2012). Cultivating diversity and competency in STEM: Challenges and remedies for removing virtual barriers to constructing diverse higher education communities of success. *Journal of Undergraduate Neuroscience Education, 11*(1), A44.
Wilson, M., Hunt, M., Richardson, L., Phillips, H., Richardson, K., & Challies, D. (2011). Āwhina: a programme for Māori and Pacific tertiary science graduate and postgraduate success. *Higher Education, 62*(6), 699–719.

Chapter 4
Enhancing Global Research and Education (G-STEM) at Spelman College

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Abstract Across the USA, there is a disproportionally lower number of African-American women who choose to pursue degrees and careers in the STEM (science, technology, engineering, and mathematics) disciplines. Spelman College, a historically Black college and a global leader in the education of women of African descent, has made strategic and focused efforts to increase the international experiences of all students; however, there are specific challenges related to STEM students. To meet these challenges, the "Enhancing Global Research and Education in STEM" program (G-STEM) was created to provide African-American STEM students with formally mentored international research experiences so that they complete their undergraduate STEM major with transformative worldviews. The G-STEM program has created 15 international partnerships, and offers STEM research placements across the globe. A total of 104 students have participated in this program; and 98% of these students have graduated, or are set to graduate. Of those that have graduated, 42% are currently enrolled in STEM graduate programs (MS or PhD) or health-career graduate programs (medicine, nursing, dentistry). These numbers indicate that the exposure to structured international research experiences may significantly influence a student's likelihood of graduation and further pursuit of a career in the STEM disciplines. This chapter reviews the development of the G-STEM program, highlighting successful international research partnership typologies, recruitment and retention practices of underrepresented students, and the development of an integrated mentoring program. Student experiences and outcomes are presented, followed by a discussion of the barriers to STEM student participation in international research experiences.

Keywords STEM education • African Americans • Women • Global research • Undergraduate

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C.B. Leggon, M.S. Gaines (eds.), *STEM and Social Justice: Teaching and Learning in Diverse Settings*, DOI 10.1007/978-3-319-56297-1_4

4.1 Introduction

Spelman College, in Atlanta, Georgia, USA is a college primarily for African-American women. Founded in 1881, Spelman College is "a global leader in the education of women of African descent." Spelman College's 2100 students come from 41 states and 15 foreign countries. Spelman's mission is to empower women to engage the many cultures of the world and to inspire a commitment to positive social change through service.

"Enhancing Global Research and Education in STEM at Spelman College" (G-STEM) began in 2010 as an National Science Foundation (NSF)-funded initiative, with additional funding support received from the United States Department of Education, Title III HBCU-SAFRA, Part F. The primary goal of the G-STEM program is to provide tailored international research experiences to STEM undergraduates, such that a greater number of Spelman STEM students graduate as globally engaged scholars. To accomplish this task, the G-STEM program worked synergistically with different offices and departments on campus to identify various mechanisms by which our students could have access to, and engage in international research experiences. A multifaceted approach was utilized to create and further develop international research experiences for our students. A formal structured mentoring program was developed, such that each student received extensive mentoring related to her research project, as well as support related to international travel. This chapter reviews the development of this program, highlights the successes, lessons learned, and the broader impacts that G-STEM has had on increasing the participation in STEM-related fields of one underrepresented group—African-American women.

4.2 Background and Context

Across the USA, in the early 2000s, approximately 50% of STEM bachelor's degrees and 31% of STEM doctoral degrees were awarded to women (NSF, 2009a). However, in terms of later employment in STEM fields, women constituted only 26% of those with bachelor's degrees, and only 31% of those with doctoral degrees (NSF, 2008). Although the numbers of women entering the STEM disciplines and workforce are low, the number of African-American women already in the STEM disciplines is even lower. African-American women receive only 5.3% of the STEM bachelor's degrees and only 2.6% of the STEM doctoral degrees awarded each year (NSF, 2009b). Of all individuals in the STEM workforce, African-American women constitute only 1.6% of those with bachelor's degrees, and 1.4% of those with doctoral degrees (NSF, 2009b). These numbers clearly indicate large disparities in the numbers of African-American women in the STEM disciplines and workforce.

Not only is there a need for greater representation of minorities within the STEM disciplines, there is also a need to prepare them for the rapid globalization of research and development that has occurred over the past decade. Although the USA, the

United Kingdom, and Germany have been the primary contributors of Science and Engineering (S&E) scholarly research articles (NSF, 2008), there have been many notable advances in research productivity from other countries such as China, South Korea, Brazil, and Turkey (NSF, 2008). In addition, there has been a steady increase in the rate of research collaboration between countries, as measured by the number of co-authored research articles from multiple international institutions (NSF, 2008). These trends indicate a movement toward the globalization of research and science.

These data indicate that women—particularly African-American women—are not well represented in the STEM disciplines. In addition, the rapid globalization in the sciences imposes a high demand for cross-culturally skilled workers with intellectual flexibility. Clearly there is a need to establish innovative strategies for recruiting and retaining in the STEM disciplines African-American women who will be well-prepared to navigate the global environment of STEM education and the workforce.

4.2.1 Spelman College's Opportunities and Challenges

Spelman College is currently ranked 5th in the USA for awarding bachelor's degrees in STEM to African-American students (NSF, 2009b). Spelman is ranked 2nd in the country as the undergraduate institution of origin of African-American graduates who later receive a PhD in a STEM field (NSF, 2009b). Spelman has made a substantial impact, not only on the number of African-American women entering the workforce with STEM baccalaureate degrees, but also in the number of African-American women who earn doctoral degrees in the STEM disciplines. Consequently, Spelman College is uniquely positioned to develop and test innovative strategies for increasing the number of African-American women in STEM disciplines.

Even before G-STEM, Spelman College's Study Abroad & International Exchange Program was well established; approximately 25% of each graduating class engaged in a study abroad experience. In 2010/2011, Spelman College took several measures to prioritize undergraduate participation in international experiences, including:

- *Quality Enhancement Plan (QEP)*. With the establishment of the Gordon-Zeto Center for Global Education, the QEP, also known as Spelman Going Global!, identified global learning as its focus. Through the QEP, the College sought to increase the number and significance of international opportunities for students through curricular and co-curricular integration.
- *Seven-Year Strategic Plan* (2010–2017). The goal of the Strategic Plan was to ensure that every Spelman student had a global academic experience before graduation.

As these initiatives were being established, it became evident that STEM students faced unique challenges to studying abroad. For example, 2007–2009 data indicate that while 23% of Social Science majors and 35% of the Humanities majors participated in study abroad experiences, only 15% of the STEM majors participated in study abroad activities. Several barriers to Spelman College STEM students' pursuing international experiences were identified:

- STEM students are often required to take many lab- and research-intensive courses, not only for their major, but also to prepare for their post-graduate education entrance exams.
- Until relatively recently, many post-baccalaureate institutions in the USA did not accept credits for STEM courses taken outside of the USA.
- Many STEM students engage in intensive research collaborations with the faculty, making it difficult to leave for an extended period of time while running experiments.
- Many students may have simply been unaware of the resources available to them to facilitate an international research experience.
- Until the implementation of the QEP and the establishment of the Gordon-Zeto Center for Global Education, very few STEM faculty members were available as champions for promoting global travel experience for STEM students.

Given Spelman College's unique position to contribute to the advancement of African-American women in the STEM disciplines, and the efforts and challenges just outlined, it was evident that Spelman would need to develop study travel opportunities specifically for their STEM students, to address the barriers to international travel. At the same time, Spelman wanted to develop a program that would not only enable STEM students to continue to advance in their major, but also increase the likelihood of their retention in the STEM pipeline. These factors were the catalysts to submit a grant proposal to the National Science Foundation*, Enhancing Global Research and Education in STEM at Spelman* College—which became the G-STEM Program.

4.3 The G-STEM Program

"Enhancing Global Research and Education in STEM at Spelman College" (G-STEM) began in 2010 as an NSF-funded initiative, with additional funding support received from the Department of Education. The primary goal of the G-STEM program is to provide international research experiences designed to increase the number of Spelman STEM students graduating as globally engaged scholars. To accomplish this goal, the G-STEM program works synergistically with different offices and departments on the Spelman College campus to identify various mechanisms by which students can have access to and engage in international research experiences. A multi-pronged approach is used to create, develop, sustain, and institutionalize international research experiences in colleges, universities, and industrial laboratories. The primary focus of the G-STEM multi-pronged approach is developing G-STEM Scholars intellectually and culturally; also, there is a focus on sustaining and institutionalizing G-STEM in the infrastructure of Spelman College, as shown in Fig. 4.1.

The four objectives of the G-STEM Program are to:

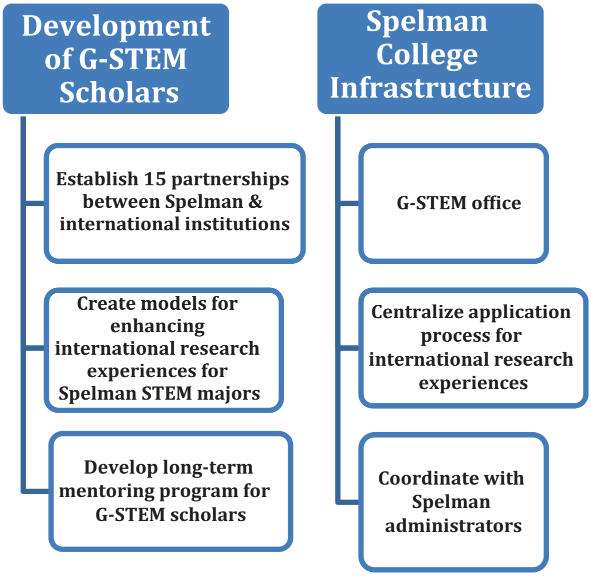

Fig. 4.1 Two-Pronged Approach to G-STEM

- Establish 15 new research partnerships between Spelman College and international institutions,
- Increase the number of undergraduate STEM students choosing to participate in international research experiences from 15% to 35%,
- Develop an integrated long-term mentoring program for G-STEM Scholars, and
- Disseminate the global experiences of G-STEM students to local, national, and international audiences.

To achieve these objectives, a centralized G-STEM office was created and staffed with a Program Manager and an Administrative Assistant, who were directly supervised by two faculty members as Co-Directors. The G-STEM Office served as the central location for the global research experiences for Spelman STEM students, and continuously coordinated activities across many divisions on and off campus: Study Abroad Office, Financial Aid Office, Office of Undergraduate Studies, STEM department chairs and individual faculty members, Title III Office, and the international partners (Fig. 4.2).

The first priority for the G-STEM personnel was to develop a strategy to create successful international research opportunities, as well as a formalized plan for mentoring and advising the G-STEM students. The following sections detail the strategies for each of the objectives, highlighting successes and lessons learned during the process.

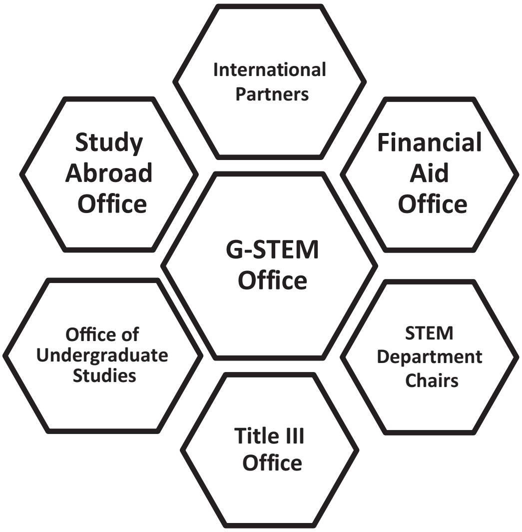

Fig. 4.2 Spelman College G-STEM Office

4.3.1 Establishing International Research Opportunities: A Varied Approach

At the start of the G-STEM program, there were several study abroad providers, such as the School for International Training (SIT), and the Danish Institute for Study Abroad (DIS) that already offered research experiences in their curricula; however, they were limited in scope, intensity of research opportunities, and geographic distribution. Consequently, our greatest challenge was to develop new strategies to create a more diverse range of STEM research-related international experiences for our students during both the academic year and summer. These strategies were organic in nature and often developed as the G-STEM program grew.

4.3.1.1 One-on-One Partnerships

During the first year of the program, several students were interested in gaining research experience while studying abroad during the semester. Although they had already been accepted into programs at the university of their choice, these programs did not offer independent research credit. This meant that:

- Each student would need to be willing to pursue the research experience in addition to her full load of courses; and
- A faculty member at the host institution would need to be willing to supervise a student in their lab for only one semester.

Given that Spelman required G-STEM Scholars[1] to engage in a minimum of ten research hours per week each semester, coupled with the fact that we did not have additional funds to support the international mentor, we were uncertain about being able to individually match our students to specific labs. Each of these G-STEM Scholars was instructed to review the various ongoing research projects at each of their schools, and to submit to the G-STEM office a list of the top five projects on which they would be interested in working. Also, each G-STEM Scholar had to draft a narrative about why she was interested in each of the projects, and what in her own background and research experiences made her qualified to work on each project. Once the list was received, one of the G-STEM co-directors reached out to the study abroad organization to provide background on the G-STEM program, and what each student was hoping to gain through an international research experience. In some cases, the study abroad provider suggested that Spelman College directly reach out to the relevant academic department chairperson to determine if our request was even possible to fulfill; in other cases, the study abroad provider initiated the conversation on our behalf with the relevant departmental representative.

The initial outreach to the host institutions was extremely well received, and all the department chairs were willing to discuss possible options with their faculty members. Detailed information was sent to the department chair about each Scholar—including the curriculum vitae (CV), academic transcript, details of previous research experiences, and the write-up that each had developed detailing the research experiences in which they were interested. The department chair was also informed about the Spelman mentoring component, to make it clear that each student would be mentored and well prepared before her departure, and would have a mentor while studying abroad. The department chair presented this information to various faculty members: in some cases, those faculty members reached out to the G-STEM program for further information; and in one case an online interview was scheduled with one of our interested students. As a result, all six of the students who were interested in engaging in research were successfully placed. Four students were placed in the Computer and Information Sciences department and the Chemistry department at Queen Mary University of London, and two were placed in the Biology department at the University of Sussex. We were pleasantly surprised at the willingness of these international departments and faculty members to mentor our Scholars in an intensive research project for only one semester, and were even more impressed that they expressed a desire to continue to do so.

There were several noteworthy logistical issues involved in developing these more personal one-on-one agreements with host institutions. Once each Scholar was successfully placed into a research lab, a letter of agreement was drafted and signed by representatives at Spelman College and the host institution. These letters stated that:

- The designated faculty member in the host department agreed to mentor Spelman G-STEM Scholar(s),
- The Scholar would engage in at least 10 h of research per week, and
- The Scholar would produce a scientific report at the end of the term.

[1] Upon acceptance to the G-STEM Program, students are referred to as G-STEM Scholars.

Because each G-STEM Scholar was pursuing a research project in addition to her course work (and was therefore not actually receiving course credit for her work), we had to determine if there were any visa-related rules or restrictions. Even though each Scholar was conducting research in an academic context, the work could be viewed as volunteer work; laws related to this type of work vary from one country to another. Interestingly, although six of our Scholars traveled to England under the same conditions and agreements, two of them were required to obtain a visa that would cover this additional volunteer work, while the other four were not.

Finally, we also had to examine whether there were any liability issues related to our Scholars working in the different labs. Again, because each Scholar was not conducting her research in the context of course/course credit, we had to ensure that our Scholars were covered in the event of an accident or emergency situation while working these "extra" hours in the lab. This involved a conversation with the company that provides our students with international health coverage, as well as the Safety Office of the host institution. Four of our Scholars were covered in the case of an emergency in the lab, while the other two had to purchase supplemental coverage from their host institution. It is important to note that these are issues unique to this type of partnership.

In sum, the success of these partnerships depended on three main factors

- Ensuring that our Scholars were qualified to pursue this endeavor, and could clearly articulate their previous experience(s),
- Presenting a complete and compelling case to each department chair at the host institution, and
- Clearly articulating the role of the Spelman mentor, and Spelman's intensive mentoring process.

The host mentors worked closely with the Spelman mentors and Scholars prior to departure, providing reading lists and procedures with which they expected the Scholars to be familiar before arrival. All host mentors were strong and dedicated mentors to our Scholars as soon as they arrived for the semester, and were extremely valuable in helping the G-STEM program to navigate the institutional barriers to these types of experiences. This one-on-one partnership works well for specific students, but does require quite a bit of lead-time in terms of the placement of each student.

4.3.1.2 Study Abroad Program Partnerships

Many of our students were interested in traveling to specific destinations through a study abroad provider, such as the Council on International Educational Exchange (CIEE), the Institute for the International Education of Students (IES), SIT, DIS, or Arcadia. All of these programs already had mechanisms in place for students to engage in research experiences, either through designated research/internship/independent study courses, or as a primary component of their program. For students interested in these specific programs, agreements were made between Spelman College and the study abroad provider regarding the expectations and requirements of the research experience. These agreements varied by program, location, and availability of existing resources to supervise a research project.

The most straightforward partnerships were developed with study abroad providers who either already had a research component embedded in their program, or had the ability to add one (for example, SIT, CIEE, and DIS). For over 50 years, SIT has been the primary study provider for students interested in conducting immersive, hands-on field-research. SIT has very clear and structured programs across the globe; we had great success through their semester program sending students to Brazil, Chile, and Australia.

CIEE is another organization with various mechanisms for students to gain research experience. Several of our Scholars participated in the CIEE summer ecology program in Monteverde, Costa Rica. This program focuses on developing an independent research project guided by professors at the host site. The first year we sent Scholars to this site, we had an agreement stipulating that the Scholars would engage in research for a minimum of 80 h during the summer, and would produce a scientific report. Scholars continued to travel through this program in subsequent years, with great success. A slightly different approach was taken through two of CIEE's semester programs: Buenos Aires, Argentina and Belfast, Ireland. One of our Scholars was interested in conducting a public health project in Buenos Aires during her semester there, and the CIEE personnel in Argentina were willing to work with us to help develop this project. We worked directly with one of the CIEE professors, who taught courses for the CIEE students in Argentina. Prior to the Scholar's arrival, conversations about the project and project expectations were held with the Scholar, the CIEE professor, the G-STEM office, and the Spelman mentor. For the Scholar traveling to Belfast, an approach was taken similar to the "one-on-one partnerships" discussed above: a representative from CIEE took the lead in making contact with the academic department of the host institution, and doing much of the logistics in terms of creating the research experience for the Scholar, within the G-STEM guidelines. There was a mechanism in place for the Scholar to receive course credit for her research experience so that she did not have to take a full load of courses in addition to her research.

Spelman College has long partnered with Arcadia, The College of Global Studies, to send students abroad for academic course credit. As the G-STEM program was being developed, we spoke extensively with Arcadia representatives about our program, the need for students to be able to engage in quality international research experiences, and that a shift was occurring within the Study Abroad environment that would likely result in increasing demand from colleges and students across the country. By the summer of 2012, Arcadia had made arrangements with the Royal Veterinary College in London, England, and at the University of Granada, Granada, Spain, to offer an 8-week research-only summer experience for our Scholars. Eight of our Scholars were paired with research mentors at the host institutions, and worked a minimum of 40 hours per week on their research project while abroad. In the first year, only Spelman students traveled through Arcadia for this new partnership. However, it was such a success that Arcadia made it available nationwide and added additional research sites the following summer. This Arcadia partnership worked extremely well for G-STEM Scholars because: they were able to focus all of their time abroad on their research project; they were with a cohort of students all of whom were conducting research; and there was strong academic support provided by Arcadia staff and the host mentors.

Many of our STEM Scholars have been interested in pursuing international research projects related to Public Health. One of the few programs meeting this need, the IES Health Studies program specifically focuses on the health care system and public health challenges in South Africa. Although students do not typically do a research project through this program, IES worked with us to develop public health-related research projects for our students. In the first year, two G-STEM Scholars worked with and were mentored by researchers at the University of the Western Cape. However, unlike other students in this course, G-STEM Scholars were unable to become immersed in community experiences because of their time requirements in the lab. Therefore, the next summer we constructed the research experience differently: the academic program advisor created a partnership with a physician at a local hospital in Cape Town who mentored these two individuals to develop public health-related research projects that could be conducted in the hospital. By visiting the local hospital during the week, the G-STEM Scholars not only conducted research but also interacted with local communities. Overall, the Scholars were satisfied with their South African research experiences that were tailored to their specifications; however, the G-STEM Scholars did not have the same support as those in other programs because the infrastructure to fully support student research was not in place for this specific program. G-STEM Scholars reported missing out on some of the cultural opportunities that the rest of the class was having, with feeling slightly isolated from the other students, and overwhelmed with the demands of the research project—which were in addition to the regular course activities.

The primary disadvantage of this partnership was "forcing" a research experience into a program that was not specifically designed for one. One lesson learned from this is that although it may be *possible* to create a research project for a student traveling abroad, the overall experience of the student may suffer if the program does not have the mechanisms and infrastructure in place to support the research activities.

4.3.2 Recruiting and Retaining the Students

The lack of diversity in STEM disciplines and occupations in the USA, coupled with the need for intercultural communication and global perspectives, makes recruiting and retaining underrepresented students in STEM extremely important from both national and global perspectives. Increasing and enhancing diversity in STEM careers requires early exposure to STEM. Such exposure enhances academic performance in STEM fields and increases the probability that students might consider a career in STEM. By taking these factors into account in recruitment and retention efforts, Spelman College is well positioned to increase the number of African-American female students participating in international research experiences.

Spelman College's model for the successful recruitment and retention of African-American students into international research experiences is based on a concept of S^3 or Social Capital, Social Media and Communication, and Social Space.[2]

- *Social Capital*. Social connections have value that may not be easily quantified. Spelman College fosters a nurturing, family-like environment in which faculty members are supportive of African-American students. We have observed that many students are initially excited to travel abroad as a STEM major with financial support and mentoring by a Spelman faculty member.
- *Social Media and Communication*. We find text messaging to be the most effective method for getting essential information to and from students quickly. Information about the program and the G-STEM research experiences are also available through a variety of online channels. Abstracts of all projects are made available through the Digital Commons system of the Robert W. Woodruff library of the Atlanta University Center in Atlanta, Georgia, USA. The research experiences of each of our Scholars are updated weekly through the Spelman College G-STEM blog. General updates regarding the program and the Scholars are provided regularly via social media sites, and full details of the program can be found at the Spelman College G-STEM webpage.
- *Social Space*. The G-STEM Office was strategically located to facilitate easy access to office personnel. Moreover, the G-STEM Office established an open-door policy in order to build trust and establish a relationship with students. Strategically located space coupled with an open-door policy creates a social space that develops and cultivates students' comfort with traveling abroad. In addition, it provides students' families with a reliable source for information about G-STEM and the study abroad experience (Fig. 4.3).

4.3.2.1 Recruitment

Recruitment to the G-STEM Program is multifaceted. In addition to using such social media as Facebook and twitter, potential applicants to G-STEM are identified through a STEM Student Nomination Process with input from Department Chairs, Faculty Mentors, PIs of STEM-related grants, and offices such as the Study Abroad Office. Moreover, the G-STEM Office conducts outreach activities that include information sessions, roundtables, and applicant workshops.

4.3.2.2 Intake and Screening

Before the final application is submitted, potential applicants are screened using a two-step process:

[2] S^3 is a concept developed by Ms. Karen Clay while serving as the Global STEM Program Manager.

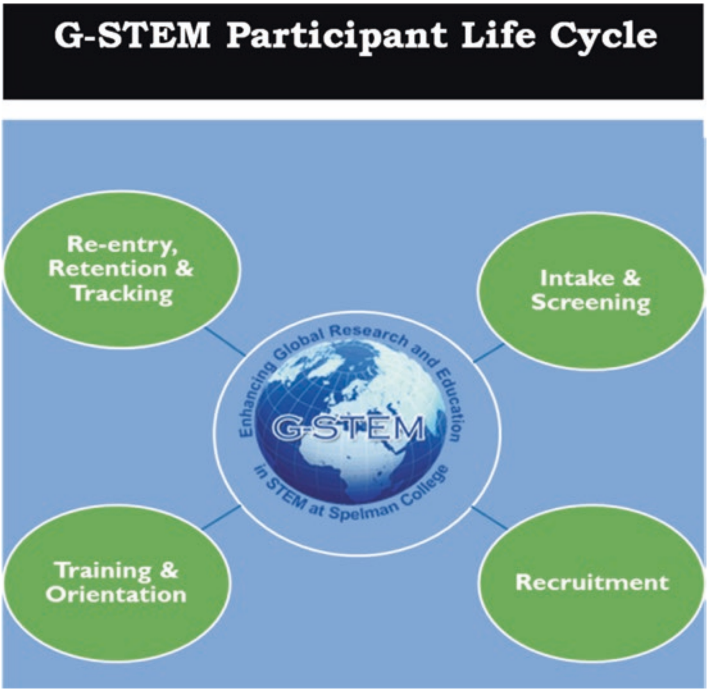

Fig. 4.3 G-STEM model

- Tracking students interested in applying to the G-STEM program by using a dedicated database that includes sign-in sheets, scheduled meetings, preliminary interviews, and general application assistance.
- Using a web-based preliminary application that requires approval of the Chair of the student's major department before submitting the final application.

4.3.2.3 Training and Orientation

Before leaving for their international research experience, the G-STEM Program and the Gordon-Zeto Center for Global Education provide training and orientation for G-STEM scholars. These orientation workshops are tailored to the geographic region of the study abroad site, and consist of Program Orientation, Language and Culture Orientation, Study Abroad Office Orientation, Study Travel Seminar (a requirement for all global travels that is vital to the assessment of the QEP), and National Science Foundation (G-STEM funder) Responsible Conduct of Research Training. Separate guidelines are available online and in hard copy for all stakeholders: applicants, participants, faculty mentors/administrators. Skype information sessions are held with participants and representatives of partner institutions. Finally, an ongoing communication process with assigned faculty mentor, Scholars, and research sponsor is established.

4.3.3 Creating a Mentoring Program

The Spelman College G-STEM Program recognizes that long-term, effective mentoring is critical for promoting the scholarly development and academic success of the G-STEM Scholars. Mentoring begins before G-STEM Scholars leave for their international research experience, persists during the experience abroad, and continues after students return to Spelman College.

4.3.3.1 Pre-departure

To successfully pair each G-STEM Scholar with a Spelman mentor, G-STEM Program personnel work with department Chairs to identify faculty members with relevant research experience, strong mentoring skills, and international research collaborations. After mentors are identified and Scholars' research projects are solidified, faculty members are given each Scholar's information, and asked to determine if they are willing to serve as a mentor for that Scholar.

The G-STEM office facilitates regular meetings between the G-STEM Scholars and their mentors prior to departure. During the initial meetings, questions and concerns about program and curricular requirements—especially as related to the Scholar's major—are addressed. G-STEM faculty mentors work closely with the Scholar's academic advisor to ensure seamless advising during this process. Following this, the G-STEM personnel facilitates a meeting so that a mentoring contract can be developed between the mentor and Scholar. This agreement establishes how often the pair will communicate while the Scholar is away, the method of communication, and any expected reports that the Scholar is to submit during that time. In addition, the mentor and Scholar identify any necessary preparatory work the Scholar should complete prior to her departure, such as reviewing the literature specifically related to her research topic, or developing her expertise in necessary lab techniques. This document is signed and returned to the G-STEM office.

4.3.3.2 Support Abroad

Throughout the research, the Spelman mentor and international research sponsor work with the Scholar to ensure that the research and/or laboratory experience meets both research and program objectives. Faculty mentors maintain weekly contact via email and videoconferencing with their Scholar to discuss research and travel experiences, and provide guidance when needed on how to push through the disappointment often associated with failed experiments. The Spelman mentor serves as a sounding board on ways to best communicate with others in the lab. Each Scholar is required to submit to both the mentor and the G-STEM Office weekly reflection papers addressing her research and sociocultural experiences. This intense communication provides strong support that contributes to the Scholar's development as an international researcher.

4.3.3.3 Re-Entry, Retention, and Tracking Support

After they return to Spelman, Scholars continue to be mentored. Often, Scholars struggle with reverse culture shock when they return, and can discuss that not only with their mentor, but also with the cohort of other students who were away during the same time. Some Scholars return with additional data collection and analyses to conduct, and consequently continue to work closely with both their international and Spelman mentors. The faculty mentor works closely with the Scholar to prepare her final scientific report that is typically submitted to the G-STEM office within 3 months after her return; each mentor must approve and sign off on the submission of the report. Faculty mentors also provide individual guidance to prepare Scholars to present their research. After completing the program, many G-STEM Scholars continue to communicate with their mentor to seek guidance on post-graduation plans and career/graduate school advice.

This continuous, focused mentoring by faculty helps Scholars to integrate their study abroad research experiences into their undergraduate careers, thereby helping them to become highly competitive candidates for graduate study and STEM careers.

4.4 Outcomes

4.4.1 Partnerships

Over the course of the grant, the G-STEM office successfully developed 16 international research partnerships/agreements. The collection of these partnerships allowed students to choose from a total of 35 research sites in 21 countries, with all STEM disciplines. Spelman G-STEM Scholars traveled most frequently to England, Spain, France, Scotland, Germany, and South Africa, and less frequently to South Korea, China, India, and Australia.

As noted earlier, a variety of approaches was used to establish international research opportunities: working directly with academic departments; working with study abroad companies; working with existing international schools and programs; and working with Spelman faculty (Fig. 4.4).

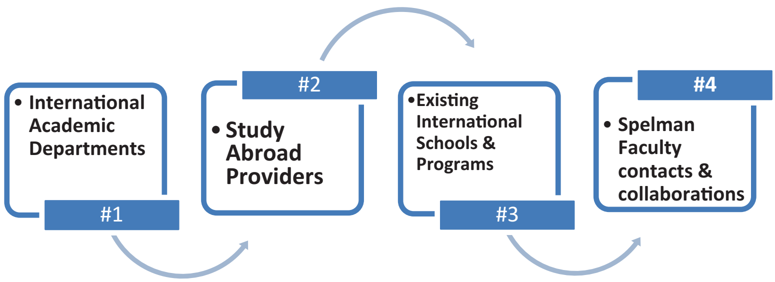

Fig. 4.4 Partnership strategies

4.4.1.1 International Academic Departments

During the first two years as the G-STEM Office was being built and students were being recruited, the G-STEM Office worked directly with the faculties of Queen Mary, University of London, and University of Sussex to locate and refine two funded research projects for our Scholars at these institutions. Also, we worked with the study abroad companies to identify research projects for our Scholars traveling during the semester to Ireland, Australia, Argentina, Chile, and Brazil, and for students traveling during the summer to Costa Rica and South Africa.

4.4.1.2 Working with Study Abroad Companies: Arcadia University

In 2012, Arcadia University developed several summer research opportunities that enabled Spelman Scholars to travel to England and Spain for course credit through the Arcadia program, and spend all of their time conducting research. This successful arrangement was very popular among our Scholars; Arcadia now offers this program nationally.

4.4.1.3 Working with Existing International Schools and Programs: AGMUS

Spelman College established a successful partnership with the Ana G. Mendes University System (AGMUS) Student Research Development Center, in Puerto Rico. Spelman College developed a Memorandum of Agreement (MOU) with AGMUS enabling G-STEM Scholars to apply for these international research placements; through this agreement, a total of 17 different research placements were made for G-STEM Scholars at seven sites. A MOU was also drafted with eight different research universities around the globe enabling G-STEM Scholars to travel to specific labs at each institution over the summer to conduct research.

4.4.1.4 Build on Spelman Faculty Members' International Contacts

Another strategy we used to create international research opportunities was to work directly with Spelman faculty members with an existing summer study-travel course, or who were willing to expand their existing international collaborations. Two faculty members already had established collaborations with researchers in India and France, and worked with the G-STEM Office to develop summer research projects for Scholars with a background in the faculty members' specific research areas interested in those countries. We worked with three faculty members who ran summer travel programs to Brazil, South Africa, and Barbados to develop meaningful research opportunities for STEM students, even when research was not the primary focus of the trip—as was the case for Brazil and South Africa.

4.4.2 Student Outcomes

From 2010–2016, G-STEM supported international research experiences for a total of 104 G-STEM Scholars in seven disciplines: Biology: 56; Chemistry/Biochemistry: 13; Computer Sciences: 2; Dual Degree Engineering[3]: 8; Environmental Sciences: 10; Mathematics: 12; Physics: 3 (Fig. 4.5).

Over the initial funding period,[4] the major outcomes from the G-STEM Program were: international education travel experience; retention in STEM; presentations and awards; and G-STEM Scholar development.

4.4.2.1 International Education Travel Experience

Prior to the launch of the G-STEM Program, only 15% of graduating STEM students had participated in international education travel experiences—with less than 5% of those students pursuing international research experiences. At the end of its funding period, G-STEM had increased the percentage of students who pursued international research experiences from 15% to 32%, and through the College's Gordon-Zeto Center for Global Education, an additional 40% of STEM students pursued international travel experiences—thereby creating a total of 72% of STEM students engaging in academically related international travel.

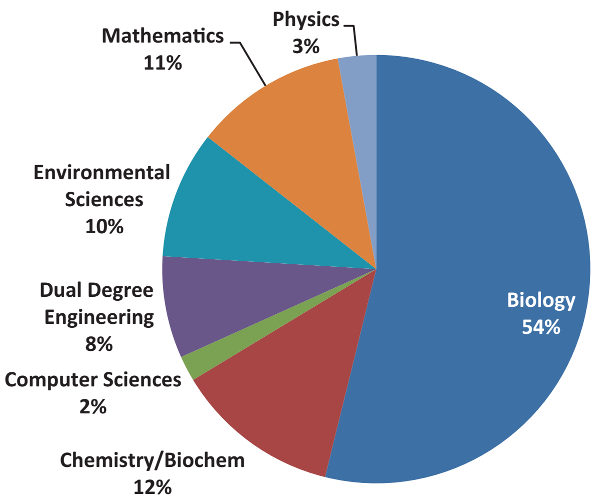

Fig. 4.5 Majors of G-STEM Scholars: 2010–2016

[3] In the Dual Degree Engineering Program, Spelman College students spend 2 years taking engineering courses at the Georgia Institute of Technology.

[4] The initial funding period is the 5 years during which the G-STEM Program was funded primarily by the National Science Foundation. At the end of these 5 years, the G-STEM Program was funded primarily by Spelman College.

4.4.2.2 Retention in STEM

Since completing the G-STEM program, 60% of G-STEM Scholars have graduated from Spelman, and 38% remain enrolled at the school. Among those Scholars who graduated, 32% are currently enrolled in STEM graduate programs (either MS or PhD), and 10% are pursing degrees in health-related fields (medicine, nursing, and dentistry). Overall, 42% of graduating G-STEM Scholars pursue advanced degrees in STEM-related fields. These numbers are promising, and suggest that the G-STEM program is having an impact on the retention of African-American women students in the STEM pipeline.

4.4.2.3 Presentations and Awards

All G-STEM Scholars have made oral or poster presentations at Spelman College's Annual Research Day. Thirty-two G-STEM Scholars presented their research at regional, national, and international conferences; six won awards for their presentations. In addition, G-STEM Scholars are co-authors on peer-reviewed articles based on their G-STEM research experience.

4.4.2.4 G-STEM Scholar Development

The development of G-STEM Scholars was tracked internally by the G-STEM Office and Spelman mentor. In addition, Scholars' development was tracked by an external independent program evaluator, as required by the initial funding agreement. From 2010 to 2015, annual evaluations of the G-STEM Program were conducted by an external evaluator. All evaluations used a mixed methods approach that consists of both quantitative and qualitative data. Systematic analyses of program documents provide quantitative and qualitative data. Additional sources for qualitative data include systematic analyses of: Scholars' journals; pre- and post-surveys; interviews with G-STEM Scholars, Spelman College faculty mentors for G-STEM Scholars, and G-STEM program staff.

During their international research experiences, G-STEM Scholars were required to keep a journal to chronicle their research experiences and to enable them to reflect on those experiences. Earlier G-STEM scholar cohorts submitted their journal entries periodically through email. Over time, however, the G-STEM Office developed and implemented an electronic journal format that could be accessed by the Spelman mentors and external evaluator in real time.

Each year, two surveys were administered to the G-STEM Scholars. The pre-survey was administered electronically before each G-STEM Scholar left the USA; the primary purpose of this *pre-survey* was to provide feedback on G-STEM Scholars' orientation so that the G-STEM Program could make whatever adjustments were warranted in real time—a continuous improvement process. The *post-survey* was administered electronically approximately 2–3 weeks after they returned to the USA and had time to readjust. The post-survey was designed to elicit feedback concerning Scholars' perceptions of their international research experience—including: communication; the most satisfying aspects of their international research experience; most important lessons learned; professional socialization; and the special benefits of being a G-STEM Scholar.

- *Communication*. As part of the external evaluation of the program, G-STEM scholars were asked in what way they benefited from writing a journal of their G-STEM research experience. Scholars said that the major benefit was that the journal enabled them to document their experiences and visualize their goals—and progress toward those goals. Documentation and reflection were intended consequences of requiring G-STEM Scholars to keep a journal. Analyses of journal entries in real time revealed evidence of professional socialization—that gradually over time Scholars tended to increasingly describe themselves as scientists. Survey data revealed *two unanticipated* consequences. The first was that Scholars used the journal as a mechanism through which to deal with their feelings. The second was that keeping a journal enhanced G-STEM Scholars' articulation skills, as discussed by one Scholar: "Being able to articulate my feelings more (I'm not much of a writer) and being able to become a better writer as a whole."
- *Most satisfying aspects of international research experience*. Across cohorts, G-STEM Scholars reported that the most satisfying aspects of their international research experience were: living in another environment; experiencing another culture; making professional connections and meeting new people from different schools and places; and learning new things. For some G-STEM scholars, the major influence of international research was informing and confirming their decision to earn a PhD and pursue a career in a STEM field.
- *Most important lessons learned*. G-STEM Scholars were asked about the most important lessons they learned during their summer research experience. Their responses can be grouped into two major categories: lessons about science and lessons about the Scholars themselves.

  – *Lessons learned about science*: G-STEM Scholars learned that:

    Science is universal
    Experiments do not work on the first try; failure is part of the scientific process
    Norms and values of the scientific community shape how research is conducted and how researchers should conduct themselves.

  – *Lessons learned about themselves*—how to

    Be independent
    Live alone
    Adapt to different cultures—both scientific and social; including how to seek advice from others
    Travel efficiently
    Use limited resources
    Time management.

- Across cohorts, the most important things that G-STEM scholars reported learning—both in and out of the laboratory—were:
  - Independence
  - Patience
  - Keeping an open mind.
- *Special benefits of being a G-STEM scholar*. Across cohorts, there was consensus among G-STEM Scholars on the special benefits of being a G-STEM Scholar:
  - Receiving a combination of unique travel, cultural, and research experiences
  - Gaining a global perspective on research
  - Not only learning about other countries and cultures, but also seeing the USA from a different perspective
  - Financial, institutional, and social support to conduct research internationally
  - Information and experience to inform and enhance career decisions
  - Networking: connections that would not exist otherwise.
- Professional socialization. The extent to which the Scholar feels integrated into the research experience is positively correlated with thinking of herself as being a part of the research team—"we" instead of "they"—and making meaningful contributions to the research—as a full-fledged participant. Professional socialization includes:
  - Norms and values of the scientific community
  - Importance of professional reputation
  - Criticality of collaborations to the progress of almost every research project
  - Importance of professional connections.

The benefits to being a G-STEM Scholar can be summed up in two words—competitive advantage. Respondents summed up their G-STEM international research abroad experience as "life-changing."

4.5 Lessons Learned

4.5.1 Lessons Learned About Recruiting G-STEM Scholars

Across the initial funding period, there were several actions that we learned increased the ability to recruit students into the program:

- Increasing and enhancing visibility of the G-STEM Program
- Recruiting motivated, well-prepared students using a variety of stakeholders—G-STEM Program personnel, Department Chairs, and academic advisors

- Recruiting students without extensive research experience (most of these programs were developed for novice students, and in some cases even offered courses related to the research process).

4.5.2 Lessons Learned About Retaining G-STEM Scholars

Several activities and events occurred that definitely impact the ability to retain G-STEM Scholars, both in the program, and in STEM fields:

- Criticality of preparing Scholars for their research experience and international travel through a series of cross-cultural workshops tailored to the geographic region of the study abroad site.
- Although it may be *possible* to create a research project for a student traveling abroad, the overall experience of the student may suffer if the program does not have the mechanisms and infrastructure in place to support the research activities. Working directly with study abroad providers to meet the requirements of the G-STEM program either by refining what was already in place, or developing something completely new.
- Criticality of creating a community of Scholars. Before, during, and after the research experience abroad, Scholars must feel that they are a core member of a community consisting of previous and present G-STEM Scholars. This community provides professional support and encouragement.

4.5.3 Lessons Learned About Mentoring

The Spelman College G-STEM Program recognizes that long-term, effective mentoring is critical for promoting the scholarly development and academic success of G-STEM Scholars. The mentoring program provides a coordinated, integrated process focusing on

- Advising Scholars as they consider and select study abroad sites (academic year and summer).
- Supporting Scholars in integrating their study abroad research experiences into their undergraduate careers, thereby helping them to become highly competitive candidates for STEM careers and graduate studies.
- Preparing the Scholars to make the most of their time and experiences—both academically and personally.
- Preparing Scholars to effectively engage in research in a diverse global setting through a series of cross-cultural orientation workshops.
- Supporting Scholars while they are abroad.
- Continued advising and mentoring upon their return and reintegration into Spelman College.

4.5.4 Lessons Learned About Partnerships

The rationale underlying the G-STEM model for developing new research partnerships is to expand from extant partnerships between individuals and between institutions. The success of these partnerships depends on:

- Students qualified to pursue international research.
- Presenting a complete and compelling case to each department chair at the host institution.
- Clearly articulating the role of the Spelman mentor, and Spelman's intensive mentoring process.
- Memoranda of understanding between Spelman College and host institution, and between G-STEM Scholar and mentors clearly articulating responsibilities, deliverables, and timelines.

4.5.5 Lessons Learned About Sustainability and Institutionalization

The development and implementation of the G-STEM Scholars Program is inextricably intertwined with the development, integration, and institutionalization of the G-STEM Program with the Spelman College infrastructure. The G-STEM Program has increasingly become more visible across the Spelman College campus through its representatives participating in numerous campus-based events; for example, it is part of the first-year student orientation sessions. Moreover, faculty mentors use data collected through a Scholar's research abroad in their courses during the academic year. This information can be used to develop case studies, for data analysis purposes, and/or to further investigate a given project in their lectures or laboratories.

The G-STEM Program is still developing through a continuous improvement process. Data from external and internal evaluations are used to make whatever adjustments are warranted in real time. Care is consistently taken to ensure that the G-STEM Scholars Program continues to integrate the efforts of various offices and divisions on Spelman's campus (the Study Abroad Office, the Financial Aid Office, the Office of Undergraduate Studies, the STEM departments, the World Language departments, and the Career Planning and Development Office) and fit seamlessly into the larger structure, goals, and objectives of the College. G-STEM program growth is incremental insofar as it starts with realistic numbers of students and partners and increases steadily. Incorporating results from program evaluations facilitates the introduction of curricular changes at Spelman College, and ensures the long-term success of G-STEM.

In sum, and perhaps most importantly, the G-STEM Program and G-STEM Scholars' experiences provide data that enhance understanding of critical junctures in the transformation of Scholars' self-conception from student to researcher. Moreover, it provides effective strategies, and promising policies and practices that can inform other efforts to increase and enhance the participation of underrepresented groups in STEM.

While the G-STEM Program has been fully integrated into the Gordon-Zeto Center for Global Education, the commitment of the Spelman administration to its long-term sustainability is critical, especially since the G-STEM program has laid the foundation for structured, mentored international research experiences for STEM students with well-documented and recognized impacts.

References

National Science Foundation. (2008). *National science board, science and engineering indicators* (Vol. 1). Arlington, VA: National Science Foundation.

National Science Foundation/Division of Science Resources Statistics. (2009a). *Science and engineering degrees: 1966–2004*. Retrieved from: http://www.nsf.gov/statistics/nsf07307

National Science Foundation/Division of Science Resources Statistics. (2009b). *Women, minorities, and persons with disabilities in science and engineering*. Retrieved from: http://www.nsf.gov/statistics/wmpd/underrl.htm

Part II
Teaching and Learning STEM in Informal Settings

Chapter 5
Recent Research on Science Communication and Engagement in Informal Settings in South Africa

Anthony Lelliott

Abstract This chapter provides an analysis of recent research which has been conducted in South Africa in the fields of science communication and science engagement in informal settings. The majority of science communication research has been made available via meetings such as the Public Communication of Science and Technology (PCST) and the African Science Communication Conference (ASCC). Presentations at PCST have been varied, from Indigenous Knowledge Systems (IKS) and outreach to health and social media, while the majority of presentations at the two ASCC conferences focused on science journalism, "show and tell" and policy issues. The relatively few published articles with the field of science communication indicate that there is considerable scope for an expanded research agenda. The field of science engagement research has tended to rely on the interests of a few individuals. Despite this, it has confirmed that many of the findings of similar research in developed countries hold true in South Africa, for example, that learning is incremental, and affective outcomes are as important as cognitive ones. Research studies on science fairs show impressive agency and initiative by the student participants, but resource constraints are hampering greater engagement with such informal learning opportunities. In summary, while informal sites are making strides in science communication and engagement, there are historical inequities in terms of space and culture which need to be addressed to ensure greater participation by the majority of the population.

Keywords Science communication • Science engagement • Informal settings • South Africa

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C.B. Leggon, M.S. Gaines (eds.), *STEM and Social Justice: Teaching and Learning in Diverse Settings*, DOI 10.1007/978-3-319-56297-1_5

5.1 Introduction

Science communication is a term normally given to the dissemination of science knowledge to the general public. Although it has been part of the sharing of knowledge for centuries, science communication has gained increasing importance over the past few decades as scientific and technological achievements have played increasing roles in people's lives.

Science engagement is a relatively new term for science communication activities in which people ("the public") not only learn about or "understand" science, but also actively participate in science. This may take the form of visiting a science center or choosing to be involved with science outside a formal educational setting. The term "engagement" has developed from the notion of the "Public Understanding of Science" (PUS) in the 1980s onwards, whereby scientists considered that people needed to understand science better in order to support it. PUS tends to be associated with the deficit model of science communication, in which the public is regarded as being relatively ignorant and needs one-way communication by experts to rectify the deficit (Stocklmayer & Bryant, 2011). More recently, the dialogue model, in which the various publics are engaged in two-way communication, has held sway (Trench, 2008). Science engagement tends to be associated with the dialogue model.

Informal learning is usually contrasted with the terms "formal" and "non-formal." Informal science learning is associated with lifelong learning of science, technology, engineering, and math (STEM) which takes place outside of formal classrooms. Researchers such as Falk (2001) suggest that learning processes do not differ according to their physical setting. Bell, Lewenstein, Shouse, and Feder (2009), in their committee report, use the term informal environments or settings to show that it is indeed the physical space that is important rather than the type of learning taking place. This chapter takes a similar view, examining STEM learning in different informal environments. Like most countries, South Africa is home to a variety of informal settings in which science engagement and learning can occur. Such settings include zoos, aquaria, science centers, museums, and visitor centers. Unlike countries in the developed world, there is very little research into how such settings contribute to visitor engagement with science. This chapter provides an overview of recent science research in the field of science communication as well as engagement in informal settings in South Africa. It is divided into three main sections: science communication; engagement in science centers, zoos and aquaria; and student participation in science fairs.

Science communication and engagement both have a social justice agenda due to South Africa's apartheid history. Although the majority of the country's population was not specifically excluded from museums and zoos, the 1950 Group Areas Act made it difficult for black people to go to museums and zoos because the museums were in white areas. Similarly, the Separate Amenities Act provided that there should be separate amenities such as toilets, parks, and beaches for different racial groups. These laws were clearly exclusionary.[1] Although the apartheid acts were

[1] www.sahistory.org.za.

repealed in 1991, and the majority black population has been encouraged to visit these institutions since 1994, the history of exclusion has meant that a generation of citizens grew up without welcoming access to museums and zoos. Similarly, the involvement of [African] schools in science fairs is a recent phenomenon, which has developed in the post-apartheid era.

5.2 Science Communication

One of the main reasons given for the importance of science communication over the past half century has been to improve the scientific literacy of the world's population (Gregory & Miller, 1998). This in turn has two drivers: a more informed citizenry, who understands both scientific principles and scientific advances, and an increasing number of people who become scientists and engineers. Africa is not insulated from such sentiments: there is general concern that African countries need to develop more rapidly, and their need for trained scientists and engineers is acute. Furthermore, as new scientific and technological advances, such as mobile phone technology and genetically modified organisms (GMO), are used by ordinary citizens, those same citizens need to understand both their benefits and their drawbacks. Such understanding will be greatly enhanced if the general public is scientifically literate.

However, there is also a critique of the process of science communication which comes from the discipline of sociology of science. Communication forums in which the "expert" scientist imparts knowledge to the lay public have been criticized as being a deficit model (Wynne, 1991). The very term "public understanding of science" is regarded as derogatory: science is being promoted by its "producers," while the ignorant public is encouraged to try not only to understand it, but also to appreciate it. The negative term "scientism" refers to the use of the scientific approach as a worldview which imposes itself on others, to the exclusion of their beliefs. Over the past 20 years, a more balanced view has emerged, which accepts that there are several "publics" or audiences who are involved in science communication, and they can legitimately speak back to science. It is not a one-way dissemination model but participatory conversation model, in which both parties shape the issue, the agenda, and the discussion (Trench, 2008).

Again, Africa could be regarded as a key player in these conversations (although her voice has been seldom heard). Since the decolonization of the 1950s and 1960s, there has been an increased interest in an African worldview which is different from that of the Western view. In Southern Africa, the philosophy of *ubuntu* has been promoted as being in contrast to the materialist Western scientific viewpoint. In the *ubuntu* view, all people live only in connection with other humans; the individual is only important in its connectedness to others. Similarly many scholars view indigenous knowledge (often referred to as Indigenous Knowledge Systems—IKS) as a legitimate kind of knowledge (Agrawal, 1995) which has the same value as western scientific knowledge.

The discussion above would suggest that science communication in an African context would be focused on the need for modern science to be shared with the various publics in Africa, but with the proviso that African worldviews (IKS) are part of the discussion. To what extent has this happened in recent years? The following section is based on a literature search of science communication papers available electronically on the Internet from conferences and in journals. What follows is inevitably a subjective selection, but is the best available representation of the current state of science communication in South Africa today.

5.2.1 Conference Papers

The Public Communication of Science and Technology (PCST) network consists of individuals and groups throughout the world who produce and study PCST. The biennial Public Communication of Science and Technology conferences have been held since 1989, with the inaugural one in Poitiers, France. Various conferences have included some papers by Africans or about Africa, while two recent African Science and Communication Conferences (ASCC) provide indications of topics of interest for Africa.

The first PCST conference held in Africa was in 2002, PCST-6 in Cape Town, South Africa. The main conference theme was "Science Communication in a Diverse World," and preference was given to "papers giving perspectives from different cultures or comparing different cultural settings." Sub-themes included outreach and communication to rural communities, conceptual developments in communication of S&T (meaning science and technology), evaluation of communication and awareness programs, and teaching/learning science communication. An analysis of presentations shows that participation in PCST conferences tends to be dominated by the host country (and neighboring countries if in a densely populated area like Europe). Table 5.1 shows that this was true of PCST-6, with African presentations in the majority over those from Europe or elsewhere.

Of the presentations from African countries, all but three were from South Africa. An analysis of the topics of these presentations, which gives an indication of the main science communication areas of interest, is shown in Fig. 5.1. The dominant topic (19% of the presentations) was outreach and communication to communities,

Table 5.1 Summary of presentations at PCST-2002

Continental area	Presentations
Africa	58
Europe	54
Americas	35
Asia/Oceania	31
Cross-continental	4

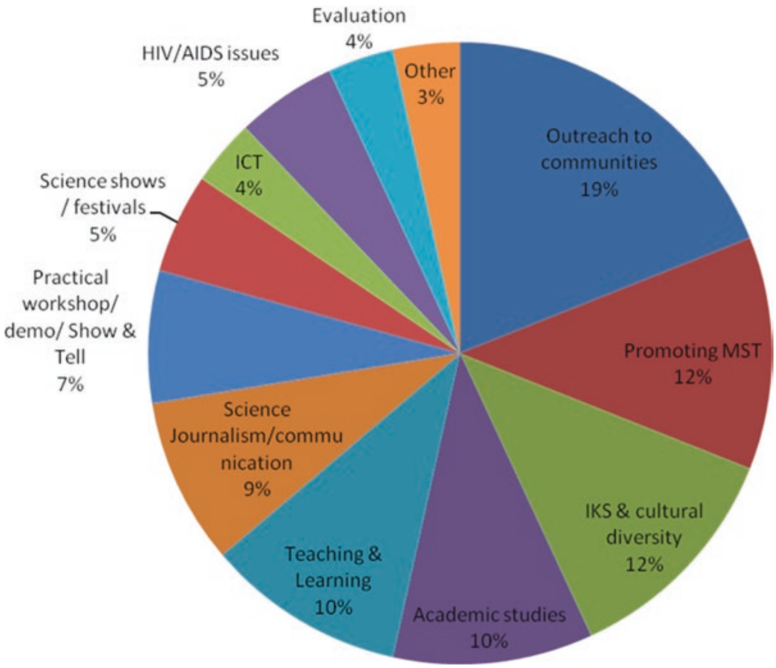

Fig. 5.1 Topics of presentations from Africa at PCST-2002

many of which were rural. In addition to being a theme of the conference, communication to rural communities is a very pertinent focus of much of science communication in Africa. Not only are many communities relatively isolated from mainstream science and technology, but in South Africa, the legacy of apartheid has meant that many communities (even urban ones) have felt excluded from participation in science. Apartheid policies (particularly forced removals, the creation of "homelands" for different cultural groups, and low levels of education) specifically excluded the majority of the population from science-related activities and employment. The prevalence of "outreach" presentations at the conference shows that the science communication community was trying to rectify this situation.

Another topic of note was IKS and cultural diversity—a main theme for the conference which accounted for 12% of presentations, and which is discussed further below, at the African Science Communication Conferences. Academic studies (10%) were varied and included "Views of distance education science students on the social responsibility of scientists" and "Medical Research Council scientists and the media—Attitudes to and experiences of reporting their findings to the public." Such studies can be regarded as being part of the academic discipline of science communication, and although comprising only one tenth of the African presentations indicates a potential kernel for the discipline to develop from. Similarly, papers on science journalism/communication (9% of the presentations) suggest that the study of science communication has a basis for subsequent growth.

In subsequent years, an analysis of regional participation at PCST conferences has been difficult, as not all data is available on the PCST and conference websites. However, it appears that in 2006 in Seoul, Korea, there were four African presentations, eight in 2010 (New Delhi, India), and four in 2012 (Florence, Italy). These focused on topics such as scientific rationality, inspiring students, interventions in science journalism, and communication within (and about) a science research institution. At the 2014 PCST conference in Salvador, Brazil, there were 17 presentations which included African participation, mainly focusing on health issues. The 2016 PCST conference in Istanbul, Turkey included 11 South African presentations, covering various aspects of science communication from paleontology to gender and social media.

Although African participation at these international conferences has been relatively low, there have been two African Science Communication Conferences in South Africa. An analysis of the topics at these conferences provides further insight into the state of the field.

At ASCC 2006, there were over 70 (seventy) plenary presentations, with over 40 (forty) by South Africans. Delegates from Nigeria and Kenya made six and five presentations, respectively, while there was representation from another seven African countries (one or two presentations each). There were nine presentations from India, and a few from Europe and the USA. The ASCC conference in 2009 was a much smaller affair, with only 43 presentations (30 from South Africans), and single sessions run by delegates from seven other African countries (and five from India). Few conclusions can be drawn from these figures, though it would appear that South Africa, Nigeria, and Kenya are the three leading countries in Africa where science communication is both practiced and researched.

Figures 5.2 and 5.3 provide a breakdown of topics at the two South African conferences from which some trends can be discerned when compared with PCST 2002. First, the topic of "outreach to communities," so dominant at the PCST conference in 2002, decreased to 12% and 3% in the ASCC 2006 and 2009 conferences, respectively. Instead, presentations involving science journalism dominated (22% and 31%), suggesting that a larger proportion of delegates came from the media industry. This may reflect the greater prominence given to science and technology issues in the media, at least in South Africa. Second, the category of practical workshop/demonstration/show-and-tell increased from 7% in the PCST 2002 conference to 15% at ASCC 2006 and 26% in 2009. This can probably be viewed as a positive development, as these presentations involved practical activities such as "Efficient and cost-effective science communication: 10 simple paper activities" and an "Astronomy outreach workshop," as well as discussions such as "Communication through storytelling." Such presentations were participatory, and may have been more beneficial for delegates than passively listening to talks, thus helping to develop the field more effectively. Third, "academic studies," remained at low levels across all three conferences (6, 2, and 3 presentations, respectively), suggesting a limited presence of universities at the conferences (which is of concern). The academic community needs to be involved more effectively if the field of science communication is to develop in the region. Fourth, surprisingly, presentations involving IKS and cultural diversity dropped from 12% to 7% to zero percent across

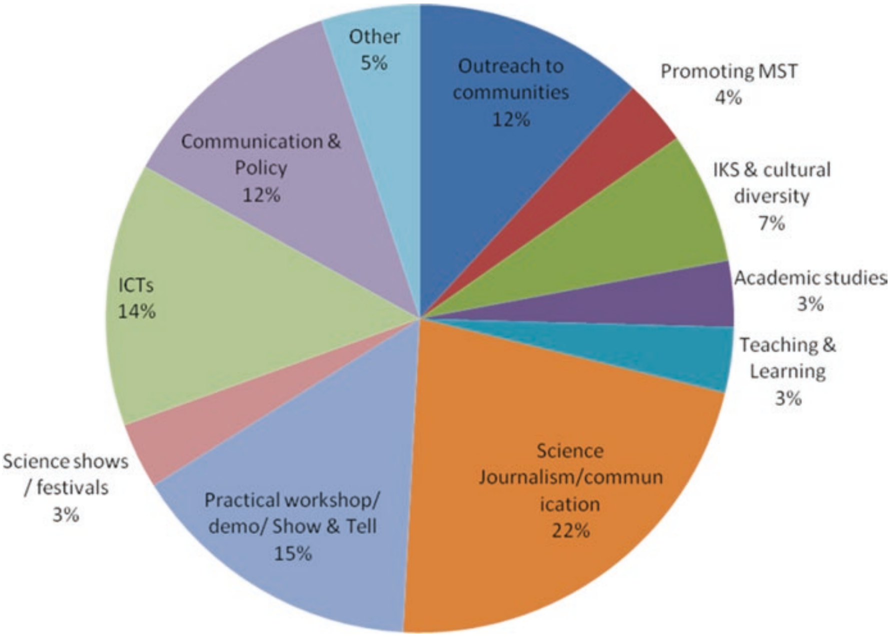

Fig. 5.2 Topics of presentations from Africa at ASCC 2006

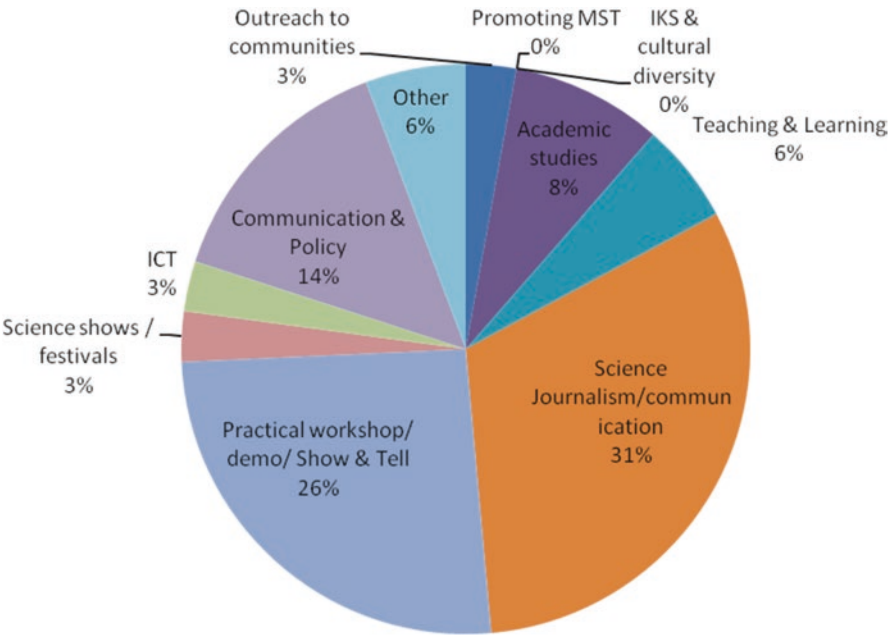

Fig. 5.3 Topics of presentations from Africa at ASCC 2009

the three conferences. In South Africa, the Department of Science and Technology (DST) runs an IKS sub-program and one would expect that there would have been an increasing area of interest rather than a decreasing one. Finally, it is interesting to note that presentations involving science communication and policy were both present in the ASCC conferences, yet absent from PCST 2002.

This brief analysis of three science communication conferences in South Africa in the 21st century suggests that the field of science communication is in the process of development, but still has a considerable way to go if its role is to become influential in Africa. As in other fields such as science education, Southern Africa tends to dominate the scene, with relatively limited participation from other regions. An examination of published academic articles relating to science communication has a similar bias, and it is to these that we now turn.

5.2.2 Published Articles

Science communication research in Africa has been published in a few international journals over the past two decades. Joubert (2001) provided a useful summary of priorities for science communication in South Africa early in the new century. She suggested that the newly democratic country already had successes in the form of science festivals and science centers, but needed to clearly define its role, and develop science and technology for current and future generations. Scientific literacy is a topic that several researchers have investigated in the 1980s and 1990s. Maarschalk (1988) reported an ongoing study in South Africa relating to scientific literacy and informal learning, but the outcomes of the research are not available. Laugksch and Spargo (1996a, 1996b) devised a Test of Basic Scientific Literacy which was used to determine the science literacy of high school students entering tertiary education in South Africa. Although undoubtedly a useful measure, the test has not been widely taken up by other African researchers. This is possibly because the concept of scientific literacy has been widely contested; is it a global notion that has universal value, or is it culture-specific? In his very helpful and widely cited overview of the concept, Laugksch (2000) notes that different interest groups have different conceptions of what scientific literacy is. He concludes that wherever it is being discussed, used, or measured, the concept needs to be spelled out clearly, so that a particular group's audience knows what they are dealing with.

A number of African academics (e.g., Aikenhead & Jegede, 1999; Ogunniyi & Ogawa, 2008) have contested whether a universal scientific literacy is appropriate for non-western audiences. Jegede contends that most science education is "neither culturally appropriate nor culturally inclusive" (Jegede & Kyle, 2007, p. 9), and calls for science education (and hence scientific literacy) to be designed to be appropriate for non-western communities. Although these arguments are concerned with science education, they have a direct bearing on science communication, as the issues of cultural sensitivity and inclusiveness are just as pertinent to the latter as to the former. Gastrow (2010) suggests that approaches to public engagement with science have evolved over past few decades from a "scientific literacy" perspective to an "attitudes towards science's perspective" to the current "science in society" model. The latter is likely to fit best with the critiques by African scholars such as Olugbemiro, Jegede, and Meshach Ogunniyi (see Chap. 9).

Both Gastrow (2010) and du Plessis (2011) refer to several surveys of public opinion of science conducted by Pouris (former CEO of the Foundation for Education, Science, and Technology, which later became SAASTA—South African Agency for Science and Technology Advancement) over the period from 1991 to 2006 (Pouris, 1991, 2001). The 1991 survey was conducted on 1300 respondents, all of whom were ethnically White and is therefore of limited value given the small percentage of White members of the South African population. However, in his survey of 1000 participants (across all race groups) Pouris (2001) found that South Africans had comparable interest in new inventions and technologies to people in the USA and the European Union, and less interest in energy/nuclear power and space exploration. Overall, South African respondents did not consider themselves to be well-informed (less than 28%) about such issues. South Africans also appeared to be relatively optimistic about the benefits of science (in relation to other countries), while at the same time holding reservations that it may affect people's more traditional ways of life. Such surveys are valuable records, and are currently being updated by the Human Sciences Research Council in South Africa.

A key area of science communication which has had some exposure in the regional and international literature is that of genetically modified foods. Genetic engineering (popularly known as genetic modification—GM) involves the introduction of one or more genes from one organism to another (often unrelated) organism to improve specific characteristics such as yield or pest-resistance. On the African continent, genetic engineering of crops such as maize and cotton is regarded by proponents as being vital for food security. Conversely, opponents of GM cite potential health concerns and the untested nature of the technology as reasons why it should not be adopted. During the 1990s and early in the new century, the South African government sought to establish a biotechnology industry in South Africa. In the light of this, Molatudi and Pouris (2006) examined research output by South Africa in the microbiology, molecular biology, and genetics publications worldwide. They found an increase in microbiology publications, but a decline in the other two, which they concluded threatened investment and government policies.

From the science communication viewpoint, publications regarding genetic modification have focused mainly on how GMOs are represented in the media. Gastrow (2010) found that GMO issues were generally under-reported in the South African print media, but were more extensive in the online media. He also found that articles tended to be one-sided, with GM plants being reported unfavorably. In his interviews with science journalists and academics, Gastrow found that journalists and the public tend to have polarized views about GMOs, that there is some friction and mistrust between journalists and scientists and that the government does not provide clear communication regarding biotechnology activities within public institutions. He makes a number of recommendations regarding clearer and increased communication regarding biotechnology, for the public to understand its implications better and to promote improved relationships between scientists, journalists, and the public.

Mwale (2006, 2012) examined debates regarding GM maize in the Southern African print media (Zambia, Malawi, Zimbabwe, and South Africa) between 1997 and 2007.

He argues that "babelisation" has taken place in the debate, resulting in rhetorical moves between the protagonists; slippage regarding the content of the debate and "moments of engagement" where there was real debate. Mwale's basic premise is that the newspapers concerned tended not to actively mediate the debate, but instead merely relay it to the public. This resulted in slippage, where issues were not properly engaged with or probed, so that the issues of GM maize presented were covered in a very superficial manner. However, Mwale did identify examples of real debate which, in his opinion, took place where political voices dominated. If the latter can be encouraged in such types of debate, then Mwale suggests that deliberative democracy can be promoted in the region.

In a recent article, Lelliott conducted a survey of over 800 visitors to the Cradle of Humankind World Heritage Site, West of Johannesburg (Lelliott, 2016). The Cradle of Humankind is an area rich in hominid fossils, which rivals East Africa in terms of numbers and completeness of fossils discovered, especially in recent years. The aim of the study was to determine the views of the general public regarding the term "Cradle of Humankind" as well as their acceptance of the notion of human evolution. While the majority of participants understood the term "cradle" as an origin or birthplace of humans, 63% appeared unaware that there are other potential claims to the notion of cradle of humankind elsewhere in the world. Nearly 60% of those surveyed accept that humans have evolved from an apelike ancestor, while 25% rejected this notion. This figure rose to 37% for South African visitors, suggesting that considerable further education and communication about evolution and Africa's overall role as the birthplace for humankind is important.

Finally, a number of agencies are attempting to promote more effective communication of science-related issues on the continent. These include SAASTA in South Africa, the Training Centre in Communication (TCC) in Kenya, the National Office for Technology Acquisition and Promotion (NOTAP) in Nigeria, Africasti.com (Africa Science Technology & Innovation News), African Federation of Science Journalists, and scidev.net (online at http://www.scidev.net/en/). How successful they are will be determined by future surveys of the publics' attitudes towards science (using some of the above examples as baseline data), and the extent to which science and technology are taken up by the citizens of Africa.

It is one thing to communicate science to the public and another for people to engage with it and learn about it. Although learning traditionally takes place in a classroom, there is considerable evidence that significant learning can take place elsewhere. We now turn to the research on engagement with science in informal settings in South Africa.

5.3 Engagement in Science Centers, Zoos and Aquaria

While there are plenty of STEM learning initiatives taking place across South Africa, there is little evidence for either formal or informal settings providing clear learning gains. Over the past 15 years, Lelliott's research projects have attempted to examine how informal environments can contribute to learning.

Research in Europe, America, and Australia has focused on the general public and family visits to museums and science centers. While these are important, they do not reflect the reality of such institutions in Africa, and particularly in South Africa. Colonialism tended to promote museums as Western constructs which excluded African citizens (Scott, 2007). Many of today's adults therefore, lack the experience of visiting museums when they were young with the result that relatively few museum visitors are made up of families and the general public. Instead, school groups predominate, and for this reason Lelliott (2007, 2010, 2014) examined school students visiting astronomy-focused science centers in his doctoral study. He used qualitative methods of gathering data from 34 students, such as interviews and personal meaning mapping—a form of concept mapping (Falk, 2003)—before and after the school classes visited a science center (Lelliott & Pendlebury, 2009) and a planetarium. His main findings showed that the learning that takes place was not traditional school learning that could be assessed using a formal test. Instead, the learning was incremental and unexpected. The students added small facts to their existing repertoire of knowledge about astronomy, referred to as "enrichment" by Vosniadou (1994) and "addition" by Anderson, Lucas, and Ginns (2003). Some students also restructured their existing knowledge which was likely to lead to better understanding and retention. For example, individual students were able to explain how the sun can be used to tell the time, understand that planets are actual worlds in space, or discriminate between the different planets and different types of star. Further findings included elevated levels of enjoyment and wonder as a result of the visit, as well as students being motivated to try out activities or research the topic on their own.

Several other studies in the region have confirmed that learning does indeed occur in out-of-school contexts, but that it is not the same type of learning one sees in the classroom. For example, Molahloe (2011) researched 80 grade 11 students who visited a water treatment plant in Lesotho. Molahloe collected data from questionnaires, interviews, and observations of the visit, and found that most learners gained knowledge through enrichment, while some learners with incorrect prior knowledge failed even to enrich their existing understanding. "Conceptual capture" occurred where students slightly modified their existing knowledge (Vosniadou, 1994), for example, the number of students who learnt that river water was the source of their tap water increased from 3 before the visit to 51 afterwards. She also noted that students' knowledge about community health was influenced by their interaction with the physical facilities at the treatment plant. The concrete nature and realism of the visit experiences appear to have influenced their learning.

Brown (2012) carried out a qualitative study of 31 students at Delta Environmental Center in Johannesburg, in which five students formed the main focus of the research. Using mind maps, a survey tool, and observation of post-visit activities, Brown found that students participating in "energy dialogues" resulted in improved knowledge about the causes and consequences of energy usage, but did not translate into individual behavior change. They did, however, align themselves with group values, and engaged in energy-related activities during the timeframe of the research.

A study by Nyamupangedengu (2010) was particularly insightful: she conducted an analysis of worksheets used in several informal learning institutions in Gauteng

Province in South Africa, and determined that museums prepare worksheets in a variety of formats: such as role-play worksheets and "scavenger hunt" worksheets. However, the most used format were structured worksheets which require short answers to questions. An analysis of the structured worksheets showed that the worksheets exhibit some features that are likely to facilitate learning, although the cognitive level of tasks was fairly low. Her findings suggest that the worksheets are not optimally designed to facilitate learning during museum field trips (Nyamupangedengu, 2010). She further identified ways in which worksheets can assist students to learn about the biology exhibits: as a guide, for engagement with exhibits and exhibitors, as a prompt to ask questions, to maintain focus, and to promote collaboration. Furthermore, the role of the teacher in mediating worksheet use and in briefing learners appeared to be a key influence on learning. The students briefed by teachers who allowed a degree of free-choice in visiting exhibits were more collaborative and appeared to have had a more enriching learning experience (Nyamupangedengu & Lelliott, 2012).

A limited number of studies of teachers who take class visits in out-of-school contexts have also been conducted. In a small-scale study of five teachers in Gauteng Province, Mosabala found that the teachers had varying motivations for taking their students to informal settings, and had no clear purpose for their visit (Mosabala & Lelliott, 2012). Further, during the visits the teachers did not interact with their students except for control purposes. There was no evidence of teachers using the visit to reinforce concepts learnt in class, although they did perform at least limited follow-up in class afterwards in the form of worksheet completion or discussion. Mokgobanama (2011) worked with a group of 49 Grade 11 and 12 Life Sciences teachers who attended workshops on learning about evolution at a science center concerned with human evolution. He found that some teachers who visited the science center showed knowledge gains, and their attitudes towards teaching evolution became more positive. However, he also found that the visit itself both introduced and reinforced alternative conceptions about evolution, which relates to Scott's concerns from her study of evolution in museums, about how images are taken up by visitors (Scott, 2007).

Rapule conducted an experimental study in which 750 grade 10–12 students were randomly selected from five secondary schools in the Potchefstroom area (Rapule, 2007). After the full group was given a multiple choice physical sciences pre-test, half of them (the experimental group) were taken on visits to Potchefstroom Science Center three times over a six-month period. The control group was not provided with any form of intervention. Results of the post-tests indicated that the experimental group's results were statistically significantly improved compared with the control group. The study does not offer any insightful findings regarding science centers, and merely shows that providing students with an intervention in the form of science center visits improves their test scores.

In contrast, Fish's study of 117 grade nine students demonstrates that, even though the sample size is relatively small, students from different cultural and language backgrounds varied considerably in their ability to learn from a science show about sound, held at a science center. Fish, Allie, Pelaez, and Anderson (2016) assessed students on their enjoyment of the show and their conceptual understanding about aspects of sound covered in the show. Although all three groups enjoyed the show to the same extent, the urban group outperformed the township group, and both showed much greater conceptual gains than the rural group. These findings mirror other studies which show that rural, and to a lesser extent township students, are considerably behind their urban counterparts in science performance (Reddy, Buhlungu, Daniel, Southall, & Lutchman, 2006). Fish and colleagues' research suggests that South African science centers need to pitch the science they present at the appropriate level for their visiting school groups. Clearly, the least privileged enter science centers with very little scientific knowledge and exit with the smallest gain.

Although providing a different informal setting from museums and science centers, there have been a few evaluations of zoo programs in South Africa. Mann evaluated two differently designed dolphin presentations at an aquarium in Durban. Mann-Lang, Ballantyne, and Packer (2016) found that by changing the presentation style and the nature of the content from a "theatrical" style to an ecology focus, the enjoyment for visitors was maintained while there were significant impacts on conservation learning. An evaluation of 101 visitors who completed a questionnaire after exiting the Dangerous Creatures exhibit at the same venue in 2014 shows that knowledge about reptiles increased slightly. However, some misconceptions were also picked up, such as "snakes make good pets" (Mann, 2014). In her doctoral thesis Venter (2014) compared conservation education programs of zoos in three countries: South Africa (Pretoria), Uganda (Entebbe), and Malaysia (Kuala Lumpur). In a survey of over 500 primary and secondary school students, Venter showed that the conservation education programs varied in their effectiveness across the three countries. While attending zoo conservation education programs had the potential to increase the attitudes and values of learners, this was not always the case. Where students entered the zoo with a high level of knowledge, there was little significant change as a result of the visit.

Another area of informal learning in its infancy in Africa is science cafés, inspired by the Café Scientifique movement (www.cafescientifique.org). While there are several reports of science cafés in the media across Africa,[2] there have been no substantial studies of their efficacy. A short article comparing youth science cafés with more formal learning suggests that they have the potential to inspire young people as well as being good training grounds for scientists to share their research with a lay audience (Lelliott, Plantan, & Gaines, 2012).

So what do these studies tell us about learning in informal settings in South Africa? The research can be said to be ad hoc and reliant on individuals' own interests. There does not appear to be a coherent program of investigation across the informal sector. Organizations such as the South African Agency for Science and Technology Advancement (SAASTA) and the Southern African Association of Science and Technology Centers (SAASTEC) could spearhead more research in the field if resources are made available.

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[2] e.g., http://www.scidev.net/en/science-communication/features/drinking-up-science-in-african-caf-s-1.html; http://www.scidev.net/en/news/ghana-launches-first-caf-scientifique-in-west-afr.html.

The findings suggest that learning is incremental, and affective outcomes are as important as cognitive ones. Deeper learning is also possible, but it might not be related to the objectives of the school visit. Teachers need to bear this in mind when organizing visits. How the learning is mediated is also crucial, with worksheets showing value in getting students to engage more deeply with the science presented, using verbal discussion. The need for teacher preparation and follow-up when running school excursions is also identified. Finally, the findings demonstrate that while some issues of science engagement have parallels in the USA and Europe, others are particular to the South African situation. The great majority of the research has been with school groups. While this is valuable in the South African context, broader studies with adult populations would give a clearer picture of how informal settings influence learning and attitudes.

5.4 Expo Research

South Africa runs a number of regional science fairs, known as "expos" (short for expositions) in which students are encouraged to present projects they have prepared at school and home over a period of weeks or months. The national event is sponsored by Eskom, the electricity supplier for the country, amongst others, and its mission is "to develop young scientists who are able to identify a problem, analyze information, find solutions, and communicate findings effectively" (see http://www.exposcience.co.za/). Over the past decade, educational researchers in South Africa have carried out a number of studies into science expos, which are described below.

Alant (2010) carried out an ethnographic study of a student and his schoolmates preparing for the Expo competition in a region in KwaZulu Natal province. The title of the article refers to the immense amount of work the students put into their preparation, and Alant refers to the nearest English equivalent as "burning the midnight oil." Alant notes that there are institutional practices of the Expo which tend to be exclusionary, firstly the project categories of "rural" and "development" to which black students' projects are normally allocated. She claims that the black learners have won few of the mainstream awards, from which they could be considered to be excluded because of their race. The second practice that Alant critiques is that of the evaluation criteria. The poster presentation and interview with the participants by the judges are both in English, and the criteria refer to traditional "experiment-style" projects. The black learners in Alant's study had produced technology models, which were not as valued by the criteria, and many struggle to express themselves in English. Alant concludes that (at least in 2005) the Expo competition was not conceptually and organizationally flexible enough to be the vehicle of empowerment it was intended to be; that it was excluding while claiming to be inclusive.

Shortly after, in Gauteng Province, Taylor found the Eskom Expo to have similar limitations for social inclusion. Working with students from an African township,[3]

[3] Townships were initiated under South Africa's Group Areas Act during apartheid, which demar-

Taylor held focus group discussions with nine students who worked on projects in 2006 and 2007. Using a phenomenographic approach, Taylor identified four conceptions of Expo which had motivated the students. These involved success (now and in the future), positioning as a future scientist, and engagement in competition with others. Unfortunately for the South African school system, the learners saw no relationship between their projects and their lived experience of classroom science. Instead, success was seen as external to their schooling. This is of interest for this chapter, as it demonstrates that students can view out-of-school science as their possible future, rather than the science carried out in the classroom. The students' experience of participating in the Expo was not positive, which they saw in terms of "losing." All the students received certificates of participation, but none of them in Taylor's study was awarded a medal. The phenomenographic conceptions identified by Taylor involved the group's projects being sub-standard due to weaknesses, lack of resources, and lack of adult assistance. The group also perceived the judges as being unfair. On the basis of this qualitative study, Taylor concludes that due to the extreme inequality in access to resources, as well as scientific knowledge at school, science "perhaps science competitions such as Expo are not an effective means of encouraging learners from disadvantaged backgrounds into careers in science" (Taylor, 2011, pp. 77–78).

Ramnarain and Beer (2013) report on another qualitative study: the experiences of three 9th-grade students preparing for the Expo for Young Scientists that is organized by the science teacher organization, KASTE (KwaZulu-Natal Association for Science and Technology Education). In this study, the students merged the world of school science with their world outside school to create a "hybrid space." The students were able to use support from both school and home, and, unlike the students in Taylor's study, each was awarded a medal for their project (two silvers and a bronze). The study demonstrates that the hybrid space between home and school is a fertile area for students to appropriate. However, the authors caution that only ten students in the class of 46 participated in the science expo, and they were all achieving relatively well in science classes.

Ndlovu (2014) looked at factors affecting student participation in a regional science fair in Western Cape Province. In a survey of 36 schools she found that only 5.1% of eligible schools in the region participated, with a main deterrent being distance from the venue (lack of access to transport to the science fair venue). She also found that historically advantaged schools had a greater participation rate as well as greater success in the competition. Ndlovu's recommendations from the study all relate to increased provision of resources for disadvantaged schools.

Finally, Ngcoza, Sewry, Chikunda, and Kahenge (2016) carried out a study in the Eastern Cape of South Africa. They purposively selected four disadvantaged schools and interviewed students (and their teachers) who participated in the regional Expo competition as well as the Expo coordinators (who organized the competitions). The study found that there were some positive learning experiences on the part of

cated residential areas for different race groups (black, Indian, colored, etc.) Even today, many people in townships belong to a low income group, and there is a high rate of unemployment.

the students, as well as confidence building. Challenges included resources available as well as interest on the part of the teachers. The coordinators found it easier to work directly with learners rather than with teachers only.

The positive aspects that can be taken from all four studies are the impressive agency and initiative shown by the students. However, it appears that a relatively small proportion of the students in each region where the studies were conducted actually participated in the competitions. Issues of resource availability were prominent for the schools, as well as teacher interest.

5.5 Conclusion

Both science communication and science engagement in South Africa are flourishing. The country boasts over 20 science centers, numerous museums, zoos, and other informal sites such as visitor centers. While the research on science communication and engagement is relatively limited, informal sites appear to be doing as well in terms of learning and affective issues as their counterparts in developing countries. What is of some concern, however, is that the institutions themselves are mostly situated in towns and cities, while, for historical reasons, the majority of South Africa's population still lives in townships and villages. These population centers are removed from the sites of informal learning, and unless resources can be more equitably distributed in the country, disparities will continue to exist. Similarly, a culture of visiting museums and zoos was never engendered in the majority population during apartheid times. Informal learning institutions need to make especial efforts to be as inclusive as possible, not only for school children, but also for their parents, so as to encourage a broad representation of the country's population to engage with science.

References

Agrawal, A. (1995). Dismantling the divide between indigenous and scientific knowledge. *Development and Change, 26*(3), 413–439.

Aikenhead, G., & Jegede, O. (1999). Cross-cultural science education: A cognitive explanation of a cultural phenomenon. *Journal of Research in Science Teaching, 36*(3), 269–287.

Alant, B. (2010). 'We cross night': Some reflections on the role of the Eskom expo for young scientists as a means of accommodating disadvantaged learners into the field of science and technology. *Perspectives in Education, 28*(4), 1–10.

Anderson, D., Lucas, K., & Ginns, I. (2003). Theoretical perspectives on learning in an informal setting. *Journal of Research in Science Teaching, 40*(2), 177–199.

Bell, P., Lewenstein, B., Shouse, A., & Feder, M. (Eds.). (2009). *Learning science in informal environments: People, places, and pursuits*. Washington, DC: National Academies Press.

Brown, M. (2012). *Exploring learning through energy dialogues in an informal learning centre* (MSc Research Report). Johannesburg: University of the Witwatersrand.

du Plessis, H. (2011). *Science and society: Public Understanding of Science (PUS) in South Africa and other collaborations*. Paper presented at the Human Sciences Research Council Seminar series. Retrieved from http://www.hsrc.ac.za/Document-3944.phtml

Falk, J. H. (2003). Personal meaning mapping. In G. Caban, C. Scott, J. H. Falk, & L. D. Dierking (Eds.), *Museums and creativity: A study into the role of museums in design education* (pp. 10–18). Sydney: Powerhouse Publishing.

Falk, J. H. (Ed.). (2001). *Free-choice science education*. New York: Teachers College Press.

Fish, D., Allie, S., Pelaez, N., & Anderson, T. (2016). A cross-cultural comparison of high school students' responses to a science Centre show on the physics of sound in South Africa. *Public Understanding of Science*. doi:10.1177/0963662516642725.

Gastrow, M. (2010). *The public understanding of biotechnology in the media*. Pretoria: Human Sciences Research Council.

Gregory, J., & Miller, S. (1998). *Science in public: Communication, culture and credibility*. Cambridge, MA: Perseus Publishing.

Jegede, O., & Kyle, W. (2007). *Concerns and issues in scientific literacy in the post-modern era*. Paper presented at the NARST Annual Meeting, New Orleans, LA.

Joubert, L. (2001). Priorities and challenges for science communication in South Africa. *Science Communication, 22*(3), 316–333.

Laugksch, R. C. (2000). Scientific literacy: A conceptual overview. *Science Education, 84*(1), 71–94.

Laugksch, R. C., & Spargo, P. E. (1996a). Construction of a paper-and-pencil test of basic scientific literacy based on selected literacy goals recommended by the American Association for the Advancement of Science. *Public Understanding of Science, 5*(4), 331–359.

Laugksch, R. C., & Spargo, P. E. (1996b). Development of a pool of scientific literacy test-items based on selected AAAS literacy goals. *Science Education, 80*(2), 121–143.

Lelliott, A. D. (2007). *Learning about astronomy: a case study exploring how grade 7 and 8 students experience sites of informal learning in South Africa*. PhD thesis, University of the Witwatersrand, Johannesburg. Retrieved from http://wiredspace.wits.ac.za/handle/10539/4480

Lelliott, A. D. (2010). The concept of spatial scale in astronomy addressed by an informal learning environment. *African Journal of Research in Mathematics, Science and Technology Education, 14*(3), 21–34.

Lelliott, A. D. (2014). Understanding gravity: The role of a school visit to a science Centre. *International Journal of Science Education, Part B, 4*(4), 305–322. doi:10.1080/21548455.2013.818260.

Lelliott, A. (2016). Visitors' views of human origins after visiting the cradle of humankind world heritage site. *South African Journal of Science, 112*(1/2), 8. doi:10.17159/sajs.2016/20150210.

Lelliott, A. D., & Pendlebury, S. (2009). "A large object with a small museum": A narrative analysis of Tlotlo's experience of an astronomy science center. *Curator, 52*(3), 241–260.

Lelliott, A. D., Plantan, T., & Gaines, M. (2012). From South Florida to South Africa: A collaborative approach for making science sensible to learners in informal and formal settings. *International Journal of Education, 4*(4), 53–64.

Maarschalk, J. (1988). Scientific literacy and informal science teaching. *Journal of Research in Science Teaching, 25*(2), 135–146.

Mann, J. (2014). Snakes are scary—Or are they? *International Zoo Educators Journal, 50*, 19–21.

Mann-Lang, J., Ballantyne, R., & Packer, J. (2016). Does more education mean less fun? A comparison of two animal presentations. *International Zoo Yearbook, 50*, 155–164.

Mokgobanama, D. (2011). Learning about evolution: The influence of an educational visit and intervention on teachers' knowledge and attitudes (MSc Research Report). Johannesburg: University of the Witwatersrand.

Molahloe, M. (2011). *The impact of a visit to Lesotho Water and Sewage Authority (WASA) on learners' knowledge about community health* (MSc Research Report). Johannesburg: University of the Witwatersrand.

Molatudi, M., & Pouris, A. (2006). Assessing the knowledge base for biotechnology in South Africa. *Scientometrics, 68*(1), 97–108.

Mosabala, M., and Lelliott, A. D. (2012). *Investigating perceptions of teachers and their learners about museums visits*. Paper presented at the 20th Annual Southern African Association for Research in Mathematics, Science and Technology Education Conference, Lilongwe, Malawi.

Mwale, P. N. (2006). Societal deliberation on genetically modified maize in southern Africa: The debateness and publicness of the Zambian national consultation on genetically modified maize food aid in 2002. *Public Understanding of Science, 15*(1), 89–102.
Mwale, P. N. (2012). *Questioning genetically modified maize: a case of public debate in the Southern African media (1997–2007)*. Unpublished PhD, University of the Witwatersrand.
Ndlovu, M. (2014). Investigating some background factors affecting student participation in science fairs: A case study of a regional expo for young scientists. *ICERI2014 Proceedings* (pp. 2381–2388).
Ngcoza, K. M., Sewry, J., Chikunda, C., & Kahenge, W. (2016). Stakeholders' perceptions of participation in science expos: A south African case study. *African Journal of Research in Mathematics, Science and Technology Education, 20*(2), 189–199. doi:10.1080/18117295.2016.1192238.
Nyamupangedengu, E. (2010). *Worksheets and learning in South African museums* (MSc Research Report), Johannesburg: University of the Witwatersrand. Retrieved from http://wiredspace.wits.ac.za/handle/10539/8542
Nyamupangedengu, E., & Lelliott, A. D. (2012). An exploration of learners' use of worksheets during a science museum visit. *African Journal of Research in Mathematics, Science and Technology Education, 16*(1), 82–99.
Ogunniyi, M. B., & Ogawa, M. (2008). The prospects and challenges of training south African and Japanese educators to enact an indigenised science curriculum. *South African Journal of Higher Education, 22*(1), 175–190.
Pouris, A. (1991). Understanding and appreciation of science by the public in South Africa. *South African Journal of Science, 87*(8), 358–359.
Pouris, A. (2001). *Interests, Public attitudes and Sources of Scientific Information in South Africa*. Paper presented at the 6th International Meeting on Public Communication of Science and Technology, CERN, Geneva, Switzerland.
Ramnarain, U., & Beer, J. (2013). Science students creating hybrid spaces when engaging in an expo investigation project. *Research in Science Education, 43*(1), 99–116. doi:10.1007/s11165-011-9246-1.
Rapule, S. (2007). *Assessing the impact science centres have on the holistic development of science learners*. PhD thesis, North-West University, Potchefstroom.
Reddy, V., Buhlungu, S., Daniel, J., Southall, R., & Lutchman, J. (2006). The state of mathematics and science education: Schools are not equal. In S. Buhlungu, J. Daniel, R. Southall, & J. Lutchman (Eds.), *State of the nation: South Africa 2005–2006* (pp. 392–416). Pretoria: HSRC Press.
Scott, M. (2007). *Rethinking evolution in the museum: Envisioning African origins*. Abingdon: Routledge.
Stocklmayer, S. M., & Bryant, C. (2011). Science and the public—What should people know? *International Journal of Science Education, Part B, 2*(1), 81–101. doi:10.1080/09500693.2010.543186.
Taylor, D. (2011). 'They are using laptops, we are using boxes': Township learners' conceptions of expo. *African Journal of Research in Mathematics, Science and Technology Education, 15*(1), 67–79. doi:10.1080/10288457.2011.10740702.
Trench, B. (2008). Towards an analytical framework of science communication models. In D. Cheng, M. Claessens, T. Gascoigne, J. Metcalfe, B. Schiele, & S. Shi (Eds.), *Communicating science in social contexts* (pp. 119–135). Dordrecht: Springer.
Venter, E. (2014). *A comparative evaluation of educational programmes at zoological institutions in three countries*. Pretoria: University of South Africa.
Vosniadou, S. (1994). Capturing and modeling the process of conceptual change. *Learning and Instruction, 4*, 45–69.
Wynne, B. (1991). Knowledges in context. *Science, Technology & Human Values, 16*(1), 111–121.

Chapter 6
Zoo Programs in South Africa

Elize Venter and Ulrich Oberprieler

Abstract In its position as one of the research facilities of the South African National Research Foundation (NRF), the National Gardens of South Africa (NZG)'s Strategic Plan regarding science engagement links to the three strategic thrusts as defined by the NRF, namely science awareness, science education, and science communication. A great variety of programs are offered at the NZG in order to fulfill its mandate regarding the provision of a platform for science. Approximately 140,000 school learners participate annually in the educational programs facilitated at the zoo. The demographics of the school learners changed together with the political changes South Africa underwent during its democratization process resulting in a dominance of black visitors. The NZG encourages research on both science engagement programs and visitor studies. Daily education programs and youth courses are continuously monitored and evaluated, focusing on the effectiveness of the programs to bring about a change in knowledge, attitudes, and behavior. Although the NZG strives to encourage the participation of under-represented groups in the STEMI workforce through its science advancement educational activities, there are still many challenges, including poverty and a lack of a culture of life-long-learning, which hinders the participation of previously disadvantaged learners in these programs. In spite of these challenges, the NZG is proud to contribute to a changing and changed society, while pursuing its vision of "nature and humanity in balance."

Keywords Zoo • National Zoological Gardens of South Africa • Science engagement • Science awareness • Science education • Science communication

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C.B. Leggon, M.S. Gaines (eds.), *STEM and Social Justice: Teaching and Learning in Diverse Settings*, DOI 10.1007/978-3-319-56297-1_6

6.1 Introduction

In South Africa, increasingly strong emphasis is placed at the highest political levels on science and technology in the national development of the country across all social sectors (Department of Science and Technology, 2014). The South African Department of Science and Technology (DST) collaborates with a wide network of institutions in the delivery of science engagement programs. This network includes educational institutions, science councils, science centers and museums, the South African Environmental Observation Network (SAEON), the South African Biodiversity Institute (SANBI), as well as the National Zoological Gardens of South Africa (NZG) (Department of Science and Technology, 2014). In its position as one of the research facilities of the South African National Research Foundation (NRF), the NZG's Strategic Plan regarding science engagement links to the three strategic thrusts as defined by the NRF, namely science awareness, science education, and science communication.

As such, zoos represent one of the primary points of engagement between live animals, biological science, and publics of all ages (Wagoner & Jensen, 2010). Science lessons offered at zoos, being distinct from formal education environments, have the potential to excite and stimulate the interest of learners (Lukas & Ross, 2005; Randler, Baumgärtner, Eisele, & Kienzle, 2007). Jensen (2011) found that the experience of viewing live animals can have a powerful impact on learners to construct a new understanding of wildlife, of nature, and of the role of humans intervening in this natural world.

The National Zoological Gardens is the largest zoo in South Africa and also the only zoo in the country with a national status. Approximately 140,000 school learners, most of whom are from previously disadvantaged communities or race groups, participate annually in the educational programs facilitated at the zoo. The NZG also participates in various off-site science festivals which draw especially large numbers of high school learners. Furthermore, the NZG's life science club, called the ZooClub, annually has 80–100 members that regularly attend science engagement activities. The ZooClub is an initiative of the NZG's "Program for Science Careers" and engages mostly learners from previously disadvantaged groups. It aims to encourage and support youth development and advancement through the conservation of biodiversity.

6.2 A Short History of the NZG and an Overview of Learner Audiences

On October 21, 1899, Dr. J.W.B. Gunning, the then Director of the State Museum in Pretoria, moved a collection of animals from the museum's premises to the farm "Rus-in-Urbe" on the banks of the Apies River, just north of Pretoria's center. This was the beginning of what was to become the National Zoological Gardens of

South Africa (NZG) (Oberholzer, 1992). Animals donated to the State Museum for the purpose of being mounted for displays were kept in the museum's yard, as Dr. Gunning did not have the desire to kill them. This initial animal collection consisted of a serval, a striped polecat, a leopard, a jackal, a genet, baboons, vervet monkeys, various antelope species, dormice, a bat, a spotted eagle-owl, 50 other birds, a monitor lizard, a python, and a tortoise. Fish were added to the collection in 1910 when the City Council of Pretoria donated the Sammy Marks fountain and fish pond. The zoo became independent from the State Museum in 1913, and at first had the main role of an intermediate home for animals destined for Europe and the USA. The zoo was given national status in 1916 and is since known as the National Zoological Gardens of South Africa (Labuschagne & Walker, 2001). On April 1, 2004 it ceased to exist as a Declared Cultural Institution of the South African Department of Arts and Culture to become a National Facility of the National Research Foundation (NRF), a unit of the South African Department of Science and Technology (DST). Its animal collection now focuses on African species, but the NZG also houses a large diversity of exotic trees, most of which were planted during its early history.

The demographics of the school learners visiting the NZG and also of those attending structured non-formal programs changed together with the political changes South Africa underwent during its democratization process. Attendance is thus now closer to reflecting the South African demographics, with a dominance of black visitors.

6.3 The Role of the National Zoological Gardens of South Africa in Science Engagement and Education

One of the five Strategic Objectives of the NZG is "to provide a high quality and high impact platform for science advancement and public engagement in conservation, biodiversity and environmental sustainability." This objective reflects the education philosophy of zoos and aquariums internationally by incorporating the principles of environmental education and education for sustainability, collectively known as conservation education (World Association of Zoos and Aquariums, 2015).

Science engagement, as defined by the NRF Strategic Plan 2015–2020, has been a core function of the NZG for many years, and about one third of the total number of visitors to the NZG is in direct response to organized educational activities for schools and higher education institutions. A strategic plan for science education and engagement was developed which took due cognizance of the principles enshrined in, amongst others, the strategic plans of the NZG and the NRF, the DST's Ten-Year Plan "Innovation towards a knowledge-based economy," the Department of Science and Technology's "National Norms and Standards for a Network of Science Centers in South Africa," and the World Association of Zoo and Aquariums' (WAZA) "Conservation Strategy" (National Zoological Gardens of South Africa, 2015).

In addressing the key focus areas adopted by the NRF, the NZG places special emphasis on the collaboration with the South African Agency for Science and Technology Advancement (SAASTA), a business unit of the NRF, as well as the NRF's national drivers of science education initiatives targeting the youth, namely:

- Participation: Creating and raising awareness among the public and learners about the scope, importance, and application of science;
- Performance: Creating an impact on the level of achievement of learners in school as well as of higher education students; and
- Career choice: Increasing the number of learners choosing careers in science, technology, engineering, mathematics, or innovation (STEMI).

The astounding diversity of living organisms, their complex interactions to sustain different ecosystems, the importance of conservation in sustainable development, the impact of human endeavors on global change, and their threat to biodiversity are emphasized in the various initiatives. The NZG has also identified a number of focus animals that illustrate the relationship between research in addressing problems, the application of the research results through appropriate interventions, the impacts of zoo-based conservation breeding programs, and the requirements for sustainability. Examples are the lion, African savanna elephant, vultures, African penguin, rhinoceroses, and pangolins.

The NZG encourages research on both science engagement programs and visitor studies. A network with local universities and other stakeholders was formed in this regard. Furthermore, the NZG networks with other National Facilities of the NRF, local zoos and science centers, national and provincial education authorities, as well as the South African Association of Science and Technology Education Centers (SAASTEC) and the International Association of Zoo Educators (IZE) to share experiences and learn from others.

The NZG thus plays a valuable role in developing human capital, especially by stabilizing the transition from one part of the formal education system to the next, as well as in public engagement in science. This is summarized in Fig. 6.1.

The Department of Science and Technology is currently finalizing a national strategy for science engagement. Both the NRF and the NZG have aligned their strategies and activities to this document.

6.4 The NZG Academy: An Overview of the NZG's Science Engagement Programs

The NZG Academy is a conceptual framework integrating and coordinating the NZG's human capital development initiatives. Its delivery is based on five programs, three of which (indicated on the left of Fig. 6.2) relate to the NZG's responsibility regarding science engagement (i.e., conservation education and public engagement in science).

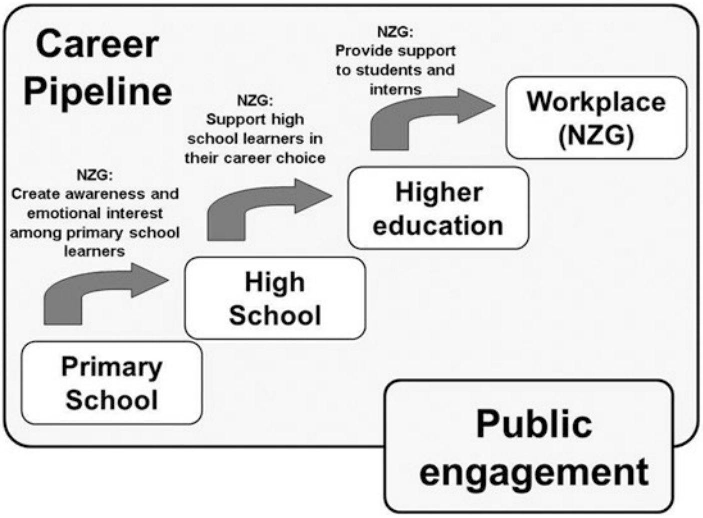

Fig. 6.1 The role of the NZG in the human capital development pipeline and public engagement in science

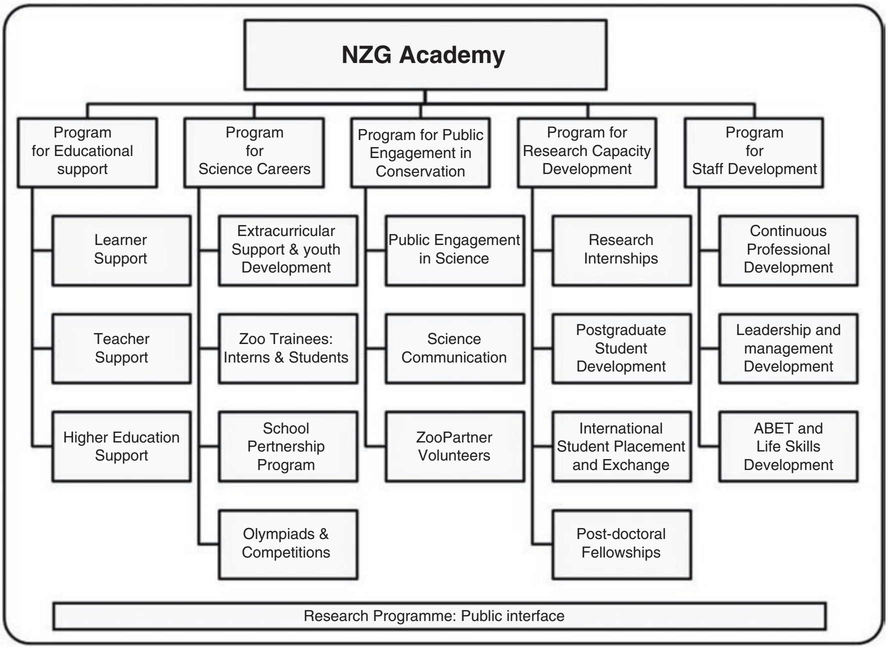

Fig. 6.2 The NZG Academy, a conceptual framework for science engagement and human capital development

As the Program for Research Capacity Development and the Program for Staff Development are largely beyond the context of this publication, these will not be discussed in detail.

6.5 Program for Educational Support

The objective of this program is "to support quality teaching and learning in the life sciences." This program focuses on the interaction with schools and higher education institutions, facilitating education interactions with both learners/students and teachers/lecturers. The NZG, through its diverse collection of animals and plants, forms an ideal platform to offer quality teaching and learning in the life sciences through the engagement of these target audiences in activities and programs that support and enhance curriculum delivery.

6.5.1 Learner Support

All lessons for school learners are aligned to the Curriculum Assessment Policy Statements (CAPS) of the South African national and provincial Departments of Basic Education. These aim to expose learners and teachers to the NZG's animal collection and biodiversity information through visits to the NZG, thereby increasing their awareness of biodiversity and its conservation via dynamic and interactive learning opportunities. Lessons are either offered daily during the school term, while themed lessons cover a specified topic and are facilitated during a certain time only. Currently the daily lessons offered are:

- The Application of Genetics—Further Education and Training (FET) Phase
- Understanding Biodiversity—FET and Senior Phases
- The Rhino Crisis—Senior Phase
- Birds—Intermediate and Foundation Phases
- Discovering Reptiles—Intermediate and Foundation Phases
- Creepy Crawlies—Intermediate and Foundation Phases
- Do Not Litter (puppet show)—Foundation Phase.

The following themed lessons are currently facilitated:

- National Symbols—Foundation Phase
- National Water Week—Intermediate Phase
- The Magic of Owls—Intermediate Phase
- Seas and Oceans Alive—Intermediate Phase

- Ecosystems—Senior and FET Phases
- Endangered Species—Senior and FET Phases
- National Science Week—FET Phase.

The NZG participates in a number of science festivals in various parts of the country. The purpose of these festivals is to expose high school learners, especially those from disadvantaged communities, to developments in science and technologies. Various government units as well as the business sector operate display stands that are visited by large numbers of learners. In addition to informal exposure, learners also benefit from attending formal presentations on various topics. Those covered by the NZG include the themes of biodiversity and genetics.

6.5.2 Teacher Support

The NZG places strong emphasis on empowering teachers—especially those not enrolled for further studies at higher education institutions—through workshops and training programs. These are usually delivered on request by the provincial Departments of Basic Education. Teachers from mostly rural schools and previously disadvantaged communities attend these workshops. Popular topics for workshops are biotechnology, evolution, and biodiversity. These workshops are well attended, especially if new topics are introduced to the curriculum.

6.5.3 Higher Education Support

The NZG plays a supporting role in the curriculum of higher education institutions through lectures, practical involvement, and guided tours at the zoo. These include:

- A lecture and practical on snakes and envenomation for a postgraduate qualification for medical practitioners.
- A series of lectures on small population management, husbandry, and research to undergraduate students in agriculture.
- A practical on how to identify individual mammals within a group, and population management to undergraduate students in nature conservation.
- A series of community engagement projects for undergraduate students in engineering.
- A series of community engagement projects for undergraduate students in the fine arts.
- A series of lectures for undergraduate students from India in wildlife management.
- A series of lectures and practicals to undergraduate students in animal husbandry from Belgium.

6.6 Program for Science Careers

The objective of this program is “to encourage and support career development and youth advancement through the conservation of biodiversity.” This program seeks to develop and utilize opportunities to contribute to youth development through science exposure and conservation activities. It focuses on exposing youth to the application of life and conservation sciences, both in-situ and ex-situ, using the latter as a starting point and reference. It is based on an approach of graduated engagement of youth that positions them for future employment, primarily (but not exclusively) in the life science and conservation fields, both within or outside the zoo environment.

6.6.1 Extracurricular Support and Youth Development

The NZG plays an important role in exposing the youth to the wonders of life and creating awareness about career opportunities in the natural sciences. This is achieved via a career ladder by offering a variety of graduated youth courses. These youth courses which are facilitated mainly during the school holidays include topics such as:

- The World of Reptiles. This one-day course for Grade 4–7 learners deals with the fascinating variety and adaptations of reptiles.
- Scavenger Hunt. This course is offered to Grade 4–7 learners. The learners explore, investigate, and collect data of different species of animals, i.e., their habitats, feeding habits, and general behavior, while participating in an exciting treasure hunt.
- Meet the Birds. This one-day course is offered to Grade R–3 learners and entails a variety of activities dealing with biological aspects of the avian world. In addition, children also build bird feeders and learn about the food requirements of urban birds.
- Monkey Tricks. This one-day course is offered to Grade R–3 learners to teach the characteristics of primates, their communication and adaptation, as well as zoo-based behavioral enrichment programs for primates.
- An Introduction to Bird Identification. This course for Grades 4–7 introduces learners to the art and skills of bird identification while encouraging them to observe and interpret bird behavior.

The NZG’s flagship course for Grades 7–12 is called the Junior Nature Conservators course. Although this course was initially established to train children in animal husbandry, giving them the opportunity to assist our conservators (zoo keepers) with the husbandry and care of zoo animals, it now focuses on a wider exposure to science and science careers. This four-day course deals with a variety of themes, from animal nutrition to basic hygiene, from veterinary care to behavioral enrichment, from designing a zoo enclosure to addressing conservation issues. Once children have successfully completed this course, they are eligible to join the ZooClub.

The NZG’s life science club, called the ZooClub, has the vision “to encourage and support youth development and engagement through the conservation of biodiversity.”

It annually has from 80 to 100 members who regularly attend science engagement activities. The majority of members are from socially disadvantaged groups. The club's objectives focus on exposing youth to the application of life and conservation sciences and thus to various career options in this field.

Members participate in an annual calendar of events which include activities such as animal husbandry, school curriculum support, visits to science centers and other science institutions, public speaking, observing animal behavior, and more. In addition, ZooClub members participate in various longer term projects. A previous project dealt with alien invasive plants on the zoo grounds, while a current project deals with "water conservation."

Included in this project is the members' participation in the miniSASS, a learner-based version of the Stream Assessment Scoring System. ZooClub members regularly assess the health of the Apies River flowing through the zoo grounds, submitting the data to a national system. Members are thereby exposed to the scientific method and contribute to a national project.

The NZG also plays a significant role in supporting ZooClub members to participate in science competitions, such as the Eskom Expo for Young Scientists, the NZG Life Sciences Competition, and the WESSA National Quiz Competition. The participation and achievements (regular winning of prizes) of the ZooClub members are evidence of the success of this initiative.

One of the highlights of the ZooClub during 2013 was the "Save the Rhino" campaign which coincided with World Rhino Day. This event was hosted jointly by the NZG, the Department of Environmental Affairs, the South African National Parks (SANParks), the City of Tshwane, the South African National Biodiversity Institute (SANBI), Unitrans, and the Walter Sisulu Environmental Centre. A street parade, in which more than 1000 learners participated, signaled the sustained commitment of the youth to the future of the country's environmental security and integrity. Following the street parade, representatives of the Children of South Africa handed a Memorandum of Support to the Minister of Environmental Affairs.

Members of the ZooClub also participate annually in a competition run by the Bushveld Mosaic Environmental Course. This exposes members to the sciences not only via their competition projects, but they are also exposed to assignments completed by the course students. Most importantly, the competition includes a weekend visit to the Pilanesberg Game Reserve. As most of the members are from disadvantaged communities, this is often their first visit to a larger conservation area.

6.6.2 Students and Interns, Collectively Referred to as ZooTrainees

The NZG links into national mentorship initiatives via its ZooTrainee Capacity Development Program. This program provides opportunities for higher education students to complete the work-integrated-learning component of their qualification.

Depending on the requirements of the higher education institution concerned, students may thus spend 3, 6, or 12 months at the NZG. In this way the NZG contributes to the qualifications on nature conservation, ecotourism, and tourism management students.

In addition, the NZG participates in a number of national initiatives to provide work experience to youth (referred to as interns) who have recently completed a science qualification, but have not yet been able to enter the job market. The most significant of these is the DST Internship Program and the South African Youth Service Program—both administrated by the NRF. Graduates are thus placed on a one-year contract in several of the NZG's departments where they gain valuable experience for their future careers. Each student or intern also has to complete a research project which is presented during a ZooTrainee symposium.

The NZG also participates in the Professional Development Program of the NRF. Young researchers are placed in the NZG Research Department to conduct research for a masters or doctoral thesis, while some are involved on a post-doctoral basis.

Funding for such contracts is secured via the various programs or is provided by the NZG's annual budget. Each ZooTrainee is mentored by a NZG staff member to ensure optimal exposure and development.

6.6.3 The NZG's School Partnership Program

The NZG's School Partnership Program, started in 2011, is an initiative in which two socio-economically disadvantaged high schools are given support in improving learner performance and increasing their interest in STEMI learning areas. These "adopted" schools are included in various educational activities at the NZG, for example, the Life Sciences Competition, National Science Week as well as debates, and Mandela Day celebrations.

Although two primary schools were also adopted in 2011, the program is now limited to two high schools, namely Saulridge High School and Soshanguve High School. Both are situated in disadvantaged communities.

6.6.4 Olympiads and Competitions

The NZG facilitated an annual Youth Symposium for a number of years; however, this initiative had to be discontinued when funding was no longer available. During this symposium, high school learners presented the findings of their research projects. Initially most of the projects were literature studies, but a subsequent change in the entry requirements encouraged learners to complete practical applied research.

As mentioned above, members of the ZooClub enroll annually for the Eskom Expo for Young Scientists.

The annual Life Science Competition allows teams from various high schools to compete with each other. Every team consists of two or three learners who have to answer a number of theoretical or practical questions relating to the life sciences. As of 2015, funding from the Department of Science and Technology has enabled greater participation. The competition currently involves 40 schools from four provinces.

6.7 Program for Public Engagement in Conservation

This program focuses on engaging visitors to the zoo in science and technology. The objective of this program is "to promote enhanced knowledge of the natural world by the visiting public." It consists of the following entities: public engagement in science; science communication; and zoo partner volunteers.

6.7.1 Public Engagement in Science

Most South Africans enjoy outdoor activities. Indoor life science engagement activities, such as those offered by museums, galleries, and science centers, are thus less attractive than activities in natural areas, conservancies, and zoos. The NZG aims to capitalize on this trend by not only offering a traditional zoo experience to visitors, but also engaging them in physics, chemistry, geology, and other basic sciences underpinning life on Earth. For this reason the NZG is recognized by the Department of Science and Technology as an outdoor science center and is awaiting accreditation.

The zoo's animal exhibits, augmented by the Aquarium and Reptile Parks, are thus enhanced by interactive displays usually seen in science centers. These displays deal with topics such as the principles of leverage as seen in animal bodies, sound waves as transmitted through water or collected by ear pinnae, or forces exerted by animal jaws. In this way a large target audience is reached including communities from disadvantaged areas.

The NZG currently launches a series of animal talks where a facilitator emphasizes how biology relates to the other natural sciences. The animal talks are also an ideal opportunity to engage the public in technologies used in conservation projects, from animal tracking devices to genetic analysis.

Emphasis is placed on the NZG's participation in the focus days, weeks, or months (such as World Environment Day or National Marine Week) in order to enhance the global or national message conveyed through these activities. The NZG also partners in local, national, or international awareness campaigns, and projects such as the United Nations' international years, the international zoo community's awareness campaigns, or local actions such as "Penguin Promises."

6.7.2 Science Communication

The NZG's science communication campaigns engage the public with broad issues relating to the conservation of biodiversity and environmental sustainability. Through public lectures, talks and short courses, social and formal media, and a dynamic website communication campaigns give public audiences a deeper understanding of biodiversity conservation and research.

6.7.3 ZooPartner Volunteers

The NZG's volunteer program, called the ZooPartners, encourages members to play an active role in science engagement by focusing on interactions with the visiting public. Activities such as the animal talks are thus driven by a volunteer corps.

6.8 Program for Research Capacity Development

The NZG is probably the only zoological garden in the world that has a statutory mandate to undertake research, through its declaration as a National Facility of the NRF in 2004. This requires the organization to inculcate a culture of research amongst its staff, undertake research capacity development to empower staff to engage in research, and engage and support under- and postgraduate student development. The objective of this program is "to develop high quality human resources for scientific inquiry into relevant aspects of conservation of threatened and endangered species in Africa."

This program is driven primarily by the NZG Department: *Research & Scientific Services*. It is a structured set of activities, which is aimed at demystifying research in the minds of participants and seeks to engage them through practical learning and involvement. These include research internships, postgraduate student development, international student placement and exchange, as well as the involvement of postdoctoral fellowships.

The NZG' research programs are widely recognized, not only due to the high quality outputs but also for its human development achievements.

6.9 Program for Staff Development

Staff development and knowledge enhancement are crucially important to meet the needs of a National Facility and a modern zoo. The NZG integrates various learning and training opportunities, both in-house and externally, into a staff development program. The objective of this program is thus "to develop and maintain high quality human resources within the NZG."

The NZG Department: *Human Resource Management & Organizational Development* drives the process of transforming the NZG into a highly capable, diverse, responsive, and knowledge-led organization. In this way a transformation of the staff complement has been achieved to reflect South African demographics.

6.10 Evaluation of the Education Programs

Daily education programs and youth courses are continuously monitored and evaluated, focusing on the effectiveness of the programs to bring about a change in knowledge, attitudes, and behavior. Quantitative surveys are used to evaluate the Intermediate, Senior, and Further Education and Training Phase programs. The youth courses for children in the Foundation Phase are evaluated by means of drawings where the children attending the courses are asked to complete drawings focusing on the outcomes of the specific course, both before and after attending the course (Venter, 2015).

In addition, the NZG's education programs were recently evaluated as part of a research project by Venter, Loubser, and Dreyer (2015). These researchers conducted semi-structured interviews with NZG staff, and analyzed the collected qualitative data by means of a logic model. The best practices and weaknesses of the NZG's educational programs were identified in this project. One of the weaknesses, as indicated by staff members, is that only some of the education programs are evaluated, mainly due to time constraints and staff shortages. Another weakness is that not enough emphasis is put on education at the NZG, as noted by one interviewee: "I don't believe that zoos really put enough emphasis on it. There are various reasons for that. One of them being that everybody is always into conservation and research, while education is seen often as a second rate function." At the time of this study, there was no formal agreement between the NRF/NZG and the Department of Basic Education to offer specific services and programs such as teacher training. A formal agreement will strengthen the relationships between the formal and the non-formal education sectors.

The best practices as acknowledged by the interviewed staff members were that the staff members were dedicated and enthusiastic, and that their efforts are paying off, as one education officer explained: "The energy that I'm putting in is equivalent to the output, you know, because I'm enjoying myself. I'm seeing the kids developing and achieving certain things and I can now be rest assured that there are lots of indicators that it is successful." This education officer also felt that he gets sufficient support and encouragement from the NZG management on a personal level. Lastly, even though there is no formal agreement between the NZG and the Department of Basic Education, the educational programs offered by the NZG are linked to the school curriculum. This makes it worthwhile for teachers to bring their learners to the zoo (Venter et al., 2015).

It also needs to be acknowledged that the NZG is a respected participant in the DST's science engagement endeavors.

6.11 The Way Forward in Terms of Developing and Sustaining Innovative Programs to Enhance the Participation of Groups Under-Participating in STEM

The future plans to develop and sustain innovative programs to promote the involvement of under-participating groups in the STEM workforce include the following:

- Review the Junior Nature Conservators course to include greater linkage to the NZG's animal collection, especially farm animals. This will ensure greater exposure and thus familiarization of city children with animals and thus indirectly encourage relevant career choices.
- Include further animal husbandry activities in the annual ZooClub program. The purpose of this is again to remove the psychological barrier between city children and animals, encouraging careers in the biodiversity sector.
- Review the ZooClub projects and convert them into citizen science projects where possible. Although the ZooClub members do participate in projects such as the Eskom Expo for Young Scientists and the Stream Assessment Scoring System, the scientific learning opportunities are not yet fully addressed.
- Investigate higher education bursary support for school leaving ZooClub members to enable learners from lower income groups to study further after having completed their school career.
- Register the NZG as a science center in the DST's Science Centre Network which is currently reviewed.

6.12 Conclusion

A great variety of programs are offered at the NZG in order to fulfill its mandate regarding the provision of a platform for science. However, although the NZG strives to encourage the participation of under-represented groups in the STEM workforce through its science advancement educational activities, there are still many challenges that hinder the participation of previously disadvantaged learners in these programs. Some of these are:

- Poverty. For many learners travelling costs from rural areas as well as entrance and course fees are not affordable.
- Culture. A culture of life-long-learning is greatly lacking. Parents thus often do not realize the need to send their children to educational activities at the NZG.
- Materialism. Those who rise from poverty are often extremely materialistic, pursuing high-income careers; therefore, a career in the sciences or research is not considered.

In spite of these challenges, the NZG is proud to have contributed to a changing South African society. The following achievements are noted:

- The NZG has transformed into a fully fledged National Facility since being transferred to the National Research Foundation in April 2004.
- The NZG's research capacity, with the resulting human capacity development programs, is now well established and respected.
- NZG staff participates in many national and international science engagement initiatives, often playing a leading role.
- The NZG is the only zoo in the country that is recognized as a living science center by the Department of Science and Technology.
- The NZG is a popular destination for both learners and teachers to address the challenges presented by the CAPS documents of the Department of Basic Education.
- The ZooClub plays a crucial role to support and encourage learners to participate in science-related activities and competitions, thus laying a foundation for a future career.
- The structured ZooTrainee Program for students and interns plays a critical role in bridging the gap between higher education and the workplace.
- As a public outdoor facility, the NZG does not only play the traditional role of zoos in conservation education, but increasingly also in the broader field of science engagement—in both the formal and informal sectors.

The NZG is thus truly pursuing its vision of "nature and humanity in balance."

References

Department of Science and Technology. (2014). *Science engagement framework. Science and society engaging to enrich and improve our lives*. Pretoria: Department of Science and Technology.

Jensen, E. (2011). *Learning about animals, science and conservation at the zoo: Large-scale survey-based evaluation of the educational impact of the ZSL London zoo formal learning programme*. London: University of Warwick and Zoological Society of London.

Labuschagne, W., & Walker, S. (2001). Zoological gardens of Africa. In V. K. Kisling (Ed.), *Zoo and aquarium history* (pp. 331–349). Boca Raton: CRC Press LLC.

Lukas, K. E., & Ross, S. R. (2005). Zoo visitor knowledge and attitudes toward gorillas and chimpanzees. *The Journal of Environmental Education, 36*(4), 33–48.

National Zoological Gardens of South Africa. (2015). *Science engagement strategic plan.* Pretoria: The National Zoological Gardens of South Africa.

Oberholzer, J. M. M. (1992). *Die geskiedenis van die Nasionale Dieretuin van Suid-Afrika, Pretoria, 1899–1984*. Pretoria: Universiteit van Pretoria.

Randler, C., Baumgärtner, S., Eisele, H., & Kienzle, W. (2007). Learning at workstations in the zoo: A controlled evaluation of cognitive and affective outcomes. *Visitor Studies, 10*(2), 205–216.

Venter, E. J. (2015). Using children's drawing to evaluate their learning in an informal setting. In *ISTE international conference proceedings 2015*. Pretoria: UNISA.

Venter, E.J., Loubser, C.P. & Dreyer, J.M. 2015. A comparative evaluation of educational programmes at zoological institutions in three countries. D.Ed. (Didactics) thesis, UNISA, Pretoria.
Wagoner, B., & Jensen, E. (2010). Science learning at the zoo: Evaluating children's developing understanding of animal and their habitats. *Journal of Psychology & Society, 3*(1), 65–76.
World Association of Zoos and Aquariums. (2015). *Committed to conservation: The world zoo and aquarium conservation strategy*.

Chapter 7
Science Museums as Critical Partners

Judy Brown and Amy Rubinson

Abstract Informal science learning institutions provide an invaluable resource to supplement science knowledge and excite people about STEM fields. However, not everyone has access to these resources. The reduced access and opportunities in low-income communities has life-long implications on educational and professional accomplishments. This chapter describes insights gained through a nearly three-decade journey of initiatives geared at addressing disparities of who visits museums and who participates in out-of-school-time programming. We begin the chapter with an investigation of the income disparities related to out-of-school-time learning opportunities. We further expand on this by detailing the components of building a strong science identity and acceptance within the field. Most of the chapter is a case study of one out-of-school-time program and the techniques we used to guide low-income youth and youth of color toward developing strong science identities and excitement about science. We close with suggestions related to making the informal learning center welcoming to underrepresented individuals in STEM fields. Ultimately we make the case that informal science learning institutions remain a relatively under-utilized community resource available to help close the STEM participation gap between low-income students of color, and their higher socio-economic peers. Additionally, these institutions may be a key resource to help close gaps created by income level in the STEM fields and the higher education community.

Keywords Science museums • Science education • United States

7.1 Introduction

Discrepancies in academic achievement have long plagued American educators, yet little attention has been paid to the social justice issues around accessibility to STEM education in informal learning environments. Why would it be

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C.B. Leggon, M.S. Gaines (eds.), *STEM and Social Justice: Teaching and Learning in Diverse Settings*, DOI 10.1007/978-3-319-56297-1_7

Fig. 7.1 Youth participants engaging as research assistants for a local marine scientist

considered an equity issue in the USA? The answer is complicated, socio-economic in origin, and revolves around use. Access and opportunity in under-resourced communities significantly shape life-long educational and economic possibilities. Shouldn't all children have equal life chances? Is it right or just that differences in opportunity to learn be based on circumstances that children cannot control?

Frost Science (formerly the Miami Museum of Science) staff and board members alike struggled with these questions. Except for children visiting the museum on field trips with their school, there were few people of color visiting our museum in the late 1980s. Juxtaposed with the release of *A Nation at Risk: The Imperative for Educational Reform* (1983), the highly diverse population of our community and the need to address the larger societal issue as to who would be the next generation of scientists, engineers, and technologists, the Museum began a targeted initiative to address the obvious disparity among families who were visiting the museum and the children and youth who were participating in our out-of-school-time programming (Fig. 7.1).

7.2 Digging Deeper into Disparity: Out-of-School-Time Learning

Within the context of economic globalization, the need to advance students' STEM-related competencies and skills has become a national priority; there is now a growing recognition of the important role that informal learning environments can play in the acquisition of science learning. Girls of color and youth in lower-income families in particular are far less likely than their more affluent peers to have access to, or to participate in, out-of-school science-enrichment offerings, placing them at an educational and long-term economic disadvantage. In fact, an analysis carried out by The Time to Succeed Coalition (2013) found that by age 12, economically disadvantaged children receive about 6000 fewer hours of learning time than their more affluent peers, and that they had been outspent by about $90,000 on learning and enrichment activities. By not having equitable access to enriched learning experience, children miss out on activities that may motivate interest and foster identity development and engagement with science.

While many parents begin to use museums as educational resources with their children at a very young age, underserved communities often do not have the familiarity with museums to consider them as a resource or even a viable option for leisure activities. Since 80 percent of waking time is outside of school, the importance of family/adult engagement and their expectations for their child's future career aspirations with respect to STEM is paramount to changing the existing paradigm.

7.3 It's All About Science Identity

Close your eyes and imagine a scientist. What does the person look like? Is the person alone or with others? What is the person wearing? What is the person doing? Where is the person? How we imagine a scientist shapes our perceptions of who should and should not be working in that field. For many children by age four, a concept of what a scientist looks like is already formed –mostly by the media—as a wild haired, bespectacled, White male. CSI and other media programs are changing these images, but they remain strong for many.

Growing up, children develop opinions from their experiences in life, and identities are constructed based on those experiences, their interactions with the environment around them, and the other individuals present. This includes the active and passive roles that individuals play, and the unspoken messages relayed by the physical setting. Just as knowledge is constructed based on prior experiences, an individual's overall self-efficacy as someone who can like and can excel in science accumulates over time. We have long been aware of the critical role of parents as our children's first and most important teacher, but we now have empirical support that parental expectations are perhaps the greatest predictor of career paths in the future. Children who have parents working in STEM fields are more likely to take a STEM major in college (Chute, 2009), while low-income youth of color often do not perceive STEM fields as being within their reach because of the barriers, such as the four listed below. This is reinforced in their day-to-day reality, as the percentages of African-American, Hispanic, and American Indian children who have a parent working in STEM fields are much lower than for Asian and White children (Wang, 2012).

Knowing that perceptions or stereotypes of the STEM disciplines are reflected in the choices that individuals make, to effectively increase the STEM pipeline, it is important to gain an understanding of both real and perceived barriers. Simply put, the primary barriers are:

- Believing STEM professionals are primarily White men and that STEM fields have unequal opportunities,
- Lacking technical knowledge related to STEM pathways/scholarships/future earnings,
- Absence of STEM role models, and
- Perceiving that there are many obstacles to overcome before being successful in STEM.

The low-stakes nature of informal learning settings and interaction with STEM savvy adults can often provide youth with engaging multi-modal experiences that counter many of these barriers and validate them as productive science learners. However, just as important as the actual experiences people have are the messages we project through exhibit design, marketing materials and program offerings. These messages contribute or take away from one's sense of belonging—a significant factor in career choice. Hidden messages and implicit biases, sometimes referred to as environmental micro aggressions (Sue et al., 2007), accumulate over time, and for many youth directly impact their perceptions of inclusion, and their persistence and participation in museum STEM programming. There are a number of approaches to counter the effects of stereotype threat evident in informal learning environments.

Understanding and analyzing perceptions of climate is a critical first step to this work. A key feature across all our youth programs at Frost is the use of informal educators of similar cultural and racial identity that also serve as role models and mentors to participating youth. Gathering input from both youth and parents to create a "touchstone" space that looked and felt comfortable for the target group was key to making the museum feel accessible. This space, equipped with computers and other technology tools, and available seven days a week, has provided access to needed resources and increased youths' sense of belonging. As many Frost youth state, "it's a home away from home." Museum exhibit design and signage also support these efforts through bilingual text and image choices. Individuals who have been stereotyped are quick to recognize spaces where their identities are honored instead of stereotyped.

7.4 Putting It All into Practice: Program Spotlight

Designing programmatic solutions to address the disparity in out-of-school time experiences for low-income children and youth has been the focus of much of the work of the Education Department at Frost Science for several decades, garnering national recognition and much reward. Working in close collaboration with other museums throughout the country, we have led initiatives to increase the participation of girls, primarily girls of color, in museum programming here in the USA as well as in Europe and Latin America. More recently, the Department is working with the National Council of La Raza[1], Aspira,[2] and a national network of science museums and community-based organizations to increase participation in science through afterschool programming and family engagement in ten cities in the USA that have rapidly growing Hispanic populations. Rather than presenting general program information, however, we have chosen to present one program as a mini case study to share key features that might be considered by other informal science institutions for adaptation.

7.5 IMPACT Math and Science Center

> "Being able to see many different opportunities - like before you're oblivious or blind to other opportunities but the program introduces you to more doors, everything is more clear, you can see you can do that, if I do this. Before when you weren't in this program it would be very hard to see what you had to see and plan what's your future going to be. So it's much easier now." IMPACT participant, 2015

Established in 1988, the Museum's IMPACT (Integrated Marine Program and Computer Training) program for low-income youth serves students in grades 9–12, of primarily Haitian and Hispanic background, who are the first in their family to go to college. The program is supported through a range of private, foundation, and federal grant awards, with the receipt of competitive program funding as an Upward Bound Math & Science Center program from the US Department of Education for more than 15 years. The success of the program is reflected in a 98% participant graduation rate from high school as compared to 56% of the general student population from their home schools, and an 89% postsecondary retention rate, with 64% declaring a STEM major. IMPACT is comprised of many components, both academic and personal, designed to holistically support participants' preparation for successful postsecondary education. One key factor contributing to the program's success is multi-year participation, during which time youth develop close relationships with peers and supportive adults, and enjoy new experiences that inspire interest in STEM fields.

The programming is divided into an academic year and intensive summer component. Structural features are based on research in youth development, cultural competency, dropout prevention, and many years of experience gained from conducting youth programs. This program strives to increase the enrollment of low-

[1] Founded in 1968, the National Council of La Raza (NCLA) is the largest national Hispanic civil rights and advocacy organization in the USA. www.nclr.org.

[2] The ASPIRA ("to aspire, to aim") Association is the only national Hispanic organization dedicated exclusively to developing the educational and leadership capacity of Hispanic youth. Aspira programs are used by more than 10,000 organizations operating telecenters in North America, Central America, South America, Africa, the Caribbean, and Spain through several international cooperative agreements. www.aspira.org.

income and first-generation college bound youth in postsecondary degree programs (specifically in STEM fields) through mentoring, workshops on life skills, career opportunities, STEM-focused classes, field trips, and college-readiness activities.

7.5.1 *Mentoring from Caring Adults*

IMPACT begins with a family event welcoming everyone to the current academic year. This creates a connection from the beginning to support establishment of a trusting relationship between incoming freshman families and the program staff, as well as a community of other parents with similar life goals. Family trust is essential to IMPACT's success in that the program emphasizes the development of personal relationships between staff mentors and youth that provide the academic and career guidance needed to take full advantage of the guidance provided at school. Given the language barriers (primarily Haitian Creole and Spanish) of some of the families, and inexperience navigating the formal school system, IMPACT's bilingual staff help serve as a critical link between the school system, the youth participant, and the parent/guardian(s). Throughout the four-year time period youth spend at the Museum, they regularly engage with program staff in one-on-one situations, travel to visit colleges, and attend other cultural events. These caring adults guide participants through a process of self-learning and insight with respect to how their identities as STEM learners influence their experiences and opportunities in the outside world.

New part-time staff that join the program each year for the intensive summer component are required to participate in a week-long training institute prior to engaging with youth. This is particularly important for staff from the dominant culture who may need to increase their awareness and sensitivity to cultural (and sometimes gender) differences through reading and reflection, and discussion assignments, while senior staff introduce topics such as being a mentor versus a teacher, active and engaging teaching techniques, conflict resolution, and teambuilding activities. Program staff also acquire the high-expectation mindset of the program to ensure that they relay the overall program message: yes, you can go to college; yes, you can be a scientist, mathematician, engineer, technologist, or whatever you want to be!

The academic program includes 28 Saturday Academy sessions, from 9 am to 3 pm. The daily schedule includes readiness for college, financial literacy, and STEM-themed enrichment activities, as well as time to explore and enjoy the Museum's science exhibit galleries. The activities within the college-readiness and STEM-themed classes are intentionally designed to develop life skills and professionalism (e.g., public speaking skills, critical thinking, and teamwork), and tutoring is available afterschool during the week. Through financial literacy classes, participants and their families are taught about banking and how to manage financial resources.

Because youth are together for a four-year period as peers, they teach each other the program's values and engage with each other motivating and challenging each other to strive for their highest potentials. While they are in college, many come back to work as near-peer summer mentors or serve as volunteers. When they graduate from college and move on with their careers, the sense of belonging to the museum family continues, and there is an active alumni group, many of whom are now in their 30s, providing a range of additional mentoring experiences for current youth. Evaluation activities carried out with program alumni explored whether participants perceived some components to be more helpful than other components. The significant themes that emerged from the data analysis included:

- The importance of supportive relationships with staff and peers,
- The development of positive attitudes and behaviors that lead to academic and personal success,
- The exposure to new experiences in a hands-on, fun, and engaging manner, and
- The personal guidance in preparation for college.

7.5.2 University Collaboration

During the summer, participants are divided by grade-level and led through intensive marine science investigations by college and graduate level science majors who mirror the participants' cultural backgrounds. The summer programming runs daily for six weeks, from 8 am to 3 pm. To strengthen the marine science focus, the summer program is hosted at the University of Miami's Rosenstiel School of Marine and Atmospheric Science which provides youth the sense and feel of a college campus. In this academic setting, participants engage in lab-based and group exploratory learning two days a week. The participants also spend two days a week at beach sites, where they can collect data for their research projects, learn about the application of information they learned in the labs, or snorkel to practice marine life identification. Every Friday, all four grade levels unite to attend a STEM-related field trip. Each week of the summer program covers a specific theme (i.e., marine ecology, marine biology, marine geology, meteorology, oceanography, and marine resource management). The local county public school district reviews the curriculum each year and awards participants credit for an integrated science class. Over the course of their four years in the program, participants advance from gaining a broad overview of the ocean, to conducting a guided research project on one specific topic.

Through the university collaboration, participants engage with scientists in multiple ways. Each week, participants attend an interactive seminar with a scientist. Participants are challenged during the seminars to engage in discussion, and have also had opportunities to serve as research assistants for the scientists. For example, one scientist does research on shark migration patterns, behaviors and diets, and youth have been able to contribute to his research by taking measurements, tagging sharks, and taking fin samples.

The participants have an unforgettable experience of interacting with sharks, while learning the process of research. Scientists also guide and encourage the participants' research by attending the summer research symposium when participants present their summer research projects to the university community, their friends, and family members.

Over the years, IMPACT programming has been extended beyond marine science to include other program options. These include pilot projects testing new and emerging technologies such as video production and virtual worlds. The cascading effects of many positive experiences with STEM result in participants who are excited by STEM and go on to pursue postsecondary study. A good example of this is the addition from 2001 to 2006 of BioTrac, a biomedical program strand supported by the National Institutes of Health's SEPA program. Students with an interest in biomedicine were introduced to the field through hands-on lab activities, online research, visits to biomedical research facilities, community research projects, career explorations, and internships with research scientists. Youth used technology skills acquired as part of the IMPACT program to document their experience through digital video and the development of a BioTrac website. During the summer, a subset of youth were selected to attend weekend residential programs at the University of Florida and Florida A&M University, where they gained additional exposure to postsecondary programs leading to careers in biomedical research. Other students who were entering 12th grade or college, and had completed all preliminary activities, were eligible for placement in 6–8 week summer internships in University of Miami School of Medicine's laboratories, where they participated in a broad spectrum of biomedical research activities.

Almost 10 years later, we conducted a follow-up study of 80 youth who had participated in the BioTrac strand, using data obtained from the National Student Clearinghouse. Figure 7.2 shows the average graduation rates reported for program alumni from all program years by race and ethnic group as compared with US post-

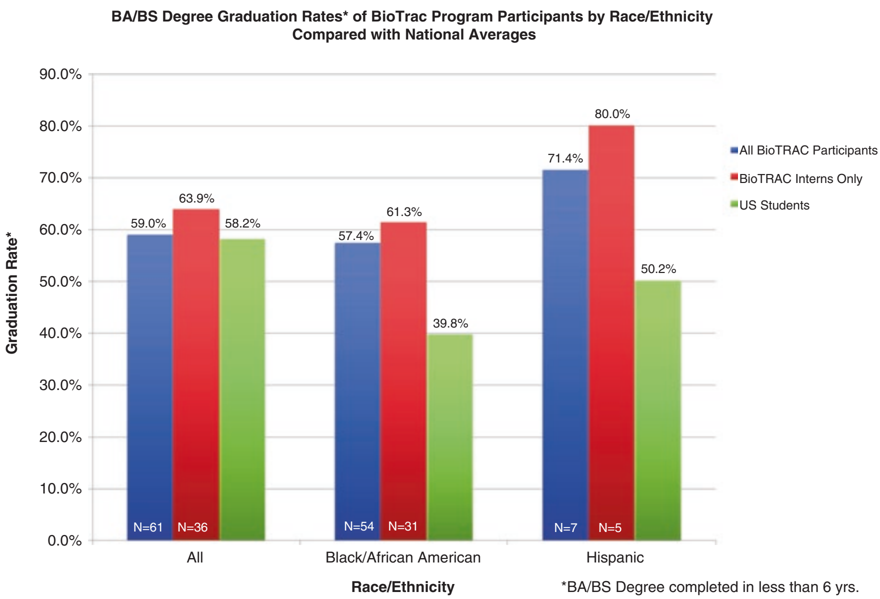

Fig. 7.2 Graduation Rate Comparison

secondary student enrollment (PSE) graduation rates (Digest of Education Statistics 2014). Of note is that PSE outcomes are not disaggregated by income. Regardless of the fact that more than two-thirds of participants are low-income and first-generation college-bound, museum youth graduated at higher rates than the national average for students from *all* socio-economic backgrounds.

7.6 What Can You Do?

If you are an informal educator you probably have questions about the challenges and obstacles to achieving this kind of environment for youth in your community. You might think that this work goes beyond the boundaries of what a science museum or science center should provide. Perhaps we have blurred the boundaries—educators who want to make a difference have always done so. There are many challenges to implementing multi-year youth programs at informal learning institutions. The grant funding model is difficult to sustain and can create tension for the program and development staff with respect to operational dollars. We propose that it is time for science centers to reevaluate their education missions and to view these practices as part of the core work of an informal science institution, practices that will have a high return on investment for the local institution, as well as long-term societal impacts. The support of leadership and board are essential to long-term success as well as buy-in from management level staff outside of the education department. All need to buy in and have a clear understanding of the stakes involved. This is particularly true for staff that have not experienced equity-related challenges in their own lives.

What if you are unable to secure multi-year funding for a youth program like the one described above? There are a number of ways to incorporate cultural competence and promote social justice through daily programming or exhibits. Here are some examples:

- Recognize individual contributions as a team effort. When STEM developments are presented as collaborations involving many people with different ideas, it may help guide those who perceive STEM as being a solitary career choice, see the field differently.
- Hire staff that represents the community you want to serve. Look for people who have succeeded in overcoming barriers similar to those confronting your students.
- Ask friends, colleagues, and program alumni to share stories of how they reached success in STEM fields, what barriers they overcame and how. These kinds of stories build strength and inspiration in individuals who may be interested in STEM but are afraid to pursue a career in STEM.
- Connect with local chapters of university engineering and computer science societies, such as the National Society of Hispanic Engineers, as a source of near-peer mentors and early career professionals who are looking for opportunities to give back as well as build their own networks.

- Create opportunities for first-hand experiences such as a restoration project, a beach cleanup or a "makers" event where staff can work alongside young people, showcasing the active social aspects of science.
- Customize a "touchstone" space for the groups you are trying to attract within the larger museum space. Find out what elements of the space are important for the community and relay those values through the space design. Involve the community in the development process through advisory boards, brainstorming sessions, and casual conversations.
- Articulate how families can make meaningful contributions to the institution. These efforts create a sense of belonging. When individuals feel wanted and needed within the space, they will want to contribute in many ways.
- Set up a mechanism such as a youth advisory board to encourage youth to take on leadership roles in STEM learning activities, both in the informal science learning institution and in the community.
- Present multiple perspectives and applications of STEM concepts. Help families relate to STEM, in culturally relevant or familiar ways. Apply it to concepts in music, chemical reactions in cooking, or botanical medicine.

In closing, there is an urgent and an incredible opportunity for the informal science education community to share the responsibility and the joy of creating engaging learning environments where youth, regardless of race, ethnicity, or income level, are empowered to become powerful assets for our country's future.

References

A Nation at Risk: The Imperative for Educational Reform. (1983). www2.ed.gov/pubs/NatAtRisk/risk.html

Chute, E. (2009). *Lack of diversity part of equation in STEM fields. Colleges try to increase numbers of women, minorities in science and engineering*. Pittsburgh Post-Gazette, Retrieved January 25, 2013, from http://www.post-gazette.com/pg/09041/947952-298.stm#ixzz0g1ceZiGK

Digest of Education Statistics: National Center for Education Statistics (2014). https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2016006

Sue, D., Capodilupo, C., Torino, G., Bucceri, J., Holder, A., Nadal, K., & Esquilin, M. (2007). Racial micro aggressions in everyday life: Implications for clinical practice. *American Psychologist, 62*, 271–286. doi:10.1037/0003-066X.62.4.271.

Time to Succeed. (2013). http://timeandlearning.org/blog/time-gap.

Wang, X. (2012). *Modeling student choice of STEM fields of study: Testing a conceptual framework of motivation, high school learning, and postsecondary context of support*. WISCAPE Working Paper. Retrieved from http://search.proquest.com.ezproxy1.lib.asu.edu/docview/968109722?accountid=4485

Part III
The Role of Professional Societies

Chapter 8
Critical Contemporary Questions for Engineering Education in an Unequal Society: Deliberations for the South African Society for Engineering Education (SASEE)

Brandon I. Collier-Reed and Jennifer M. Case

Abstract The South African Society for Engineering Education (SASEE) was established in 2010 as a forum for those committed to improving the practice of engineering education in the country. These ideals need to be seen in the context of the South African history—a continuing unequal school system and consequent racialised patterns of access and success in university studies. The major activities of the Society are formative in nature and are focused on ensuring that all engineering educators are able to critically engage with the needs of students; particularly those most at risk. The objective is for all students, irrespective of the differences in their schooling backgrounds, to have the opportunity to be successful in their studies. In this article we categorise the papers presented at the first three conferences of the Society in order to determine the research foci that have been followed to date. It is shown that the majority of articles fall into the category of "teaching and learning", with some additional work focusing on students in transition from school to first year. Less represented were themes on curriculum or on policy development. In the context of this book we suggest that social justice and equity have also been less represented. To this end, we draw on a recent piece by one of us to scope out something of an agenda in this domain.

Keywords Engineering education • Higher education in South Africa • Curriculum • Purposes of higher education

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C.B. Leggon, M.S. Gaines (eds.), *STEM and Social Justice: Teaching and Learning in Diverse Settings*, DOI 10.1007/978-3-319-56297-1_8

8.1 Introduction[1]

Engineering education has a long history in South Africa, stretching back to the early twentieth century, but it was only towards the end of that century, and in the context of a new democratic dispensation, that engineering educators started to draw together nationally around concerns on student participation and success. The first national conference on engineering education took place in South Africa in 1997 and was followed by similar events in 2000, 2002 and 2006, with the latter explicitly branded as a regional event aiming for an audience beyond national borders. Through this decade there were regular calls for the establishment of an organisation that could coordinate such events on a more regular basis and formalise such a network (Fraser, 2005). A discussion coordinated by the Engineering Council of South Africa (ECSA) in 2009 led then to the formal constitution of the South African Society for Engineering Education (SASEE) in 2010.

The mission of the society (see www.sasee.org.za) is to foster excellence and innovation in engineering education—at school, college and university levels—and to prepare people to practice engineering as a profession, to spread technological literacy and to increase student interest in technical careers through science and math education and hands-on learning. However, these ideals need to be seen in the context of the legacy of colonialism and apartheid which has meant that the educational preparedness of students entering the South African higher education sector remains largely unequal (Machingambi, 2011). There remain, more than two decades after the transition to a democracy, stark racial differences in participation patterns, especially in programmes such as engineering (see, for example, Scott, Yeld, & Hendry, 2007) even though Machingambi (2011) has suggested that a focus on greater levels of participation has during this time increasingly become "an urgent imperative" (p. 13). As recently as October 2015, the South African Department of Higher Education and Training's National Higher Education Transformation Summit (http://www.dhet.gov.za/summit) was labelled as a "call to action" in the march towards a "fully transformed higher education sector".

In order to contribute towards addressing these significant challenges, the major activities of the Society are formative in nature and are focused on ensuring that all engineering educators are able to critically engage with the needs of students; particularly those most at risk. The objective is for all students, irrespective of the differences in schooling backgrounds, to have the opportunity to be successful in their studies. This is not only to ensure that the country has a growing cohort of engineering professionals to help drive economic development, but also to help address significant disparities in society. One of the primary ways used to further this agenda is that of bi-annual workshops and biennial conferences. The workshops focus on developing better pedagogic approaches to classroom practice as well as broader student support strategies while the conferences focus on the dissemination of local research undertaken in the broad area of engineering education.

[1] Sections of this chapter draw on a keynote address delivered by Jennifer Case at the Higher Education Learning and Teaching Association of South Africa (HELTASA) annual conference, 17–20 November 2015.

This chapter on the role of professional societies and organisations in helping to address inequality, educational attainment and social justice is an opportunity to not only reflect on the contribution that the workshops and conferences have made towards these ideals during the past six years, but also to highlight some areas that may be important to consider when considering how best to move this agenda forward.

8.2 The Contribution of National Engagements

SASEE has held a conference in each of 2011, 2013 and 2015 (Collier-Reed, 2011, 2013; Pocock, 2015) with delegates representative of all higher educational institutions that offer engineering programmes at the tertiary level present. During these three conferences, 125 papers have been presented representing the breadth of the engineering education work being undertaken in South Africa. In order to understand to what level this research directly focuses on helping to address inequality, educational attainment and social justice, a meta-analysis of the titles of these papers was undertaken. As a framework for this analysis, the work recently completed by the Centre for Research in Engineering Education (CREE)[2] was drawn on. CREE identified five key research focus areas that could be used to locate their research, comprising: teaching and learning in science and engineering; students in transition; knowledge and curriculum; higher education policy and institutional dynamics; evaluation and development of methodologies. The papers presented were considered in terms of these categories and the following picture emerged.

The largest majority of papers could be located within the "teaching and learning" focus area. CREE has defined this focus area as being directed towards research that focuses on improving student learning and classroom practice by:

> … explor(ing) innovative pedagogies in science and engineering and … the ways in which different pedagogies constrain and/or enable learning. We investigate the efficacy of using technologies to aid student engagement and learning. We explore science and engineering students' disciplinary knowledge and skills and the assessment thereof, as well as their conceptions, identities and experiences in learning. We are interested in the development of academic, scientific and technological literacies and students' induction into disciplinary discourses in science and engineering. (CREE, 2015)

An important characteristic of research of this nature, CREE suggests, is that it is often undertaken by practitioners in their own classrooms. This view was borne out through the analysis of the papers where it was apparent that there were a number of practitioners who were making tentative first steps in engineering education research.

When one looks more closely at the papers in this category, there were relatively few examples of research work that could be thought of as directly talking to the

[2] CREE is recognised as one of the leading groups in South Africa with a specific focus on the research of engineering education. Constituted in 1996, the Centre has grown to include academics and researchers from across a number of institutions in the Western Cape.

theme of this book—a focus on inequality, educational attainment and social justice—although many of the papers had aspects that addressed these critical issues. An example of papers includes:

- Student identity and the need to make classroom mathematics relevant to engineering practice (Craig, 2011);
- What it takes to ask a question: Using a backchannel in an engineering classroom (Collier-Reed, 2015) and
- Creating social learning spaces to enhance the learning experience (Madhav, Joseph, & Twala, 2015).

A further well-represented focus area, and one which relates closely to the theme of this book, is that of "students in transition". CREE describes this area as concerning:

> …the way in which students navigate transitions. In addition to the transition from school to university and from university to the workplace, we consider various other transitions within higher education: moving from the supportive environment of a first-year extended degree programme into a mainstream programme, from natural to engineering sciences, the transition from the engineering sciences to design, from convergent to divergent problems, as well as the transition into postgraduate studies. We grapple with questions about the nature of the boundaries between contexts, how the difficulties in making these transitions are exacerbated for different groups of students, how the transitions impact on student identities, and what implications transitions have for curriculum development and teaching and learning in science and engineering. (CREE, 2015)

From the number and breadth of papers presented, this appears to be a rich area of research across the country. Examples of the type of research work undertaken include:

- The performance and persistence of engineering students on their journey through the first year (Vosloo, 2011); and
- Transitional distance: A new perspective for conceptualising student difficulties in the transition from secondary to tertiary education (Woollacott, Snell, & Laher, 2013).

In contrast to the first two areas described above, there were only a handful of papers presented that fell into the "knowledge and curriculum" focus area while "higher education policy and institutional dynamics" and "evaluation and development of methodologies" were poorly represented. There were, however, papers that spoke to the development of skills within students to help them as engineers play a role in shaping and contributing to the development and success of a community, such as:

- Community-based outreach as a component for engineering education (Jordaan, 2011); and
- Sustainability, citizenship and ethics within the mainstream engineering curriculum? (Langdon, 2013).

The second core activity of the Society, the bi-annual workshops, have focused on developing improved pedagogic approaches to classroom practice as well as broader student support strategies. These "master-class" workshops have included such topics as teaching large classes, (ethical) curriculum design, technology-mediated teaching and learning in engineering, educating engineering students to be professional and ethical and, most recently, sustainable engineering.

Together, these bi-annual workshops and biennial conferences have made some contribution towards ensuring that all engineering educators are able to critically engage with the needs of students; particularly those most at risk. However, the events of 2015 on South African campuses have suggested that all sectors in South African higher education might still need to reexamine their achievements and limitations over the course of the post-apartheid era. A series of protests across the country that coalesced not only in a national student uprising centred on the issue of fees and the cost of education, but also drawing in related issues around the failure of our society to meet the aspirations of many young South Africans and to deal with the nation's colonial and apartheid legacy. The sections that follow are offered in that spirit—an initial consideration of some future challenges that SASEE would do well to consider. To do this we draw closely on recent work conducted by one of us, reinterpreting these positions in the context of engineering education (Case, 2016).

8.3 A Re-Examination of the Purposes of Higher Education

Earlier in this chapter, the objective of the Society was articulated as both ensuring that the country has a growing cohort of engineering professionals to help drive economic development as well as helping to address significant disparities in society. We have seen a broad public consensus on a view that the primary purpose of education is economic in nature, and in the realm of engineering education this view seems beyond question. In South Africa specifically, with a slow-growing economy coupled with the challenges around widespread poverty, the attraction of this view is clear, and one strand of the ideas informing the recent protests under the banner #feesmustfall also rests on this assumption. On an individual level one can understand the logic of the student who knows that getting a degree (especially an engineering degree) is going to offer the possibility of helping her and her family lift themselves out of poverty.

However, our contention is that higher education in contemporary South Africa is about more than just this economic imperative, and that this holds even for the engineering education sector, which has such intrinsic links to the commercial and industrial world. In the broader higher education literature there is an important scholarly movement growing that is returning to foundational discussions on education—on the intrinsic purposes of education and how these link to what we can call the "public good". It is only fairly recently that society departed from this more fundamental view of the nature of education. Case (2016) argues that this is partly because the spectacular economic growth in the first world during the post-war period allowed for an expansion of higher education that had hitherto not been imaginable. There was a misconception in deriving a causal logic from this observation; that it was these higher levels of education that had driven economic growth, while in fact it seems if anything that the causality was the other way around—economic growth had made possible something inherently desirable to society, the possibility to taking learning to higher levels for much larger proportions of the population. The expansion of engineering education through the twentieth century not only supported economic growth, but also gave widespread opportunities for social mobility to (largely male) working class students.

Case (2016) states:

> To argue for the public good purposes of higher education is not to deny that there might be individual benefits to be derived and that these might at least in part relate to job prospects, but it is to say that if this is all that higher education is for, then we are selling it short.

She turns to the work of sociologist Andrew Sayer (2011) to build a view of higher education more grounded in a perspective on humans as inherently social beings: we derive our sense of what matters to us in the context of living amongst others. We are curious and we want to learn, we seek to do things that are interesting and fulfilling to us. Case asks: "Why should we not simply embrace the possibility that maybe a large majority of our population might desire education, might thirst for knowledge and intellectual challenge? And that the wellbeing of society at its core might rest indeed on the possibilities for individual people to live lives that are fulfilling in terms of things that matter to them?"

Another contribution to this discussion comes from Nixon (2011), who notes that while the argument about education and the public good is not new, it needs to be reworked afresh for each generation, since the meaning of "the public" changes. In this context, we need also to consider what "the public good" arguments might mean in an inherently unequal society like South Africa. And so we need to do a further layer of reimagining if we want to think about higher education and the public good in the context of the postcolony—particularly in light of the issues raised by recent student protests in South Africa.

8.4 A Re-Examination of the University in the Context of an Unequal Society

To further unpack the question of the contemporary situation for higher education in South Africa, Case (2016) turns to Mbembe (2015) and Luckett (2016). Mbembe's starting point is to locate part of the contemporary dissatisfaction with higher education in our fixation with the economic basis of higher education and considerations of efficiency. He argues that we need also to be thinking about issues of belonging in the university. What Mbembe states implicitly, in noting that many black students and staff do not feel their presence to be visible on South African campuses, Luckett takes one step further, to suggest that the geographical and economic arrangements in postcolonial Africa mean that we might have two different classes of students in our universities—those who have learnt to enjoy the rights of being a citizen from growing up in urban spaces, and those whose subjected identities result from a family upbringing in the subjected margins of our society.

The question that emerges from this discussion is what the South African Society for Engineering Education can do to help shift the views of engineering faculty towards embracing the notion of their programmes not being so much about only growing a cohort of engineering professionals to help drive economic development, but rather about education building the social cohesion that will be needed to address the deep dissatisfactions that are tearing our society apart.

In proposing an educational response to these structural realities, Case suggests it is also worthwhile to consider Basil Bernstein's (2000) notion of pedagogic rights. These are:

- The right to individual enhancement—"Enhancement is not simply the right to be *more* personally, *more* intellectually, *more* socially, *more* materially, it is the right to the means of critical understanding and to new possibilities".
- The right to be included… "socially, intellectually, culturally and personally. …[this does not necessarily mean] to be absorbed… also the right to separate".
- The right to participate… "in procedures whereby order is constructed, maintained and changed" (p. xx–xxi).

Bernstein had schooling in mind when he formulated these pedagogic rights, but they can also be repurposed to provide a framing also for higher education and for engineering education, and are in line with Nixon's vision outlined above. Case asks: "The tough South African question, if we follow Luckett's analysis, is what does it mean to make attainable these rights—at least for those students who we have admitted into the university (at great cost to themselves and to society) but whose backgrounds have not provided an experience of free access to such rights?"

Discussions have focused on curriculum reform but here we need to note that curriculum entails an engagement with knowledge, and at the level of higher education we cannot avoid the specialised nature of different knowledge traditions and forms. Recontextualisation of knowledge into curriculum always involves selection, and here we can locate current debates about *what* knowledge and *whose* knowledge is important for institutions located on the southern tip of Africa. It is within this context that we make the following suggestions for consideration by those involved in the curriculation of engineering programmes.

8.5 A Re-Examination of Curriculum Structure

Following the position established here with regard to centring higher education on its public good purposes, Case (2016) offers a range of deliberations regarding curriculum, some of which are particularly pertinent to engineering education. Firstly we discuss extended degree programmes, and then more generally issues around the structure of the engineering degree.

In South Africa there is a decade's long history of providing extended degrees, especially in engineering, for students who have come from disadvantaged school backgrounds. The idea makes a lot of sense and these programmes have indeed graduated significant cohorts over time. However, in a recent PhD study, Mogashana (2015) closely analysed the experiences of a group of senior students who had entered engineering through an extended degree programme. Although the programme had facilitated their ultimate graduation, they felt that there had also been a personal cost. They had felt the marginality of being on a different programme and that this exacerbated their sense of "otherness". Ultimately they felt they were just hanging on and counting the days to leaving the institution. In the light of this study and other critiques of separate programmes, we suggest that a significant challenge for engineering education will be to devise curriculum structures that allow students to access any additional teaching that they need, without the stigma of being in a completely separate programme.

With regard to the engineering degree in general, we note that the valorisation of professional degrees such as engineering due to their economic value has actually also created its own problems. For some school leavers this is a great choice and the professional degree is helpfully oriented very directly towards their career. However, the relatively fixed curriculum can be a real trap, especially for those who are still working out their interests and their strengths. We note with interest the system in some US colleges where the first degree is a liberal arts degree and the professional degree comes at postgraduate level. While this is unlikely to receive much support in South Africa due to cost, we argue that we have underplayed the role of formative bachelors degrees for addressing precisely the challenges of South African higher education that have been alluded to above. With the ongoing limitations of our school system (Bloch, 2009) there is a strong argument for the value of a bachelors education that offers breadth, choice, conceptual challenge, and requires a student to craft their own set of interests, their majors. The value of the open structure of the formative degree is that there is significant scope for students to explore things they think they want to, to reformulate these interests and to pick up additional input where they recognise that they need it. At the very least, engineering programmes need to embrace the inclusion of subjects that are traditionally found in the liberal arts—as encompassed in Grasso and Burkins' (2010) notion of "holistic engineering". We suggest that it is no longer acceptable to only cover the traditional engineering science domain to the exclusion of subjects that help students grapple with issues around the public good. Engineers need to be more than just technically competent; they need to be able to fully participate in the broader society.

For those students who do come into the constrained curriculum of the professional degree, and given that in contemporary South Africa there are going to be considerable inducements for students to go in this direction (recognising the need we have for engineers)—we should therefore consider closely the possibilities for curriculum reform. When an engineering programme is "owned" by a department and has a cohort moving through it in a relatively predetermined manner, there are distinct practical possibilities to work on the coherence of the curriculum offering to make sure that it requires consistent work of students and provides close and regular feedback.

8.6 Concluding Comments

The South African Society for Engineering Education has developed a significant local profile in its first 6 years. It currently has almost 150 members and its formation has resulted in a growing community of engineering education scholars and practitioners that are focused on facilitating high quality learning outcomes in engineering. However, if one considers the research outputs as reflected by the papers presented at the biennial conferences, it is apparent that there is currently limited focus explicitly on understanding how to better address inequality and issues of social justice.

Building on the arguments advanced by Case (2016), we have argued that engineering education is not just about ensuring that the country has engineering professionals to help drive economic development. Rather, we need to recover more complex ways of thinking about education and, while recognising the need for some metrics to understand "how students are doing", our evaluative judgements need to stretch beyond these. If we are trying to formulate a different conceptualisation of the role of higher education, one based on the public good, then we are going to have to realise the prescriptions for good teaching or coherent curricula are not going to be sufficient.

Returning to Bernstein's (2000) rights of inclusion and participation, we suggest that curriculum structure can serve to promote a sense of inclusion or exclusion—if one has a cohort type structure as in a professional programme like engineering, then we suggest that there are significant consequences if you have two parallel routes, because they will always differ in perceived status. Inclusion is also an important challenge for every South African lecturer in their daily practice—revolving around questions about who asks questions in class, who comes to the lecturer after class for help and how student groups operate. These are matters that the SASEE community will need to develop a high level of expertise around. We can have a carefully designed curriculum structure but if this doesn't reach down to an inclusive pedagogy and upwards to a welcoming institution, then it will not achieve its stated ends.

The nature of higher education institutions in South Africa is such that they maintain significant educational autonomy. Furthermore, for professional engineering qualifications, the ECSA (2014) plays an accreditation role in terms of a programme's design criteria, knowledge profile and graduate attributes. Taken together, this results in resistance amongst institutions to embrace the curriculum suggestions articulated above. For these ideas to be integrated into existing conversations around engineering curriculum reform, SASEE will need to play a leading role in facilitating this discussion. The existing bi-annual workshops and biennial conferences can play a significant role in this regard.

References

Bernstein, B. B. (2000). *Pedagogy, symbolic control, and identity: Theory, research, critique*. Lanham: Rowman & Littlefield.

Bloch, G. (2009). *The toxic mix: Whats wrong with SA's schools and how to fix it*. Cape Town: Tafelberg Publishers.

Case, J. M. (2016). Re-imagining the curriculum in a postcolonial space: Engaging the public good purposes of higher education in South Africa. *Journal for New Generation Sciences, 14*(3), 22–33.
Centre for Research in Engineering Education. (2015). *Research focus areas*. Retrieved from http://www.cree.uct.ac.za/research-focus-areas
Collier-Reed, B. I. (2015). *What it takes to ask a question: Using a backchannel in an engineering classroom*. Paper presented at the Third Biennial Conference of the South African Society for Engineering Education, Durban, South Africa.
Collier-Reed, B. I. (Ed.) (2011). *Proceedings of the first biennial conference of the South African Society For Engineering Education*. Stellenbosch: SASEE.
Collier-Reed, B. I. (Ed.) (2013). *Proceedings of the second biennial conference of the South African Society for Engineering Education*. Cape Town: SASEE.
Craig, T. (2011). *Student identity and the need to make classroom mathematics relevant to engineering practice*. Paper presented at the First Biennial Conference of the South African Society for Engineering Education, Stellenbosch, South Africa.
Engineering Council of South Africa. (2014). *Whole Qualification Standard for Bachelor of Science in Engineering (BSc(Eng))/Bachelors of Engineering (BEng): NQF Level 7*. Retrieved from https://www.ecsa.co.za/education/EducationDocs/E-02-PE_Whole_Qualification_Standard_r4.pdf
Fraser, D. M. (2005). *Building engineering education capacity in Africa*. Paper presented at the World Federation of Engineering Organizations Conference, San Juan, Puerto Rico.
Grasso, D., & Burkins, M. (2010). *Holistic engineering education: Beyond technology*. New York: Springer Science & Business Media.
Jordaan, M. (2011). *The Performance and Persistence of Engineering Students on their Journey through the First Year*. Paper presented at the First Biennial Conference of the South African Society for Engineering Education, Stellenbosch, South Africa.
Langdon, G. (2013). *Sustainability, citizenship and ethics within the mainstream engineering curriculum?* Paper presented at the Second Biennial Conference of the South African Society for Engineering Education, Cape Town, South Africa.
Luckett, K. (2016). Curriculum contestation in a post-colonial context: A view from the South. *Teaching in Higher Education, 21*(4), 415–428.
Machingambi, S. (2011). Is access to higher education a sufficient condition for social equity in South Africa? A critical analysis. *Journal of Social Science, 28*(1), 13–20.
Madhav, N., Joseph, M. K., & Twala, B. (2015). *Creating social learning spaces to enhance the learning experience*. Paper presented at the Third Biennial Conference of the South African Society for Engineering Education, Durban, South Africa.
Mbembe, A. (2015). *Decolonizing knowledge and the question of the archive*. Unpublished Paper.
Mogashana, D. G. (2015). *The interplay between structure and agency: How academic development programme students' make their way' through their undergraduate studies in engineering*. Cape Town: University of Cape Town.
Nixon, J. (2011). *Higher education and the public good: Imagining the university*. London: A&C Black.
Pocock, J. (Ed.) (2015). *Proceedings of the Third Biennial Conference of the South African Society for Engineering Education*. Durban: SASEE.
Sayer, A. (2011). *Why things matter to people: Social science, values and ethical life*. Cambridge: Cambridge University Press.
Scott, I., Yeld, N., & Hendry, J. (2007). *Higher education monitor: A case for improving teaching and learning in South African higher education*. Pretoria: Council on Higher Education Pretoria.
Vosloo, M. (2011). *The Performance and Persistence of Engineering Students on their Journey through the First Year*. Paper presented at the First Biennial Conference of the South African Society for Engineering Education, Stellenbosch, South Africa.
Woollacott, L., Snell, D., & Laher, S. (2013). Transitional distance: A new perspective for conceptualizing student difficulties in the transition from secondary to tertiary education. Paper presented at the Second Biennial Conference of the South African Society for Engineering Education, Cape Town, South Africa.

Part IV
Lessons Learned and the Way Forward

Chapter 9
Lessons Learned Across Settings, and the Way Forward

Cheryl B. Leggon and Michael S. Gaines

Abstract This section identifies design principles that the initiatives discussed in previous chapters have in common, and summarizes lessons learned in terms of what programs, policies, and practices are effective or at least promising. It is important to emphasize that what works for students from underrepresented minorities (URM) works for all students. It is equally important to add that there must also be activities targeted to URM learners. These lessons can be a catalyst to create direction and strategies to develop, sustain, and institutionalize innovative programs and practices addressing STEM teaching and learning as issues of social justice: commitment; communication; partnerships; institutional linkages; transformative pedagogy; community; robust evaluation; and research.

Keywords STEM • Social justice • Design principles • Institutional linkages • Sustainability

9.1 Commitment

Across formal and informal institutions and across nations, commitment is required for successful programs and practices to diversify STEM education and workforce, as discussed in a recent report from the United States: "all stakeholders must have an abiding commitment to equitable access to high-quality learning experiences for all learners and for their communities" (Parker, Pillai, & Roscelle 2016:7). A consistent commitment to social justice must be made by all relevant stakeholders, not only students and teachers, but also administrative staff, funders, and institutions that house initiatives. Staff turnover poses a threat to the continuity of an initiative.

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C.B. Leggon, M.S. Gaines (eds.), *STEM and Social Justice: Teaching and Learning in Diverse Settings*, DOI 10.1007/978-3-319-56297-1_9

Continuous external funding for equity initiatives that have robust evidence of success is critical; moreover, it can provide a bridge as an initiative becomes institutionalized. In fact, some funders require as a condition of funding that the institution housing the initiative will take it over when external funding ends.

9.2 Communication

Communication is critical to the success of targeted efforts to increase and enhance the participation of URM learners in STEM fields. The purposes, goals, and objectives of the program should be clearly articulated to all stakeholders. Moreover, expectations in terms of participants' roles and behavior should be clearly specified. This includes discussing commitment, requirements for participating, deliverables, deadlines, and milestones. Students should learn to communicate their science clearly to one another, and to non-scientists. Program administrators should keep in contact with stakeholders periodically so that everyone feels connected to an ongoing endeavor. A variety of media—including social media—can enhance communication. For example, programs can develop their own websites—one for the general public, and another for program participants only. We cannot overstate the criticality of communication in terms of disseminating program information at the local, regional, national, and international levels. Indeed, the exchange across nations of ideas, successes, and challenges can provide useful global perspectives.

9.3 Partnerships

Successful programs and initiatives are characterized by a variety of partnerships. Internal partnerships between program personnel and personnel in other units of an institution in which the program is housed maximize the use of institutional resources, and enhance the probability of the program being institutionalized. In addition, it can be beneficial for a program to forge external partnerships with other schools and organizations such as zoos, science museums, professional associations, and industry. Partnerships can be forged in different ways. For example, instead of creating a new partnership, it may be strategically beneficial to build on an existing partnership.

9.4 Institutional Linkages

Institutional linkages are relationships between and among institutions. Linkages can be forged within an institution, for example, academic departments in a college or university might collaborate and participate in a program to diversify the STEM workforce. Sometimes linkages are forged through formal agreements. Other times, they may be informal or traditional, although they might become formal agreements. Another source of institutional linkages is that between education institutions on the one hand, and industry on the other. These linkages could entail providing opportunities through internships for learners to experience working in STEM fields. Such experiences do triple duty—they: enhance understanding of scientific methods and procedures; provide socialization experiences in which student interns learn how science is conducted, and how they should conduct themselves; and influence learners' occupational choices insofar as learners can see themselves in a career in a STEM field. These institutional linkages are consistent with two recommendations from a recent report: (1) that practitioners need to reach across institutional boundaries to connect experiences in and out of school to reinforce and enhance learning, and (2) complex interventions across institutions should be developed, implemented, and evaluated (Parker, Pillai, & Roschelle, 2016).

9.5 Transformative Pedagogy

While addressing issues of underrepresentation in STEM fields, researchers and practitioners began to shift focus from the individual learner to the institutional context in which learning takes place. This entails examining the curriculum in terms of what is taught and how it is taught. Traditional methods in which information is imparted by the expert teacher to the uninitiated learner can stifle rather than stimulate creative thinking and problem solving. Rote memorization needs to be replaced with inquiry-based, hands-on activities and problem-based learning; this makes science sensible and comprehensible. Moreover, it shows learners that they can learn science in a variety of contexts, and that science is relevant to their lives. Most important, perhaps, these experiences can change learners' perceptions of who does science.

9.6 Community

Community is a key aspect of science and life. Developing and nurturing supportive communities of scholars and families is instrumental in the success of targeted programs to increase the participation of URM students in STEM fields. Experiences of doing real authentic research in laboratories and/or in the field alongside professional scientists dispel the stereotype that science is conducted alone. Similarly, learners working together on projects provide mutual support. These communities are characterized by having high standards of achievement for their members—in terms of academic achievement, degree completion, and aspiration for postgraduate study. In addition, communities provide academic, emotional and social support. An integral component of community is mentoring. Professional associations are an excellent source of mentors. One type of mentoring is peer mentoring. Peer mentoring can be especially effective if the peer mentor is of the same race/ethnicity as the learner insofar as mentoring enhances identifying with "someone like me." In tiered mentoring, former learners mentor current learners as they progress through the education and career pathways; this provides continuity and extends the community in time. Space that is dedicated to learners and stakeholders enhances the sense of community and augments individual empowerment.

9.7 Robust Evaluation

One of the most critical elements of a targeted program or initiative is evaluation. Evaluation provides evidence for the effectiveness of a program or initiative. Because resources are scarce, equity initiatives must demonstrate that they are effective in reducing disparities. Robust external evaluation provides credible evidence that an initiative is achieving its goals and objectives. It is important to note, however, that even with robust evidence of success there is always room for improvement. Robust evaluations provide support for funding and sustainability. Evaluations address what worked, how it worked, and why; conversely, evaluations can provide information on what did not work and why. Robust evaluations provide information so that adjustments can be made in real time as warranted; in other words, evaluations provide information for continuous program/initiative process improvement.

9.8 Research

There is a need for continued research on effective or promising policies, programs/initiatives, and practices and strategies that seek to diversify and enhance the STEM workforce by increasing the participation of URMs. Ideally, this research should track the career pathways of learners, and collect data on the long-term effects of participating in these initiatives. Moreover, research should systematically examine the impact of the transformative pedagogy in terms of sparking interest in and developing a commitment to a career in a STEM field. In addition, effective ways to train teachers to deliver the transformative pedagogy should be studied. Another critical item on the research agenda is to study methods of evaluation, best practices, and metrics to evaluate equity initiatives.

9.9 Concluding Remarks

Participation in the STEM workforce of people from URMs is not only an issue of quantity—that is increasing the numbers; it is also an issue of quality of education, experience, and training. Policies, programs, practices, and strategies that work for

URM learners work for all learners. We sincerely hope that teachers, funders, practitioners, administrators, researchers, and evaluators will use information in this book to stimulate ongoing discussion and catalyze action to address increasing diversity in the STEM workforce, access, equity, and social justice.

References

Parker, C. E., Pillai, S., & Roschelle, J. (2016). *Next generation STEM learning for all. A report from the National Science Foundation supported forum*. Waltham, MA: Education Development Center.

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C.B. Leggon, M.S. Gaines (eds.), *STEM and Social Justice: Teaching and Learning in Diverse Settings*, DOI 10.1007/978-3-319-56297-1