Advances in Game-Based Learning

Carmela Aprea
Dirk Ifenthaler *Editors*

Game-based Learning Across the Disciplines

Springer

Advances in Game-Based Learning

Series Editors:

Dirk Ifenthaler
Scott Joseph Warren

More information about this series at http://www.springer.com/series/13094

Carmela Aprea • Dirk Ifenthaler
Editors

Game-based Learning Across the Disciplines

Springer

Editors
Carmela Aprea
University of Mannheim
Mannheim, Germany

Dirk Ifenthaler
University of Mannheim
Mannheim, Germany

Curtin University
Perth, WA, Australia

ISSN 2567-8086 ISSN 2567-8485 (electronic)
Advances in Game-Based Learning
ISBN 978-3-030-75141-8 ISBN 978-3-030-75142-5 (eBook)
https://doi.org/10.1007/978-3-030-75142-5

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

Preface

Over the past two decades, game-based learning has grown increasingly into a popular instructional approach due to its power to motivate and engage students in complex learning, such as problem-solving, decision-making, and metacognitive thinking. There has been a lot of effort to design and develop educational games or to use existing commercial entertaining games to create a game-based learning environment. Despite some ongoing debates about the positive or negative impact of digital games perceived by many people, there is sufficient empirical evidence to support the benefits of digital games (including video and computer games) for learners on several aspects, such as cognitive, motivational, emotional, and social domains. Since games have such capability and power to motivate and benefit their cognitive thinking, educational researchers have attempted to capture the fun, challenges, and engagement of gaming experience to be applied to learning and instruction.

Accordingly, the capabilities and possibilities of emerging game-based learning technologies bring about a new perspective of learning and instruction. The purpose of this edited volume *Game-Based Learning Across The Disciplines* is to map how various disciplines such as Economics, Business Administration, Management, STEM, Social Science, or History exploit the benefits of game-based learning, but also which specific challenges they encounter and how they cope with them. It features three major parts: Part I—*Inside And Across Social Science, Business, and Economics Disciplines*, Part II—*Inside And Across The STEM Disciplines*, and Part III—*Substantiating Game-based Learning*.

In Part I, the contributions are set to explore game-based learning inside and across the disciplines of Social Science, Business, and Economics. The first chapter titled *Applying Insights from Behavioral Finance and Learning Theory in Designing a Financial Education Serious Game for Secondary School Students* (Julia Schultheis, Carmela Aprea, Chap. 1) describes the development of a serious game that aims to promote short-term financial decisions. The next chapter, *Game-Based Learning in Economics Education at Upper Secondary Level*, focuses on the presentation of a newly developed GBL environment—Moonshot—to promote the financial literacy of upper secondary students, its theoretical framework, and describe the research design of the empirical study in which the game will be implemented to assess the effects of GBL on financial literacy (Liane Platz, Michael Jüttler, Stephan Schumann, Chap. 2). Then, Jessica Paeßens and Esther Winther suggest in their chapter, *Game Design in Financial Literacy: Exploring Design Patterns for a Collaborative and Inclusive Serious Game from Different Perspectives*, a trialogue with nonplaying characters to foster and assess collaborative problem-solving (Chap. 3). The following chapter, *Development and Pilot Testing of a Financial Literacy Game for Young Adults*, present the theoretical foundations of serious games, how they have been implemented in this game, with a special focus on the game mechanics, as well as the results from the pilot testing phase of the game (Andrea Maria Pfändler, Chap. 4). *Business Simulation Games: Three Cases from Supply Chain Management, Marketing, and Business Strategy* explores some of the theoretical business concepts and models underpinning the use of educational games in business disciplines and explores how those are embedded in three business simulations as illuminative practice examples (Scott J. Warren, Meranda Roy, Heather A. Robinson, Chap. 5). Then, *Serious Games as Assessment Tools: Visualizing Sustainable Creative Competence in the Field of Retail,* shows how statistical models can help match the observed competence of players with an intended competence model formulated a priori and relates the findings to the underlying theoretical competence model (Susanne Weber, Mona Off, Tobias Hackenberg, Matthias Schumann, Frank Achtenhagen, Chap. 6). The final chapter of this part, *Gameful Learning and the Syrian Conflict: Developing Global Learning Competencies in a Complex Conflict*, discusses the *Syria Simulation* project through theoretical lenses and describes the ways in which the game's design reflects an experiential system of rules, play and culturally responsive design (Jason Rosenblum, Selin Guner, Christie Wilson, Mity Myhr, Chap. 7).

In Part II, the contributions study game-based learning inside and across STEM disciplines. The first chapter, *Designing Dynamic Learning Supports for Game and Simulation-Based Learning in STEM Education*, presents two design cases of simulation game-based learning platforms integrating dynamic learning support systems, discusses specific challenges that were encountered when incorporating the supports in the platforms (Byung-Joo Kim, Fengfeng Ke, Jewoong Moon, Luke West, Chap. 8). Next, *Fostering Learning Transfer by Employing a Learning App for Future Preschool Educators in Vocational Schools* focuses on the development of a learning app in the area of STEM education for future professionals in the area of Early Childhood Education and Care (Jana Heinz, Eva Born-Rauchenecker, Chap. 9). *A Naturalistic Inquiry into Digital Game-Based Learning in STEM Classes from the Instructors' Perspective* seeks to gain insights from instructors into their teaching practices when integrating the variant game into STEM classes (Yun Li, Armanto Sutedjo, Suzanna J. Ramos, Hector Ramos Garcimartin, André Thomas, Chap. 10). Then, *Designing an Augmented Reality Digital Game for Adaptive Number Knowledge Development* provides a detailed description of *The Nomads* game and an in-depth analysis of how underlying theories have informed the design and the development of the game (Jiaqi Yu, André R. Denham, Chap. 11). The final chapter of this part, *The Iteration of Design and Assessment for a Digital*

Game to Support Reasoning in a College Algebra Course, reports a design-based research project for an educational digital game *Functions of the Machine*, which was designed to motivate college students to learn mathematics through playing the educational game that scaffolds their reasoning, critical thinking, and problem-solving in mathematics, specifically algebra (Xun Ge, Scott N. Wilson, Jackie T. Mania Singer, William M. Thompson, Keri A. Kornelson, Jessica Lajos, Braden Roper, Javier Elizondo, Stacy L. Reeder, Leslie Williams, and Margaret L. Kleiser, Chap. 12).

In Part III, the contributions demonstrate foundations of game-based learning and a look beyond discipline-centered approaches of game-based learning. The first chapter, *Instructional Design for Digital Game-Based Learning*, focuses on possibilities to intermesh domain-specific knowledge and task structures with suitable game scenarios and game mechanics using examples from different domains (Jacqueline Schuldt, Helmut Niegemann, Chap. 13). Then, *Play Attention: Thinking Like a Game Designer with Online Instructional Design* explains why game-based learning can be impactful and describes strategies for thinking like a pedagogue and a game designer simultaneously (Christopher Lindberg, Meghan Naxer, Chap. 14). The following chapter, *The Teacher-Centered Perspective on Digital Game-Based Learning*, aims to provide an overview of quantitative and qualitative methods from diverse disciplines for the teacher-centered evaluation of game-based learning approaches (Thea Nieland, Anna Fehrenbach, Maximilian Marowsky, Miriam Burfeind, Chap. 15). *Narrative, Video Games, and Performance In Situ: Evaluating Learning Within Games and Implications for Research from a Literacy Perspective* is dedicated to establishing the relationship between the field of literacy and game-based learning (P. G. Schrader, Kenneth J. Fasching-Varner, Michael P. McCreery, Chap. 16). Next, *Could Minecraft Be a School? What Are the Transdisciplinary Implications of this Game-Based Learning Environment?* reflects on possible implications for teaching and learning if schools stopped requiring a planned curriculum and instead would engage in an immersive game-based learning environment (Bryan P. Sanders, Chap. 17). The final chapter, *Looking Back and Moving Forward with Game-based Learning Across the Disciplines*, highlights the current state of research in game-based learning with a specific emphasis on cross-disciplinary perspectives as well as concludes with future directions for research and practice (Carmela Aprea, Dirk Ifenthaler, Chap. 18).

Without the assistance of experts in the field of game-based learning, the editors would have been unable to prepare this volume for publication. We wish to thank our board of reviewers for their tremendous help with both reviewing the chapters and linguistic editing.

Mannheim, BW, Germany Carmela Aprea
Mannheim, BW, Germany and Perth, WA, Australia Dirk Ifenthaler

Contents

About the Editors

Carmela Aprea (aprea@bwl.uni-mannheim.de) is Full Professor and Head of the Chair of Economic and Business Education—Instructional Systems Design and Evaluation at the University of Mannheim (Germany). She holds a Diploma in Business and Economics Education from the Goethe University Frankfurt (Germany) and a PhD in the same field from the University of Mannheim (Germany). In addition, she is co-founder and director of the Mannheim Institute for Financial Education (MIFE). Besides game-based learning and assessment, her research interests are financial literacy and pension planning, financial education, mental representations of economic concepts, visual learning and resilience in work-related and educational contexts. Besides her research activities, she advices national and international organizations such as the Deutsche Bundesbank, the Swiss National Bank, and the OECD with regard to financial literacy and financial education issues.

Dirk Ifenthaler (dirk@ifenthaler.info; www.ifenthaler.info) is Professor and Chair of Learning, Design, and Technology at the University of Mannheim, Germany, and UNESCO Deputy Chair of Data Science in Higher Education Learning and Teaching at Curtin University, Australia. His previous roles include Professor and Director, Centre for Research in Digital Learning at Deakin University, Australia, Manager of Applied Research and Learning Analytics at Open Universities, Australia, and Professor of Applied Teaching and Learning Research at the University of Potsdam, Germany. He was a 2012 Fulbright Scholar-in-Residence at the Jeannine Rainbolt College of Education at the University of Oklahoma, USA. Dirk's research focuses on the intersection of cognitive psychology, educational technology, data analytics, and organizational learning. His research outcomes include numerous co-authored books, book series, book chapters, journal articles, and international conference papers, as well as successful grant funding in Australia, Germany, and the USA. He is the Editor-in-Chief of the Technology, Knowledge, and Learning, Senior Editor of Journal of Applied Research in Higher Education, and Deputy Editor-in-Chief of International Journal of Learning Analytics and Artificial Intelligence for Education.

About the Contributors

Frank Achtenhagen (fachten@uni-goettingen.de) graduated 1963 as Diplom-Handelslehrer (MSc) (Business Education and Management) (Free University, Berlin). Following professional positions include 1965 Assessor (Senate of Berlin), 1966–1969 Assistant (Institute of Business Education and Management, Free University Berlin), 1969 Dr. rer. pol. Free University Berlin, 1969–1971 Research Assistant (Akad. Oberrat) (Westfälische Wilhelms Universität Münster), 1971–2007 Full University Professor and Director (Institute for Business Education and Human Resources Development, Georg-August-Universität Göttingen), 2007—Full Professor Emeritus. He received Honorary Doctorates (1991: St. Gallen, CH; 2000: Helsinki, FIN.) His research outcomes include more than 450 publications, and he is an active member in national and international projects and research routines.

Carmela Aprea (aprea@bwl.uni-mannheim.de) is Full Professor and Head of the Chair of Economic and Business Education—Instructional Systems Design and Evaluation at the University of Mannheim (Germany). She holds a Diploma Degree in Business and Economics Education from the Goethe University Frankfurt (Germany) and a PhD in the same field from the University of Mannheim (Germany). In addition, she is co-founder and director of the Mannheim Institute for Financial Education (MIFE). Besides game-based learning and assessment, her research interests are financial literacy and pension planning, financial education, mental representations of economic concepts, visual learning and resilience in work-related and educational contexts. Besides her research activities, she advices national and international organizations such as the Deutsche Bundesbank, the Swiss National Bank, and the OECD with regard to financial literacy and financial education issues.

Eva Born-Rauchenecker (Eva.Born-Rauchenecker@TH-Rosenheim.de) studied East Slavic linguistics, earned her doctorate with a thesis on text linguistics and worked in the software industry in the field of language technologies. She was a senior scientist at the German Youth Institute in Munich from 2013 to early 2020 and now teaches at Rosenheim University of Technology in the degree program Education of Children and Young People (Faculty of Applied Health and Social

Sciences). Her research fields are training and professionalization of early childhood specialists in childcare facilities (such as kindergartens). Her focus is on early linguistic and early STEM education, on high-quality interactions between ECEC specialists (Early Childhood Education and Care) and children as well as on video-supported reflection of such interactions.

Miriam Burfeind (miriam.burfeind@uni-osnabrueck.de) works as a research assistant, certified intercultural trainer, and psychology teacher at Osnabrueck University. She has been involved in various research projects in the field of higher education and is currently leading a project to implement a gamification strategy in university seminars. Her dissertation deals with the investigation of factors in DGBL development that leads to higher motivation to learn.

André R. Denham (adenham@ua.edu) is an Associate Professor of Instructional Technology at the University of Alabama. His research focuses determining how, when, for whom, and under what conditions can we leverage the affordances of games to improving learner performance and transform instruction. To this end, he is currently pursuing three interrelated strands of inquiry: the design and development of games, the integration of GBL into the mathematics classroom, and professional development as a means of increasing the GBL knowledge of mathematics teachers.

Javier Elizondo (elizondoj@ou.edu) is the Game-Based Learning Coordinator at the K20 Center for Educational and Community Renewal in the University of Oklahoma. He received his MA in Broadcasting and Production from the University of Western Illinois. His work focuses on the research-based implementation of game mechanics to pursue instructional goals. Research papers based on his work have been published by the International Journal of Gaming and Computer-Mediated Simulations, International Journal of Game-Based Learning, Computers in Human Behavior. He presented his work in leading conferences in the game development field such as International Communication Association, the Serious Games Summit at the Game Developers Conference, National Education Computer Conference and GLS (Games+Learning+Society). Up to date Javier has produced more than 20 educational titles, 15 for the K20 Center. Twelve of those games are used every day, free of charge by students in Oklahoma. His work has been recognized by several organizations; more recently, the game *Get A Life* was awarded the Student Choice Award at the 2019 Serious Games Showcase and Challenge.

Kenneth J. Fasching-Varner (kenneth.varner@unlv.edu) joined the UNLV College of Education as an associate professor of literacy education in 2019. His areas of scholarly expertise and interest center on the intersections of identity and difference in globalized contexts, with attention to the language and literacy practices of individuals and communities. Varner examines the nature of White Racial Identity (WRI), Critical Race Theory (CRT), and Culturally Relevant Pedagogy as well as the role of international education, neoliberalism, and educational foundations within global language and literacy contexts. He is the author of over 70 publications including articles in Teacher's College Record, Educational Foundations, Democracy in Education, and Social Identities: Journal for the Studies of Race, Nation, and Culture among others and has edited or authored 13 books related to these areas of expertise. Varner studied Language, Literacy, and Culture with a focus on Critical Race Theory and Culturally Relevant Pedagogy at The Ohio State University in Columbus, Ohio.

Anna Fehrenbach (afehrenbach@uni-osnabrueck.de) works in the start-up company pearprogramming. She evaluates the learning outcomes and user-experience of PearUp, a learning platform that teaches students the basics of computer science. Furthermore, she is responsible for ensuring a successful user experience for users of PearUp.

Hector Ramos Garcimartin (hreina@tamu.edu) is a Lecturer at the Department of Educational Psychology, Texas A&M University. He teaches the Creative Studies Minor, which includes courses on Creative Problem-Solving, Six Thinking Hats, Lateral Thinking, and Personal Creativity. His research interest is cognitive fixation in decision-making processes.

Xun Ge (xge@ou.edu) is Professor of Learning Sciences in the Department of Educational Psychology, Jeannine Rainbolt College of Education, the University of Oklahoma, USA. Her primary research interest involves designing scaffolding to support ill-structured problem-solving and self-regulated learning in various open learning environments, such as problem-based learning, game-based learning, virtual and augmented reality, and makerspace learning. In her scholarly work, Dr. Ge seeks to make a linkage between cognition, metacognition, motivation, and assessment. Dr. Ge has extensive research experience in STEM education. She has published two co-edited books through Springer (one on game-based assessment and the other on STEAM education), a great number of research articles in leading journals of the Learning Design and Technology field and book chapters in highly regarded books. Dr. Ge has been recognized for various scholarly awards in her field. Dr. Ge is the President of Association of Educational Communications and Technology (AECT) and the co-editor of Interdisciplinary Journal of Problem-based Learning. She also serves in several editorial boards, including Educational Technology Research and Development, and Technology, Knowledge, and Learning.

Selin Guner (seling@stedwards.edu) is an Associate Professor of Global Studies and Political Science at St. Edward's University in Austin, Texas. She teaches a wide range of courses including International Relations, International Political Economy, Middle East Survey and Middle East Government and Politics. She also teaches graduate courses on Development. Selin Guner received her PhD from the Department of Political Science at Southern Illinois University in Carbondale, Illinois. She received her MSc and BSc in Political Science and Public Administration from Middle East Technical University in Ankara/Turkey. Her research interests include social movements in Turkey and the Middle East, political economy and democratization, and the impact of international systemic factors on democratization. Her works on these topics were published in many scholarly and policy journals. She recently published an International Relations textbook for undergraduates.

Tobias Hackenberg (hackenberg@bwl.lmu.de) studied Human Resource Education and Management at the Ludwig-Maximilians-University, Munich, from 2014 to 2019. Since 2019, he has been a research and teaching assistant at the Institute of Human Resource Education and Management, Munich School of Management, Ludwig-Maximilians-University, Munich.

Jana Heinz (jana.heinz@tum.de; heinz@dji.de) works as an adjunct professor at the chair of Sociology of Science at the Technical University of Munich and as a researcher at the German Youth Institute in Munich. After receiving her doctorate in 2006 at the Chair of General and Theoretical Sociology at the Friedrich Schiller University Jena, she has worked as a postdoc in various sociological and educational departments. In October 2019, she finished her habilitation on the topic "Uncontemporaneous modernization strategies in educational systems—between rigid structures and activated subjects." Her teaching and research focus lies on changing education systems from a comparative perspective, digital teaching and learning, and creating equal educational opportunities.

Dirk Ifenthaler (dirk@ifenthaler.info; www.ifenthaler.info) is Professor and Chair of Learning, Design and Technology at the University of Mannheim, Germany, and UNESCO Deputy Chair of Data Science in Higher Education Learning and Teaching at Curtin University, Australia. Dirk's research focuses on the intersection of cognitive psychology, educational technology, data analytics, and organizational learning. He is the Editor-in-Chief of the Technology, Knowledge, and Learning, Senior Editor of Journal of Applied Research in Higher Education, and Deputy Editor-in-Chief of International Journal of Learning Analytics and Artificial Intelligence for Education.

Michael Jüttler (Michael.juettler@uni-konstanz.de) is a postdoctoral researcher in the Department of Economics (Chair of Business and Economics Education) at the University of Konstanz. He is interested in the causes and effects of economic competencies, upper secondary education, postschool choices, and academic success, as well as in the application of quantitative methods.

Fengfeng Ke (fke@fsu.edu) is a professor of the Department of Educational Psychology and Learning Systems at Florida State University. Her main research interests are digital game-based learning, personalized e-learning, and computer-supported collaborative learning for neurodiverse learners.

Byung-joo Kim (byungkim82@gmail.com) is a PhD candidate at the Department of Educational Psychology and Learning Systems. He is working on his dissertation that explores the integration of mathematical problem representation support in game-based learning platform for middle school students. His research interests are game-based learning, mathematical problem-solving, and adaptive learning support system design.

Margaret L. Kleiser (m.l.kleiser@ou.edu) is a graduate research assistant at the K20 Center who is currently pursuing her PhD in Social Psychology at the University of Oklahoma. Her research interests primarily deal with peer relations in adolescents, but she also has some background in advanced statistics, which is why she is part of the K20 research team. She assists on many different projects and helps create literature reviews, run data analysis, and other tasks needed by the research team.

Keri A. Kornelson (kkornelson@ou.edu) is a Professor in the Department of Mathematics at the University of Oklahoma (OU). Her research interest lies primarily in harmonic analysis, focusing on overcomplete systems called frames. Her work has been funded by the National Science Foundation, the Woodrow Wilson National Fellowship Foundation, and the Simons Foundation. She helped to create the First Year Mathematics Program at OU, giving talks and publishing articles about the impact of the resulting curricular and policy changes. She has served as a subject matter expert on two serious games in collaboration with the OU K-20 Center.

Jessica Lajos (jlajos@math.ou.edu) is a Doctoral Student in the Department of Mathematics at the University of Oklahoma with a background in Psychology and research specialization in undergraduate mathematics education. Her research interests are in construct development through *Networking Theories*, creative and non-creative forms of mathematical intuition and representational fluency. Her work has been accepted to the premier national Research in Undergraduate Mathematics Education (RUME) conference and the 14th International Congress on Mathematics Education in Shanghai.

Christopher Lindberg (lindbech@oregonstate.edu) has been Instructional Design Specialist for the Oregon State Ecampus for over 3 years. Prior to that, Mr. Lindberg was the Instructional Design Coordinator for the Washington State University College of Veterinary Medicine. While in that position, he worked on *Development and assessment of a formal learning module to educate veterinary students in an intensive care unit about transfusion reactions,* which was published in the Journal of Veterinary Emergency and Critical Care. Mr. Lindberg's role in that project was designer of the learning activities that were discussed in the paper. Previous experience also includes a great deal of educational media development: graphics, web design, video editing, interactive coding, and UX/UI design. Mr. Lindberg also spent 7 years as Creative Director at an educational software development and research company, guiding a creative team and developers.

Yun Li (liyun215@tamu.edu) is a senior instructional designer and researcher in the Office of Academic Technology in the College of Medicine, Texas A&M University. Her research focus is on interactive learning environments, technology integration, and instructional design.

Jackie T. Mania Singer (jackie.mania@ou.edu) is the Director of Research and Evaluation at the University of Oklahoma's K20 Center. She has extensive experience in K12 as a teacher, a principal, a State Director, and a central office administrator. In her current work, she researches factors that impact postsecondary enrollment and persistence and student attitudes toward college and career. She has published several articles in the area of social network analysis, systems theory, and the role of the district central office in school improvement efforts. Dr. Mania-Singer is the Program Chair for the Systems Thinking in Education Special Interest Group of the American Educational Research Association and serves as an external reviewer for *Voices of Reform.*

Maximilian Marowsky (mmarowsky@uni-osnabrueck.de) is a scholarship holder of Osnabrueck University and co-founder of the educational start-up company pear-programming. He is mainly responsible for the scientific evaluation and user-centered development of the digital learning platform PearUp.

Michael P. McCreery (michael.mccreery@unlv.edu) is an associate professor and co-director of the Interaction & Media Sciences Lab at the University of Nevada Las Vegas. His research focuses on how principles of human–computer interaction can be applied to the creation of psychoeducational assessments and interventions.

Jewoong Moon (jewoong.moon@gmail.com) is a PhD candidate at the Department of Educational Psychology and Learning Systems. He is working on his dissertation that explores the integration of learning supports in virtual reality-based training for youths with autism spectrum disorder. His research interests are inclusive e-learning design, immersive learning environment design, learning analytics, and educational data mining.

Mity Myhr (mitylenm@stedwards.edu) is a Professor of History and Associate Dean of the School of Behavioral and Social Sciences at St. Edward's University. She completed her PhD at the University of Texas at Austin. She teaches courses in European History ranging from the Middle Ages to the contemporary period. Her research interests include the history of women, religion, and culture in Early Modern and Modern Europe.

Meghan Naxer (meghan.naxer@oregonstate.edu; PhD from the University of Oregon, 2016) is an Instructional Design Specialist at Oregon State University. Prior to joining OSU, Dr. Naxer was Assistant Professor of Music Theory at Kent State University. She has presented research on online higher education, game-based learning, and music theory pedagogy at regional, national, and international conferences. Her work also can be seen in Music in the Role-Playing Game: Heroes and Harmonies (Routledge), The Routledge Companion to Music Theory Pedagogy, and Engaging Students: Essays in Music Pedagogy.

Helmut Niegemann (niegemann@econ.uni-frankfurt.de) is Senior Professor in Economics Education at Goethe University Frankfurt/Main since 2014, Hon. Professor in Educational Technology at Saarland University since 2016. Professor Emeritus of University of Erfurt; Chair in Learning and Interactive Media 2003 till 2014. Associate Professor in Media Design/Digital Media (2000–2003). Head of the Department of "Design of Learning Environments" at the German Institute for Research into Distance Education (DIFF) at the University of Tuebingen (1997–2000). Professor of Educational and Developmental Psychology at the University of Technology Darmstadt (1994–1996). Senior Researcher (Educational Psychology) at the University of Mannheim (1990–1994). Freelance technical writer, IT-trainer, and author (1988–1990). Project manager at a publishing company in Mannheim (1986–1988). Assistant professor (1980–1986) and research assistant (1974–1980) at Saarland University (education). Teacher at a vocational college (BBZ) at Neunkirchen/Saar (1972–1974). PhD (education) 1978 and Habilitation 1993, Saarland University (education) 1993. MA (sociology, education, psychology).

Thea Nieland (thea.nieland@uni-osnabrueck.de) works as a research assistant at Osnabrueck University. She studies the management of digital transformations in organizational contexts and user-centered design. She has been involved in various research projects in the field of higher education and is currently working on the yUOShi project, ensuring user-centeredness in the course of the development of a DGBL application for first-year students in vocational training and education.

Mona Off (off@bwl.lmu.de) studied Human Resource Education and Management at the Ludwig-Maximilians-University, Munich, from 2013 to 2018. Since 2018, she has been a research and teaching assistant at the Institute of Human Resource Education and Management, Munich School of Management, Ludwig-Maximilians-University, Munich

Jessica Paeßens (Jessica.Paessens@uni-due.de) is a doctoral student at the Institute for Vocational and Continuing Education (IBW) in the Faculty of Education and works in the department of Prof. Dr. Esther Winther at the University of Duisburg-Essen, Germany. Her research focuses on empirical teaching-learning research, especially in the areas of collaboration. In her dissertation, she fosters social and cognitive components of collaborative problem-solving through push-and-pull bots in innovative scenarios for commercial vocational apprentices. She has transdisciplinary and international expertise in the fields of political and administrative sciences (University of Konstanz, Germany), international politics and security studies (University of Sheffield, UK), innovation and entrepreneurship

(University of Duisburg-Essen, Germany), and educational technology (University of Tartu, Estonia). She can also refer to several jobs and internships.

Andrea Maria Pfändler (Pfaendler@econ.uni-frankfurt.de) studied business administration focusing on credit management and financing, banking management, financial management, and financial controlling at the Goethe University in Frankfurt from 1992 to 1997. During this time, she worked part-time for various foreign banks (back office for the settlement of derivative financial instruments; trading assistance for shares and stock warrants). Subsequently, she worked as a salesperson for interest rate and foreign exchange products within the trading division of Dresdner Bank AG, advising and supporting central banks and later major German industrial companies on their investment and hedging strategies. From 2002 to 2004 she completed a further degree in business education at the Goethe University in Frankfurt. Since 2005, she has been teaching business administration and finance at the Wilhelm Merton School in Frankfurt. While doing research on customer complaints at banks for a two-year college-level qualification to become a mediator in 2015, she realized that many complaints were linked with a lack of financial education. This was the genesis for her doctorate, started in 2017, on the topic of "Conception, implementation and evaluation of an intervention study to promote financial education."

Liane Platz (liane.platz@uni-konstanz.de) is a doctoral researcher in the Department of Economics (Chair of Business and Economics Education) at the University of Konstanz. She is interested in the causes and effects of economic competencies, new learning methods in economics education and preparing future teachers for upper secondary education.

Suzanna J. Ramos (suzannaramos@email.tamu.edu) is a Lecturer at the Department of Educational Psychology, Texas A&M University. She teaches courses on Educational Statistics, Educational Psychology, and Research Techniques. Her research focus is on building academic literacy of children from poverty.

Stacy L. Reeder (reeder@ou.edu) is Professor of Mathematics Education and Interim Dean for the Jeannine Rainbolt College of Education at the University of Oklahoma. She is active in several national organizations, including the School Science and Mathematics Association where she recently served a term as president of the association, the Association of Mathematics Teacher Educators, the Research Council on Mathematics Learning, the National Council of Teachers of Mathematics, and the National Council of Supervisors of Mathematics. Her research agenda centers on mathematics teaching and learning, problem-solving, and teacher education. She has authored articles in numerous scholarly journals including *School Science and Mathematics*, *Investigations in Mathematics Learning*, and the *Journal of Mathematics Education Leadership*. She teaches courses in both the graduate and undergraduate mathematics education program and is actively involved in numerous ongoing efforts in Oklahoma to ensure teacher quality and to improve education for all children and students.

Heather A. Robinson (heather.robinson@unt.edu) is an online learning consultant who has worked in the technology field since 1995. She teaches courses in the areas of computer science, information systems, and learning technologies. She has a Master's degree in Information Science and a PhD in Learning Technologies from the University of North Texas. Heather is currently researching critical pedagogy and care ethics in online learning.

Braden Roper (bradenroper@ou.edu) is the Technical Lead of the Game-Based Learning team at the K20 Center. He has been developing educational games for the Center for almost 6 years, contributing to 14 game projects and being a primary or lead developer on 5. During this time, he has received his graduate degree in Computer Science from the University of Oklahoma and has since led a team of game-play programmers to produce even more educational games. One of the more recent game projects he programmed, *Get a Life*, received the 2019 Students' Choice Award at the Serious Games Showcase and Challenge. Another work of his and the Game-Based Learning team, *Functions of the Machine*, was a finalist in the same competition.

Jason Rosenblum (Jason.rosenblum@austin.utexas.edu) is an Assistant Professor of Instruction in the Learning Technologies program, within the Department of Curriculum and Instruction in the College of Education at the University of Texas at Austin. His scholarship includes research on participant experiences of sound within educational games, application of mobile games as vehicles for student engagement and best practices on project-based learning in online instructional technology courses. His current research interests also include examining game-based, mobile and augmented technology systems to support competency attainment and digital equity. His career includes teaching doctoral, masters, and undergraduate courses within learning technologies, instructional technology, digital media and game studies for UT Austin, New York Institute of Technology (NYIT) and St. Edward's University (SEU). Jason Rosenblum also served as Associate Director of the Center for Teaching and Learning at NYIT and managed an instructional computing support area at SEU. He received his PhD from the University of Texas at Austin and holds an MS in Computer Education and Cognitive systems from the University of North Texas, and a BS in Microbiology from Texas A&M University.

Meranda Roy (meranda.roy@unt.edu) is Online Learning Librarian at the University of North Texas, where she implements and promotes a variety of online tools, services, and initiatives for students, faculty, librarians, and staff. Her research interests include educational technology, training and development, academic development, program design, and evaluation.

Bryan P. Sanders (bryansanders@me.com) is a Doctor of Education and career classroom teacher working in Los Angeles who blends critical theory, social justice, technology, and constructivism. With 25 years of experience teaching, he is actively working on new projects with students to continue and expand the constructionist work of Dr. Seymour Papert. He is active in research, classrooms, discussion groups, publishing, inventing, and also on Twitter.

P. G. Schrader (pg.schrader@unlv.edu) is a chair of the department of Teaching and Learning, professor of Interaction and Media Sciences, and research scientist in the Center for Research, Evaluation, and Assessment at UNLV. Dr. Schrader completed his degree in Educational Psychology with a focus on Cognition and Instruction at the University of Connecticut. His work has broached the topic of learning in technology rich, immersive environments across disciplines, and he has examined the exchange of information within hypertext, multimedia, and massively multiplayer online games. Dr. Schrader's research has addressed a variety of contexts, methodologies, and content areas. Current projects include the examination of digital games and virtual environments from a human–computer interaction perspective. Dr. Schrader has published a wide range of studies that cover inter- and intratextuality, navigation, and learning. Dr. Schrader has received awards honoring his commitment to academics, the community, and higher education in general.

Jacqueline Schuldt (jacqueline.schuldt@tu-ilmenau.de) is a research associate at the Institute of Media Technology in the Media Production Group of the Ilmenau University of Technology since 2017. Research associate at Fraunhofer Institute for Digital Media Technology IDMT (2011–2017) and since 2014 Head of the Gamification Group. MA (2009) in Education and Educational Technology at the University of Erfurt. BA (2007) in Educational Science and Psychology of teaching, learning, and training at the University of Erfurt.

Julia Schultheis (schultheis@bwl.uni-mannheim.de) holds a Master's degree in Business and Economics Education from the Friedrich Schiller University Jena (Germany). She is a graduate research assistant and doctoral student at the Chair of Economic and Business Education of the University of Mannheim—Instructional Systems Design and Evaluation (Germany). Her research interest is in game-based learning and game-based assessment in the context of financial literacy education.

Matthias Schumann (mschuma1@uni-goettingen.de) is a Full Professor of the Chair for Application Systems and E-Business at the University of Göttingen since 1991 and is the head of the Economic and Social Science Computing Center. His current research interests include the use of ubiquitous and mobile systems in companies, the use of IT to save resources, knowledge management, and virtual learning. He is engaged in various German scientific associations, serves as track chair or reviewer in national and international IS journals and conferences, and is a member of the editorial board of the journal Wirtschaftsinformatik and Management.

Stephan Schumann (stephan.schumann@uni-konstanz.de) received his doctoral degree at Humboldt University of Berlin. Following a postdoc stage at the University of Zurich (Switzerland), he has worked as an Assistant Professor at the University of Fribourg (Switzerland). Since 2013, he has been a Full Professor of Business and Economics Education at the University of Konstanz (Germany). His research group is focused on (1) several topics of learning and instruction in upper secondary education (e.g., learning with digital media, game-based learning), (2) modeling and measurement of economic competencies, and (3) transitions from school to work (e.g., transitions of young asylum seekers in Germany).

Armanto Sutedjo (armantos0278@tamu.edu) is a doctoral student at the Department of Educational Psychology, Texas A&M University. His research focus is game-based learning and implementation.

Andre Thomas' (manink@arch.tamu.edu) passion for game-based learning resonates inside and outside of the classroom. A graduate of LCAD MFA in Game Design, he founded and serves as the director of the LIVE Lab [http://live.viz.tamu.edu/] in the Department of Visualization at Texas A&M University, where he also teaches game design, game development, and interactive graphics techniques.

William M. Thompson (will.thompson@ou.edu) has a Master's degree in Instructional Design from the University of Oklahoma. He has spent the last 8 years designing game-based learning programs for the K20 Center.

Scott J. Warren (scott.warren@unt.edu) is a Professor of Learning Technologies in the College of Information at the University of North Texas. He has studied learning games and simulations in educational contexts for more than 20 years and is the author of the book *Learning Games: The Science and Art*. After completing additional doctoral research in logistics and operations management, his research practice now also includes how stakeholders may employ holistic systems analysis and evaluation approaches with business firms as part of their organizational learning and improvement.

Susanne Weber (susanne.weber@bwl.lmu.de) studied Human Resource Education and Management at Georg-August University, Göttingen, from 1985 to 1990 and worked as a senior researcher. She holds a doctoral degree (Dr. rer. pol. 1994) from the Georg-August University, Göttingen, and fulfilled her Habilitation at Humboldt University of Berlin in 2004. Since 2005, she has been a Full Professor and Director of the Institute of Human Resource Education and Management, Munich School of Management, Ludwig-Maximilians-University in Munich.

Luke West (law19a@my.fsu.edu) is a doctoral student in the Department of Educational Psychology and Learning Systems. His current work in research projects targets learning support and level design for STEM and pedagogical e-learning.

His research interests are adaptation and immersion in e-learning design for STEM and language learning interventions and building individual learner models based on performance data.

Scott N. Wilson (scott.wilson@ou.edu) is the Director of Innovative Learning at the University of Oklahoma's K20 Center. While this educational research center is dedicated to the research of effective teaching and learning in kindergarten to graduate educational environments, Scott leads a team of researchers, designers, and developers in the application of digital game-based learning to engage learners in authentic learning experiences. He holds a PhD in Instructional Leadership and Academic Curriculum and has served as a designer, producer, and researcher of novel learning experiences and their impact on learning. A focus for Scott and the K20 Center's game team is to develop, validate through randomized controlled trials, and release serious games for use that will engage students in meaningful learning.

Esther Winther (Esther.Winther@uni-due.de) is Managing Director of the Institute for Vocational and Continuing Education (IBW) of the Faculty of Education and heads the Competence Centre for Innovation and Entrepreneurship (IDE) at the University of Duisburg-Essen (Germany). Her research focuses primarily on empirical teaching-learning research, in particular in the areas of psychometric competence modeling and measurement, the development of training and further education programs, and the design of innovative and digital teaching and learning scenarios for vocational and corporate fields of action. She researches commercial competence development, particularly in the context of joint projects. Along the lines of design-based research, she collaborates with practitioners in research projects on financial/economic literacy and numeracy as a guarantee for social participation. She has taught at various international (including Stanford University, University of California, Berkeley, University of Tokyo) and national universities (including Georg-August-University Göttingen, University of Paderborn) and formerly led the German Institute for Adult Education, Leibniz Centre for Lifelong Learning (DIE).

Jiaqi Yu (jyu53@crimson.ua.edu) is a PhD student in Instructional Technology at the University of Alabama. Her research interests are game-based learning, mixed reality, and embodied learning. She is a self-taught game developer, and she has a background in animation and filmmaking. She is currently working on her dissertation while building educational games for various learning purposes.

Part I
Inside and Across Social Science, Business and Economics Disciplines

Chapter 1
Applying Insights from Behavioral Finance and Learning Theory in Designing a Financial Education Serious Game for Secondary School Students

Julia Schultheis and Carmela Aprea

1.1 Importance of Financial Literacy and Challenges in Financial Education

During the current COVID-19 pandemic, the media has focused on the importance of financial buffers for private households. It became clear that although not everyone is able to build a financial buffer, the planning and management of one's own money is essential. Besides sudden and unforeseeable events such as the COVID-19 pandemic, studies show an increase in household indebtedness since 2008 (OECD, 2017). The increase also underlines that the management of one's financial matters is something that is relevant in all life situations to avoid over-indebtedness. The ability to reasonably deal with money and financial matters is called *financial literacy*. The increasing importance of this ability is widely acknowledged, and financial literacy is considered a twenty-first-century skill (Aprea et al., 2016; Davies, 2015; Lusardi, 2015). One component of financial literacy is being able to make reasonable and considered financial decisions. For financial decision-making and financial planning to become widespread skills, financial education programs are needed. However, meta-analyses show that such programs are not as successful as they are intended to be (Fernandes et al., 2014). One reason for this problem could be the fact that these programs mainly focus on knowledge aspects and leave motivational and behavioral aspects aside (Aprea & Wuttke, 2016). For example, imagine a person who has to draw a monthly budget. This person needs to know what aspects belong in a budget, the differences between variable and fixed costs, and how to calculate the budget. These are knowledge aspects. While the person may be able to draw the budget, because he or she is familiar with all the knowledge aspects,

J. Schultheis (✉) · C. Aprea
University of Mannheim, Mannheim, Germany
e-mail: schultheis@bwl.uni-mannheim.de; aprea@bwl.uni-mannheim.de

C. Aprea, D. Ifenthaler (eds.), *Game-based Learning Across the Disciplines*, Advances in Game-Based Learning, https://doi.org/10.1007/978-3-030-75142-5_1

it is unsure if he or she will actually draw a budget. At this point, motivation and behavior come into play, but this is often left aside in traditional financial education programs. Serious games seem to be a promising way to overcome these obstacles, as they provide the possibility to simulate decision-making processes and foster motivation. Serious games are "digital games that merge a non-entertaining purpose (serious) with a video game structure (game)" (Djaouti et al., 2011). Meta-analyses and literature reviews show their promising results regarding the promotion of motivation and the development of cognitive skills (Clark et al., 2016; Connolly et al., 2012; Sitzmann, 2011; Wouters et al., 2013).

Based on these considerations, this chapter aims to describe the design of a serious game intended to foster the financial literacy of secondary school students. It was initiated by a joint venture of two Swiss teacher associations and the Association of Swiss Cantonal Banks (VSKB Verband Schweizer Kantonalbanken) as a response to a reform in Swiss basic education curricula. The new curricula entailed a competence orientation and the inclusion of financial literacy aspects in grades seven to nine for the first time. In this chapter, we will report on the genesis of the game, with special emphasis on the theories that underlie the game. Thus, the key research question is as follows: How should a serious game be designed to support financial decisions? As researchers in the field of serious games and game-based learning highlight (e.g., Qian & Clark, 2016), designing games for a specific educational purpose presents an interdisciplinary challenge, as it requires a deep understanding of game design aspects as well as sustained knowledge of the game content and a foundation in relevant learning theories. In addition, a profound analysis of the target group and the context in which the serious game should function is required. Consequently, the structure of this chapter is as follows: In Sect. 1.2, we will outline the theoretical foundations that we used to inform the design of the financial education game. To model the game content, we particularly drew on behavioral finance (i.e., financial decision-making) and on theoretical perspectives that focus on cognitive and motivational aspects of game-based learning as well as insights from game design theory. We have chosen these approaches because they represent the state of the art in both content and learning-related regards of our specific field of application. We then delineate in Sect. 1.3 the process of developing the financial education serious game, including the target group and the contextual analysis. In Sect. 1.4, we will demonstrate how the suggestions from behavioral finance, learning theories, and game design theory as well as from the additional analyses have been translated into the design of the financial education serious game. We conclude the chapter with a discussion of the development process and the final financial education serious game and give an outlook on future research projects.

1.2 Theoretical Foundations to Inform the Design of the Financial Education Serious Game

When developing a game for learning, other findings besides game design need to be taken into account (Kalmpourtzis, 2018). These include, on the one hand, the corresponding domain science and, on the other hand, theories of learning and motivation. For the game we developed, behavioral finance is the corresponding domain science. Figure 1.1 shows the connection of these theories for the design of our game. In addition, the context needs to be addressed, i.e., the conditions under which the game is developed and/or intended to function. It includes, for example, the target group as well as the available resources. In this section, insights from behavioral finance and theories of learning and motivation are addressed. Furthermore, it will be discussed how game design elements have to be implemented in order to meet the requirements of the theories of learning and motivation. In Sect. 1.3, the context in which the game was developed will be described.

1.2.1 Relevant Insights from Behavioral Finance

Behavioral finance is a branch of financial economics, a relatively new research direction that could be understood as a kind of countermovement to traditional economic theory. In this section, we will briefly describe how and why behavioral economics differs from traditional economic theory, delineate key aspects, and argue why it is suitable for financial education.

One of the key assumptions of the traditional economic theory refers to the homo oeconomicus. Homo oeconomicus is a simplifying model assumption that represents an agent who always makes decisions based on economic considerations. As a consumer, homo oeconomicus always pursues the goal of maximizing utility. The homo oeconomicus has (1) complete information about all markets, (2) knowledge of all decision options, (3) no preferences or aversions, and (4) immediate reactions

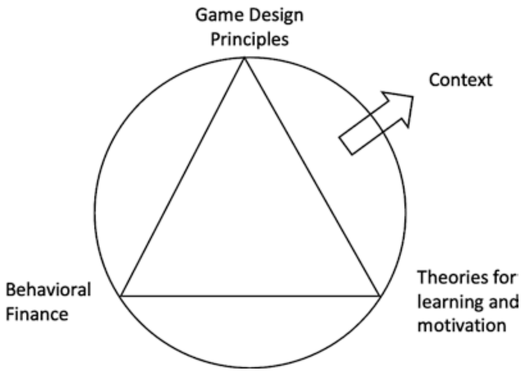


Fig. 1.1 Interrelationship of the game determinants (own representation based on Kalmpourtzis, 2018)

to changes in circumstances. Based on these core assumptions, homo oeconomicus (also known as a rational agent) makes financial decisions. This model simplifies basic economic interdependences, which allows for high abstraction and elegant mathematic modeling, while neglecting the complexity of human beings and their decision-making, including financial decisions (Daxhammer & Facsar, 2018; Glaser et al., 2004; Yoong, 2013). The main criticism of the traditional economic theory is that it considers all humans as rational agents. Psychological influences such as emotions, attitudes, or personal preferences in decision-making are completely left aside as well as the possibility of making mistakes when receiving and processing information. This is one reason why traditional economic theories fail to predict the development of economic crises.

This criticism of homo oeconomicus is now gathered under the theoretical approach of behavioral economics. Behavioral economics dismisses the concept of the homo oeconomicus by assuming that rationality is limited, and the agents are regarded as people who are exposed to psychological influences and personal preferences. Behavioral finance is a subdiscipline of behavioral economics that focuses on the cognitive and affective aspects that influence human behavior and applies insights from psychology to the decision-making process (Prosad et al., 2015). The theory of bounded rationality by Herbert Simon (1959) was the starting point for research on behavioral finance. Experiments have shown not only that people act rationally and out of self-interest but also that fairness is an important argument for them, even if it means they have to pay more (Loerwald & Stemmann, 2016). The prospect theory of Kahnemann and Tversky (1979) described how individuals make decisions and which factors influence this process: The decision-making of individuals is based on biases and is driven by heuristics. In the following, we will define heuristics and biases and illustrate selected ones in more detail.

Heuristics are shortcuts or rules of thumb that are used to approach complex problems. Heuristics can reduce complexity and help with information processing. Prospect theory describes three main heuristics: *availability heuristic*, *representativeness*, and *anchoring and adjustment heuristic*. In the following, we will describe these heuristics and illustrate them with examples for better understanding.

- The term *availability heuristic* describes how people estimate a probability depending on how quickly they think of an example or a situation. For example, one may assess the risk of having a heart attack by recalling how many of his or her friends have had a heart attack (Tversky & Kahnemann, 1974). Regarding financial decisions, individuals may assess the risk for investing in shares based on previous experience with shares or stories they heard from friends or family.
- *The representativeness heuristic* is a judgment heuristic in which the probability of an event is determined based on a stereotypical character, while information about the general probability of an event is ignored. For example, if a student in a suit is sitting in the university cafeteria, he or she will be considered a business or law student, regardless of how large the proportion of business or law students is compared to all students at the university. Regarding financial decisions, individuals may judge the development of a share based on its current performance.

Investors are likely to think that stocks that performed well recently will also perform well in the future.

- The *anchoring and adjustment heuristic* describes an approach to estimating unknown variables. Individuals usually start with a known or estimated value (the anchor) and adjust that number either higher or lower, whichever seems reasonable. For example, when one is asked how long it takes Mars to go around the sun, a person using this approach will probably begin with 365 days (how long it takes the earth to go around the sun) and then incrementally adjust the number (Tversky & Kahnemann, 1974). Regarding financial decisions, an individual who does not know how much money they spend on food in a month will start by estimating how much they spend on food weekly and then increase this number.

Biases are influences and distortions of perceptions that affect the decision-making process. Three of the most important biases are *illusion of control/overconfidence*, *confirmation bias*, and *home bias.*

- *Illusion of control/overconfidence* describes the tendency of humans to overestimate their cognitive abilities and skills, which leads to an inflated view of one's own abilities and a lower estimated risk of losses. For example, 80% of drivers consider themselves as a part of the 30% best car drivers (Loerwald & Stemmann, 2016). This is also possible in the context of financial decisions—for example, when investors make a targeted selection of stocks and bonds without considering risk diversification because they believe that their selections are safe from loss.
- *Confirmation bias* occurs when people seek out information or evidence that supports their existing thinking and beliefs. People tend to overvalue information that confirms their statements and ignore information that contradicts their statements (Andrews et al., 2018). A physician might not examine a patient thoroughly because the patient is a known hypochondriac. By doing so, a physician may not be able to diagnose a serious illness. In the field of financial decision-making, investors might seek out information that confirms their opinions and filter out potentially useful facts. This could lead to harmful investment decisions.
- *Home bias* (or ambiguity aversion) describes the preference for known risks over unknown risks. When choosing between two bets, people are more likely to choose the bet for which the odds are known, even if the odds are poor, rather than the one for which they do not know the odds (Daxhammer & Facsar, 2018). Ambiguity aversion in the field of financial decision-making can be the tendency of investors to invest in funds they already know.

Behavioral finance provides insights into the factors influencing the decision-making process. These insights are important to directly consider and counteract in financial education interventions (Altman, 2012; Loerwald & Stemmann, 2016). As discussed above, traditional forms of education fail to support actual decision-making processes. Therefore, the advantage of financial education games is the simulation of financial decision-making processes. By integrating heuristics and biases directly into a game and combining them with insights from game-based learning, we can overcome the challenges.

1.2.2 Insights from Theories of Learning and Motivation and Related Empirical Research

As explained in the introduction, serious games can promote learning and motivation. The following section will examine in more detail how games can promote cognitive and motivational elements of learning:

1. Games can help build knowledge and cognitive skills by confronting learners with problems and challenges in a virtual world. In this way, learning is contextualized and situated (Prensky, 2001). This can enable meaningful and targeted learning—for example, by providing relevant information at the time it is needed. In order to solve the given tasks and challenges, the learners also draw on their prior knowledge and experiences. They then form mental models based on the game information and previous knowledge to solve the given problems. An integral part of the game is that the game gives the learners direct feedback on their approach to problem-solving. Similar to experiential learning, the learners can try different strategies in the game world and learn from their errors. However, incorrect decisions have no consequences for the real world. Serious games thus provide a safe and error-friendly environment. The information processing that the learners go through while playing can lead to a change or consolidation of existing mental models.
2. Games can promote joy, intrinsic motivation, and a positive attitude toward learning. As games are entertaining, it is assumed that they are an attractive learning medium, especially for young people. They can therefore involve learners more emotionally, which in turn can manifest itself in intrinsic motivation. Intrinsic motivation is based on curiosity, challenge, control, and imagination. These can be found in serious games, as they stimulate sensory and cognitive processes, are goal-oriented, and tell a story (Tobias & Fletcher, 2011). The increase in motivation can then initiate cognitive processes in the learners and thereby make the process of forming mental models attractive in a playful way. Games can also fulfill the human needs highlighted by Ryan and Deci (2000) in their theory of self-determination, which includes competence, autonomy, and social relatedness. Learners can experience competence through the game's feedback on their actions, as they receive direct feedback on the success of their actions. Autonomy can be experienced through freedom when determining the strategy to solve problems. Through interactions with the game or other learners, learners can experience the feeling of relatedness. Because of the immersive character, games can also provide a flow experience, which means that the learners are highly concentrated and completely immersed in a story. Experiencing

flow can have a positive influence on learning. These motivating characteristics of games can influence learning in general as well as in specific domains.

Despite these potentials, learning with games is not a sure-fire success. This is evident, for example, in a meta-analysis by Clark et al. (2016) including 69 studies. Here was found that game design has an effect on learning outcomes. For example, game design elements such as design perspective, complexity of game story, and sophistication of game mechanics influence learning outcomes. The results of Sitzmann's (2011) meta-analysis also show that players need to be actively engaged by a game in order to maximize learning potential by having the game promote engagement with the learning content. Consequently, careful game design is essential to harness the full potential of games (Gibson, 2015). In the following section, these game design elements and the requirements from theories of learning and motivation are discussed in more detail.

1.2.3 Game Design Theory and Implications from Empirical Evidence

Game design theory provides information about the various elements that constitute a serious game. These elements are presented in the following, including empirical results about the effect that their design has on cognitive and motivational learning processes.

In general, the learning activities in a game should have clear learning objectives and relate to a specific domain. Learning goals and objectives of the game should be precisely coordinated (Kalmpourtzis, 2018). In serious games, it is also important that the serious and the entertaining elements are balanced and coordinated. To ensure this, game designers configure specific game design elements. Although there is no defined taxonomy of game design elements, many elements overlap in research and refer to the following game design elements: *game mechanics*, *narrative*, *aesthetics*, *incentive and feedback mechanisms*, and *scaffolding* (Plass et al., 2015). The elements are presented in the following paragraphs. Additionally, empirical results are provided to show how the implementation should be designed in order to have a beneficial effect on learning and motivation.

Game mechanics refer to all activities that reflect the learning-related activities in the game. The learners are confronted with a challenge and have control over the actions in the game. The adaptation of the challenge in a game can increase linearly or adapt to the success of the learners based on assessments. In order to meet the challenges, learners have to follow defined rules (framework that limits the activities of the learners) with specific goals or objectives (criteria for how to win). While playing, learners interact with the game and, depending on the game design, with other learners. The interactions with other learners can be cooperative (learners have to solve tasks together) or competitive (learners compete to solve tasks). The level of challenge has an influence on the motivation of the learners. Too low or too high a challenge can lead to frustration and reduced motivation among learners (Van Staalduinen & de Freitas, 2011). Both types of adaptation can satisfy the need for autonomy and show an increase in cognitive learning outcomes for learners (Wilson et al., 2009). Clear and specific goals can increase motivation and are a prerequisite for experiencing flow (Garris et al., 2002; Van Staalduinen & de Freitas, 2011; Wilson et al., 2009). Cooperative and competitive elements, such as multiplayer options or leaderboards, have positive effects on motivation and cognitive learning outcomes. Interaction elements can also support the feeling of social inclusion (Plass et al., 2015).

The *narrative* is the story around which the game develops. The narrative also includes the characters or avatars and the location in which a game is situated. The narrative gives the learners a context and helps them understand the goals and rules of a game. The narrative can arouse the interest of the learners. It can also trigger positive emotions and motivate learners (Dickey, 2006). It should be noted that a complex action could distract from the content, making learning difficult due to cognitive overload (Wouters et al., 2013). Empirical results also show that the development or choice of one's own avatar can lead to an increase in motivation, interest, and attention as well as positive emotions. It is assumed that this is because learners can then identify with the avatars (Fox & Bailenson, 2009; Plass et al., 2015; Yee & Bailenson, 2006).

Aesthetics refer to the visual and auditory representation of a game. These types of representation help learners perceive the reality of the game. On the one hand, the aesthetics are the visual and musical presentation of the narrative and can thus direct the attention of the learners. On the other hand, the game mechanics are integrated into the aesthetics, which means that the learners receive feedback through the aesthetics—this can be both visual and auditory. Research shows that the visual and musical elements can arouse interest and positive emotions in learners, which can lead to improved cognitive learning outcomes. Games designed in the third-person perspective are more likely to change behavior than games designed in the first-person perspective. It is assumed that because learners observe themselves from the third-person perspective, they reflect on their real-life behavior (Kapp, 2012). If the game depicts elements (e.g., a map) from the real world, learners can more easily activate their previous knowledge and transfer the game content into reality (Plass et al., 2009).

The *incentive and feedback mechanisms* of a game aim to motivate learners and give them feedback on their behavior. The learners get feedback on their actions and experience how successful these actions were. In this way, the learners get hints for future behavior in the game. Feedback can also be designed as an incentive by awarding points, money, or trophies or by unlocking new levels if learners are successful. Incentive systems can evoke joy and commitment and have a motivating effect on learners in the context of experiencing competence (Cruz et al., 2015). Feedback during the game seems to be more effective on cognitive outcomes than feedback after the game (Johnson et al., 2017).

Scaffolds are supporting elements that appear especially in learning games. They are used to provide assistance in understanding and dealing with challenges. Static scaffolds give all learners the same support (e.g., by a tutorial level). Adaptive scaffolds measure the performance of the learners and give them specific feedback on this basis. It is important to ensure that support is gradually reduced during the course of the game in order to enable an experience of competence (Plass et al., 2015).

1.3 Development Process of the Financial Education Serious Game "FinanceMission Heroes"

In this section, we will illustrate the development process while considering the theoretical and empirical findings described above. Therefore, we will describe the development steps with a focus on learning theories and behavioral finance.

The development process was inspired by a design-based research approach (e.g., Design-Based Research Collective [DBRC], 2003). In this process, a team of interdisciplinary experts (notably researchers from media psychology, business and economics education, economics, behavioral and household finance, and business ethics), game designers, media designers, and secondary school teachers collaborated closely. Hence, in the design-based research approach, designing, analyzing, testing, and redesigning alternated during the development process. As a first step, a needs analysis was conducted to learn about the needs of the persons affected by the game, such as parents, students, and teachers. The prestudy included workshops with these people, in which they were asked to describe typical situations where adolescents get in touch with financial issues. They were asked to name competencies they consider important to deal with these situations. There was also a content analysis of the new curriculum and a review of financial education programs in other countries for the same age group. This prestudy revealed situations and tasks and a first list of requirements for the game. The team of experts and the steering committee discussed the results. They decided to focus on purchasing decisions and budgeting, as these seemed to be the most important aspects for the adolescents to learn. A model of related content was built. Content-related and technical organizational requirements were identified, and everything was merged into a tender specification.

Based on the tender specification, a team of game designers was selected and was assigned to develop a digital learning game. During the game-development process, the game designers met with the steering committee and the group of experts regularly to consult about the game. The experts and selected secondary school students tested prototypes of the game at different developmental levels. They repeatedly provided feedback, which was then taken into account in the further development process. In some cases, the whole team had to make design decisions where theoretical game design insights stood in contrast with constraints of some team members. This concerned, for example, the possibility of getting into debt, the product range of the equipment store, and the control of time. The whole team discussed these aspects to find solutions that met the requirements and needs, were appropriate, and did not destroy the spirit of the game. A detailed description of the creation process can be found in Aprea et al. (2018). The result of this development process is an action game with a superhero story. The objective of the game is to encourage financial decision-making and, in particular, short-term decisions regarding the budget, as these decisions could be conceived as the core component of financial literacy (e.g., Gutter et al., 2016). In doing so, players should learn to identify and use different sources of income. In addition, the players should learn to make targeted and conscious investment decisions. The game control works by point and click. The game can be played directly in the browser as an online game, but there is also a downloadable version for Windows and Mac. In the online game, there is the possibility of registration so that scores are saved and the game can be continued at a later time. In the download version, the game scores are saved automatically. The game is also available as an app for smartphones in the AppStore and the Google Play Store. Detailed screenshots of the game design and structure can be seen in the next section.

1.4 The Developed Financial Education Serious Game: FinanceMission Heroes

In this section, we will demonstrate how the insights from behavioral finance, learning theories, and game design theory were put into action. This section is structured according to the game structure, as the game structure depicts the decision-making process. In each section, we will first describe the game design elements and substantiate their realization with insights from behavioral finance and theories for learning and motivation and game design theory. This will first be done in the form of a table, followed by a comprehensive explanation of the individual game phases and game elements. The order is as follows: narrative, configuring the avatar, tutorial, overview, equipment store, time management, level, and statement of accounts (Table 1.1).

The narrative of the game FinanceMission Heroes is a classic superhero plot with a Marvel-inspired visual aesthetic. It is placed in a fictional town. Robots have invaded the local bank, wanting to steal the money from all the savings accounts. The players take on the role of the students of the local school, and their goal is to fight the robots to protect their savings. The challenge for players is to develop a strategy that includes time management, earnings planning, and budgeting for equipment purchases. The game consists of ten consecutive levels with increasing difficulty. Each level has a number of small robots that can get in the way of players and cause them to lose important health points. The players have to win against a big robot at the end of each level. The objective is to win the fight against the final boss in the last level, after which the savings are rescued. The game was designed with a third-person perspective. With the third-person perspective, the players can watch themselves in action, which is expected to encourage a reflection on the players' decision-making process. The narrative provides a stage for the decision-making process according to behavioral finance theories. According to insights

Table 1.1 Overview of game features, behavioral finance, theories for learning and motivation, and game design theory

Game feature	Behavioral finance	Theories for learning and motivation	Game design theory
Introduction		Appealing aesthetics and storyline are expected to arouse positive emotions and the interest of the players	Narrative: The game has a marvel-inspired plot, where the players have to fight against robots who want to steal the savings from a bank Aesthetics: Marvel-inspired look
Configuring the avatar		Higher identification with avatar leads to more attention, motivation, and interest	Narrative: Players can configure the hair, skin color, and sex of their avatars Aesthetics: Different options to configure the avatar are available
Tutorial		Meets the need for autonomy and competence, as the players can skip it if players do not consider it necessary Serves as a scaffold to discover the goal of the game and to get familiar with the controls	The objective is to introduce the game controls
Overview	Option to repeat previously played levels incorporates ambiguity aversion, as the players can adjust their expectations and decide on the difficulty on their own by having the option to repeat levels	Option to repeat previously played levels meets players' need for autonomy and competence	Aesthetics: Overview screen with different levels displayed players can see the robot types in different levels and which level they already won. Mechanics: Players can decide which levels they want to play. After each finished level, new levels are unlocked. To earn additional medals, levels can be repeated
Equipment store	The availability heuristics is incorporated, as the players are likely to choose equipment for new levels based on their experience in previous levels The store options incorporate the overconfidence bias in case the players decide to go with cheap weapons into higher and more challenging levels	Meets the need for autonomy, as players can spend the money how they want to. The players also get to try different strategies and gain experience	Narrative: Players can equip their avatars for the next level. Players cannot spend more money than they have Aesthetics: Different shop levels with appealing options for weapons and clothes Mechanics: By clicking on the items, the players can take an item and buy it Scaffold: Players can get information about the equipment to see their advantages in the level

(continued)

Table 1.1 (continued)

Game feature	Behavioral finance	Theories for learning and motivation	Game design theory
Time management	Anchoring and adjustment heuristics are incorporated, as the players set the controls based on former experiences	Meets the need for autonomy, as players can decide on how they want to spend their time and earn money The players also need to adapt their time management, as the higher levels are more complex and need more time	Narrative: The players have to decide on how to spend the time: By learning, the players will get better grades and have more time to spend. By working a part-time job, the players can earn safe money. By playing, the players get to enter the level and earn more money and have a risk to lose the money Aesthetics: The time management is controlled by a labeled slider bar to indicate the available times Mechanics: The players have to click on the slider bar to set the times
Level	Anchoring and adjustment heuristics are incorporated, as the level seems to be similar and have resembling characters	Meets the need for autonomy, as players can choose different strategies in the level or even leave levels Meets the need for competence if players are able to finish the level successfully	Narrative: Level takes place in a bank, where the players have to fight the robots Aesthetics: Each level is designed differently and the robots are placed randomly Mechanics: To navigate through the levels, the players have to point at a robot they want to fight or a place they want to go. The players have to decide whether they want to use boosters in the level Feedback: The players can see the health points of the avatar
Statement of account	The statement of account addresses the dissolution of the confirmation bias by engaging players in reflecting the success of their financial decisions involved in their playing strategies	The statement of account gives the players a different form of feedback. They are informed about on how they earned and spent their money	Aesthetics: Overview of income and expenses are in table form Mechanics: The players receive information about success/no success in fighting the big robot, earned money and repair costs for equipment Feedback: The players receive a feedback on the success of their decision-making from a financial perspective

from learning theories, the narrative enables situated learning for financial decision-making. The Marvel-inspired visual aesthetics and the superhero story are expected to have a positive impact on the players' interest and motivation in playing the game.

1.4.1 Configuring the Avatar

At the beginning of the game, the players can configure and name their own avatars for the game. The game offers options for sex, haircut, and skin color. This gives players the opportunity to develop a character with which they can identify. If players can identify with the avatar, it is assumed that motivation, attention, and interest in a game will increase (Fig. 1.2).

1.4.2 Tutorial

The tutorial introduces the story, the goal, and the basic functions of the game by using explanatory bubbles. The objective of the tutorial is to teach the players the game controls. The tutorial is mandatory, but players can skip it, which meets the players' need for autonomy. The tutorial meets learning theoretical requirements, as

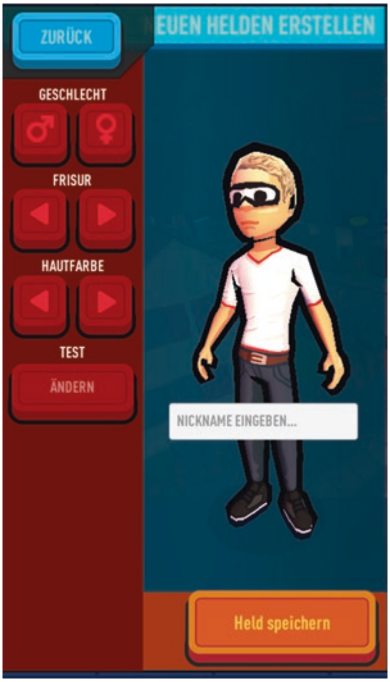


Fig. 1.2 Configuring the avatar

it is a scaffold for the players to discover the goal and to learn the controls in a secured environment.

1.4.3 Overview

The overview screen gives the players various information and options: First, the players can see which levels they have already played (and how often) and which levels they have unlocked. Second, when the players choose an unlocked level, they are given specific information about this level—for example, how many and which small robots they can expect in the chosen level and how often they have already played this level. Third, this screen also provides information about the achievements of the characters, such as their received medals and experience. The objective of this screen is that the players have to decide if they want to play levels again or if they want to play a recently unlocked level. By playing a level they have already mastered, players can earn more medals and experience points. By choosing new levels, the players can unlock more levels. The possibility to repeat levels triggers ambiguity aversion, as the players can choose a level with known challenges over a level with unknown challenges. By giving the players the option to choose the level, the game meets the players' need for autonomy and competence.

On the overview screen, players can use the calculator to calculate in advance how expensive a level will be by specifying the number of robots they want to fight and the equipment they want to buy. The calculator supports the players' anchoring heuristics by giving them the opportunity to imagine what to expect during the level. The calculator is a scaffold, as it helps the players to plan and calculate different strategies (Fig. 1.3).

1.4.4 Equipment Store

After choosing a level, the players enter the equipment store. At this point, the players can equip their characters by buying or repairing appropriate equipment for the upcoming level. In the equipment store, the players can buy weapons, protective clothes, level boosters, and capes. The overall rules for the store are as follows: (1) The players can only buy as much equipment as they have money. (2) After every newly mastered level, new equipment is unlocked. (3) The new equipment is more expensive and more powerful than the previously available equipment. (4) There are different equipment options regarding price and power. (5) Once bought, durable equipment can be used throughout the whole game. (6) Used equipment needs to be repaired (if durable good) or bought new (if consumer good).

The shopping options are fourfold: weapons, protective clothing, boosting options, and capes. The weapon helps the avatar fight the robots. The weapons are everyday objects such as road signs or frying pans. The players get information

Fig. 1.3 The overview screen

about durability and power for each weapon. Second, the players can buy protective clothing. The clothes can protect the avatar and slow down the loss of health points during the fights with the robots. Weapons and protective clothes are durable goods, which means that the players can repair and use these items as often as they want to. Third, the players can buy boosting options, which are items that give the avatar a power boost or support during a level. The boosters are consumer goods, which means the players have to buy them again after they have used them. Fourth, the players can buy capes to equip their avatar. The capes are vanity items and have no benefit in winning the game. From a behavioral finance point of view, the selection of equipment depicts anchoring heuristics, as the players will choose the equipment based on their experiences in the preceding levels. The selection of the level boosters depicts the availability heuristics, as the players decide how many boosters they need based on their experiences in the preceding levels. When the players do not spend sufficient money on the equipment, this might come from an overconfidence bias, as they think they do not need the equipment. From a learning theoretical point of view, the options in the equipment store meet the need for autonomy by offering different options to equip the characters. Furthermore, the store situates the learning by modeling purchase decisions. The similarities with situated learning are the provided context for financial decisions. The game fosters experiential learning, as the players can develop and try out different shopping and equipment strategies during the game.

1.4.5 Time Management

After the players choose their equipment, they have to decide on their time management. The game offers three options for how the players can spend their time. Each option has its own rules. First, they can spend time learning. By doing so, the avatars can improve their grades, which results in more time for the next level. The players can also spend time on a side job. In the side job, the avatars can earn money without any risks. This is the safest way to earn money but is also the least lucrative one. The third option is to spend time on a level, where the players can fight the robots. By playing the levels, the players can earn the most money but also face the risk of losing money. The players can make money the safe way with the side job, in which they also earn less, or with the levels, which are riskier but, if succeeding, are also more profitable. They can also develop a strategy in which they first earn money with the side job and then buy more expensive equipment with the earned money. A strategy regarding the grades and the curfew could be that the players will improve their grades to have more time in the first place. After the grades are improved, the players can set the controls so that they have more time in a level to fight the robots. The operation of the time slide represents an anchoring heuristic, as the players will change the settings based on their experience in previous levels, how much time they need, and whether they want to earn money without risk. If the players do not plan enough time for a level, this may be due to overconfidence bias. The part-time job provides an opportunity for the players to earn money without risk, which reflects ambiguity aversion in the game. In terms of learning and motivation theories, these settings have the following meaning: Players are free to decide on a strategy for how they want to earn money and spend their time, thus enabling them to experience autonomy. In addition, the players get a scaffolding, because the time slide controls always remain in the settings from the previous level (Fig. 1.4).

1.4.6 Level

The objective of each level is to unlock the next level; the players have to fight the big robot at the end of the level. To do so, they have to start the level by fighting small robots. The amount of small robots is announced on the overview screen. The higher the level, the higher the difficulty, which means that there are more small robots in the way and that the route to the big robot becomes longer at each level. The design of the levels is randomized and not foreseeable. The players can abort a level at any time. This causes the loss of the earned money, and the equipment (weapons and clothing) stays damaged and needs to be repaired. If the players lose too many health points, the level will abort automatically. In this case, the players will also lose the earned money, and the equipment stays damaged and needs repair. A little bar over the head of the avatar informs the players about the status of health points.

Fig. 1.4 Time management

During the levels, the players have several rules that build the framework, within which they can decide on strategies for how to solve the challenges. (1) The players can play as long as their avatars have enough health points and enough time. With each robot attack, they lose health points. The bigger the robot, the bigger the loss. This means that better and more expensive equipment is needed at higher levels. (2) As the higher levels are longer, the players need more time to finish higher levels. (3) Passageways can be blocked randomly by a door; the players have to open them with a keycard. The keycards are hidden behind small robots. As the players do not know which small robots hide the keycard, they have to fight the small robots until they find the keycard.

Behavioral finance theory is embedded in the levels as follows: The designs of the levels, the robot types, and the tasks of each level are similar. Thus, the players use anchoring and representativeness heuristics to complete the levels. The players might suffer from overconfidence bias as the difficulty of the levels increases, and the strategy needs to be adjusted regularly. Learning and motivation theories are represented by the increasing difficulty of the game, and players must gain skills and experience to meet the increasing challenge. Thus, the players' need to experience competence is fulfilled. The possibility to quit any level at any time fulfills the need for autonomy of the players (Fig. 1.5).

Fig. 1.5 The level

1.4.7 Statement of Account

At the end of each level, the players get a statement of their account. The objective of the statement is to inform the players about the amount and the source of their income and expenses and to show how expensive the repair of the equipment is. The players have to decide whether they want to repair their equipment to use it for the next level. The statement gives hints of how the players can improve their strategy. In terms of learning and motivation theory, the account statement is feedback, as players can see at a glance the results of the previous level. It also serves as a representation of a bank statement, which facilitates the transfer of learning from the game to the real world. The hints on how to improve the strategy are scaffolding for the players (Fig. 1.6).

1.5 Discussion and Outlook

In this chapter, we described the development of a financial education serious game for secondary school students. In order to promote learners' short-term financial decision-making, insights from behavioral finance, theories of learning and motivation, and game design theory were combined.

Fig. 1.6 Statement of account

Experts from various fields (e.g., economic and media education, game design, behavioral finance, and teachers) were involved in the development of the game. The resulting game, FinanceMission Heroes, has a superhero story in which players have to fight against robots. In order to be successful in the game, the players have to develop a financial strategy and adjust it regularly. During the first usability tests, the game was perceived as motivating and interesting (Aprea et al., 2018). After the development of the game, additional learning materials were developed to facilitate the integration of the game into school lessons. The materials are designed to combine the game and classroom learning in order to facilitate the transfer of the content from the game to the real world. These materials have been used and tested in class and show promising results. A further quasi-experimental study with students found that the use of the game in combination with pretraining in the area of conceptual knowledge could lead to significant learning success (Schultheis & Aprea, 2020).

However, despite these promising results, the game, which resulted from this process, has some limitations: During game development, the requirements of the different user groups, as well as the sponsors, had to be taken into account. Thus, compromises had to be found in close coordination between game designers, affected groups, and the other experts involved. One shortcoming of the game is the lack of multiplayer options, such as leaderboard or other direct interaction options. Although empirical results show a strong effect on motivation, this was not implemented due to limited funding. Another limitation results from the lack of log files. Log files would have enabled a comprehensive and in-depth analysis of gaming behavior. The sponsor has decided against log files for data protection reasons.

In addition to the limitations as discussed above, there are a number of open questions that need to be addressed in future studies. These include the following in particular:

One question will be whether the heuristics and biases implemented in the game are the same heuristics and biases on which real financial decisions are based. Therefore, the next research step will be an external validation to determine whether the decisions in the game match real financial decisions. Besides the external validation, experimental validation is planned. The effects of serious games on learning success, motivation, and the development of mental models mentioned in the meta-analyses will be investigated. Particular references will be made to the connection between the theories of learning and motivation and game design.

As already mentioned, serious games are not a sure-fire success and require a structured and comprehensive integration into a learning arrangement. Further research is needed to determine the best way to integrate the game into learning arrangements. Of course, this needs to be examined from both a practical and a learning theory perspective. In addition to the further investigation of the existing financial education serious game, the development of new serious games in the area of financial education is also planned. The focus of FinanceMission Heroes is on short-term financial decisions and, in particular, the topic of budgets. However, financial literacy also includes other financial decisions, such as retirement provision, taxes, or insurance. In this regard, systemic aspects such as economic dependencies should also be taken into account, as these are also important components of financial literacy.

References

Altman, M. (2012). Implications of behavioural economics for financial literacy and public policy. *The Journal of Socio-Economics, 41*(5), 677–690.

Andrews, R. J., Logan, T. D., & Sinkey, M. J. (2018). Identifying confirmatory bias in the field. *Journal of Sports Economics, 19*(1), 50–81.

Aprea, C., Schultheis, J., & Stolle, K. (2018). Instructional integration of digital learning games in financial literacy education. In T. A. Lucey & K. S. Cooter (Eds.), *Financial literacy for children and youth* (Second ed., pp. 69–88). Peter Lang US.

Aprea, C., & Wuttke, E. (2016). Financial literacy of adolescents and young adults: Setting the course for a competence-oriented assessment instrument. In C. Aprea, E. Wuttke, K. Breuer, N. K. Koh, P. Davies, B. Greimel-Fuhrmann, & J. S. Lopus (Eds.), *International handbook of financial literacy* (pp. 397–414). Springer Singapore.

Aprea, C., Wuttke, E., Breuer, K., Koh, N. K., Davies, P., Greimel-Fuhrmann, B., & Lopus, J. S. (2016). Financial literacy in the twenty-first century: An introduction to the international handbook of financial literacy. In C. Aprea, E. Wuttke, K. Breuer, N. K. Koh, P. Davies, B. Greimel-Fuhrmann, & J. S. Lopus (Eds.), *International handbook of financial literacy* (pp. 1–4). Springer Singapore.

Clark, D. B., Tanner-Smith, E. E., & Killingsworth, S. S. (2016). Digital games, design, and learning: A systematic review and meta-analysis. *Review of Educational Research, 86*(1), 79–122.

Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education, 59*(2), 661–686.

Cruz, C., Hanus, M. D., & Fox, J. (2015). The need to achieve: Players' perceptions and uses of extrinsic meta-game reward systems for video game consoles. *Computers in Human Behavior, 71*, 516–524. https://doi.org/10.1016/j.chb.2015.08.017

Davies, P. (2015). Towards a framework for financial literacy in the context of democracy. *Journal of Curriculum Studies, 47*(2), 300–3016.

Daxhammer, R., & Facsar, M. (2018). *Behavioral Finance: Verhaltenswissenschaftliche Finanzmarktforschung im Lichte begrenzt rationaler Marktteilnehmer (2. Auflage). UTB Betriebswirtschaftslehre: Vol. 8504*. UVK-Verl.-Ges.

Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*(1), 5–8. 35–37.

Dickey, M. D. (2006). Game design narrative for learning: Appropriating adventure game design narrative devices and techniques for the Design of Interactive Learning Environments. *Educational Technology Research and Development, 54*(3), 245–263.

Djaouti, D., Alvarez, J., & Jessel, J.-P. (2011). Classifying serious games: The G/P/S model. In P. Felicia (Ed.), *Handbook of research on improving learning and motivation through educational games: Multidisciplinary approaches* (pp. 118–136). IGI Global.

Fernandes, D., Lynch, J. G., & Netemeyer, R. G. (2014). Financial literacy, financial education, and downstream financial behaviors. *Management Science, 60*(8), 1861–1883.

Fox, J., & Bailenson, J. N. (2009). Virtual self-modeling: The effects of vicarious reinforcement and identification on exercise behaviors. *Media Psychology, 12*(1), 1–25.

Garris, R., Ahlers, R., & Driskell, J. E. (2002). Games, motivation, and learning: A research and practice model. *Simulation & Gaming, 33*(4), 441–467.

Gibson, J. (2015). *Introduction to game design, prototyping, and development: From concept to playable game-with Unity and C#*. Addison-Wesley.

Glaser, M., Noeth, M., & Weber, M. (2004). Behavioral finance. In D. J. Koehler & N. Harvey (Eds.), *Blackwell handbook of judgment and decision making* (First ed., pp. 525–546). Blackwell Pub..

Gutter, M. S., Copur, Z., & Garrison, S. (2016). Do the financial behaviors of college students vary by their state's financial education policies? In C. Aprea, E. Wuttke, K. Breuer, N. K. Koh, P. Davies, B. Greimel-Fuhrmann, & J. S. Lopus (Eds.), *International handbook of financial literacy* (pp. 217–247). Springer Singapore.

Johnson, C. I., Bailey, S. K. T., & Van Buskirk, W. L. (2017). Designing effective feedback messages in serious games and simulations: A research review. In P. Wouters & H. van Oostendorp (Eds.), *Advances in game-based learning. Techniques to improve the effectiveness of serious games* (pp. 119–140). Springer.

Kahnemann, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica: Journal of the Econometric Society, 47*(2), 263–291.

Kalmpourtzis, G. (2018). *Educational game design fundamentals: A journey to creating intrinsically motivating learning experiences*. Chapman and Hall/CRC.

Kapp, K. M. (2012). *The gamification of learning and instruction: Game-based methods and strategies for training and education. Essential resources for training and HR professionals*. Pfeiffer.

Loerwald, D., & Stemmann, A. (2016). Behavioral finance and financial literacy. Educational implications of biases in financial decision making. In C. Aprea, E. Wuttke, K. Breuer, N. K. Koh, P. Davies, B. Greimel-Fuhrmann, & J. S. Lopus (Eds.), *International handbook of financial literacy* (pp. 25–38). Springer Singapore.

Lusardi, A. (2015). Financial literacy skills for the 21st century: Evidence from PISA. *Journal of Consumer Affairs, 49*(3), 639–659.

OECD. (2017). Statistical Insights: What does household debt say about financial resilience? Retrieved from https://www.oecd.org/sdd/fin-stats/statisticalinsightswhatdoeshouseholddebt-sayaboutfinancialresilience.htm

Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of game-based learning. *Educational Psychologist, 50*(4), 258–283.

Plass, J. L., Homer, B. D., Milne, C., Jordan, T., Kalyuga, S., Kim, M., & Lee, H. (2009). Design factors for effective science simulations. *International Journal of Gaming and Computer-Mediated Simulations, 1*(1), 16–35.

Prensky, M. (2001). *Digital game-based learning*. McGraw-Hill.

Prosad, J. M., Kapoor, S., & Sengupta, J. (2015). Theory of behavioral finance. In A. Driouchi & Z. Copur (Eds.), *Handbook of research on behavioral finance and investment strategies: Decision making in the financial industry* (pp. 1–24). IGI Global.

Qian, M., & Clark, K. R. (2016). Game-based learning and 21st century skills: A review of recent research. *Computers in Human Behavior, 63*, 50–58.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68–78.

Schultheis, J. & Aprea, C. (2020). Supporting game-based learning in financial education: Do conceptual scaffolds work? *JURE conference (Junior Researchers of EARLI) Porto (Portugal).* (Conference Canceled).

Simon, H. A. (1959). Theories of Decision-Making in Economics and Behavioral Science. *American Economic Review, 49*, 253–283.

Sitzmann, T. (2011). A meta-analytic examination of the instructional effectiveness of computer-based simulation games. *Personnel Psychology, 64*(2), 489–528.

Tobias, S., & Fletcher, J. D. (Eds.). (2011). *Computer games and instruction*. IAP Information Age Publishing.

Tversky, A., & Kahnemann, D. (1974). Judgment under uncertainty: Heuristics and biases: Biases in judgments reveal some heuristics of thinking under uncertainty. *Science, 185*(4157), 1124–1131.

Van Staalduinen, J. P., & de Freitas, S. (2011). A game-based learning framework: Linking game design and learning outcomes. In M. S. Khine (Ed.), *New literacies and digital epistemologies* (Learning to play: Exploring the future of education with video games) (Vol. 53, First ed., pp. 29–54). Peter Lang International Academic Publishers.

Wilson, K. A., Bedwell, W. L., Lazzara, E. H., Salas, E., Burke, C. S., Estock, J. L., Orvis, K. L., & Conkey, C. (2009). Relationships between game attributes and learning outcomes. *Simulation & Gaming, 40*(2), 217–266.

Wouters, P., van Nimwegen, C., van Oostendorp, H., & van der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games. *Journal of Educational Psychology, 105*(2), 249–265.

Yee, N., & Bailenson, J. (2006, August). *Walk A Mile in Digital Shoes: The Impact of Embodied Perspective-Taking on The Reduction of Negative Stereotyping in Immersive Virtual Environments*. Proceedings of PRESENCE 2006: The 9th annual international workshop on Presence, Cleveland, Ohio, USA.

Yoong, J. (2013). Can behavioural economics be used to make financial education more effective? In OECD (Ed.), *Improving financial education efficiency: OECD-Bank of Italy symposium on financial literacy* (pp. 65–101). OECD Publishing.

Chapter 2
Game-Based Learning in Economics Education at Upper Secondary Level: The Impact of Game Mechanics and Reflection on Students' Financial Literacy

Liane Platz, Michael Jüttler, and Stephan Schumann

2.1 Introduction

Financial education is becoming increasingly important, especially for younger generations (Wuttke et al., 2016). One reason is a growing risk shift, stated from public institutions to private individuals, which is associated with greater personal responsibility for private provision (Hacker, 2019). Additionally, the growing number of atypical forms of employment requires a different form of security (Hermeier et al., 2019). In this regard, financial products offered for this purpose are becoming more complex and meet a lack of consumer sovereignty in financial markets (Kaiser & Lutter, 2015). Preparing young adults in schools for these dynamic challenges is increasingly necessary and therefore becomes an important educational goal at the upper secondary level.

One approach that offers great potential in promoting financial literacy is game-based learning (GBL) (Aprea et al., 2018). However, the wide range of digital and analog games available to promote financial literacy is contrasted by a research gap regarding their actual effectiveness. Although there are empirical indications of the general potential of GBL (Plass et al., 2019), it is unclear how this potential can be used for learning in this domain. The effective use of GBL to promote financial literacy, especially interest in this domain, is not a sure-fire success but depends on many aspects. These are grounded on theoretical considerations of the corresponding domain and the respective target group, in this case, students in upper secondary school who are about to graduate and start the next phase of their life, which for them entails greater economic responsibility (Förster et al., 2018). One approach to

L. Platz (✉) · M. Jüttler · S. Schumann
University of Konstanz, Konstanz, Germany
e-mail: liane.platz@uni-konstanz.de

C. Aprea, D. Ifenthaler (eds.), *Game-based Learning Across the Disciplines*, Advances in Game-Based Learning, https://doi.org/10.1007/978-3-030-75142-5_2

promoting the aspired educational goals is through the use of a serious game and its instructional framework. Game activities, which are primarily determined by game mechanics as well as reflection, are critical for learning gains (Pawar et al., 2019; Taub et al., 2019).

Against this background, the aims of the chapter are the presentation of a newly developed GBL environment—Moonshot—to promote the financial literacy of upper secondary students, its theoretical framework, and describe the research design of the empirical study in which the game will be implemented to assess the effects of GBL on financial literacy.

2.2 Theoretical Background

This section starts with a short definition of GBL and its essential elements—the game as a learning medium based on Mayer (2014) and instructional guiding through reflection according to Kolb and Kolb (2013), which is then explained and justified in more detail. Based on this, the diversity in the field of games is narrowed to serious games (Graesser, 2017), since one of the aims of this chapter is to present a game for learning purposes alone and one of its main building blocks "game mechanic" following Sicart (2008), which determines the main game activity and therefore is considered important for learning. Subsequently, it is explained how the use of GBL can contribute to fostering financial literacy in the context of financial education. A field with a long tradition of GBL applications but hardly any evidence. Finally, financial literacy as an important learning goal for students is legitimized and how it could be fostered, especially interest in this domain according to Krapp (2005). Interest has an important influence on the extent to which students also deal with the topic of finance in the future (Renninger & Hidi, 2016).

2.2.1 Game-based Learning and the Meaning of Reflection

The specific peculiarity of a game as a medium involves the combination of five characteristics: it is a rule-based simulative system that is responsive, cumulative, challenging, and inviting (Loh et al., 2015b; Mayer, 2014). There has been repeated reference to debriefing and instructional support so that GBL can reveal its promising effects as an experiential learning method (Crookall, 2015; Kerres et al., 2009; Kolb & Kolb, 2013; Taub et al., 2019).

To enable a transfer of the player's world into reality, reflection phases or debriefings are of central importance (Crookall, 2015; Zumbach et al., 2020). Students reflect on the reasons for their playing behavior and their interaction and compare their game experience with their real life. The aim is to avoid misconceptions and to establish a connection with the students' lives, especially to increase the value-based valence for the game content as well as their self-efficacy in this domain (Krapp & Ryan, 2002; Ryan & Deci, 2000).

Reflection phases are an essential prerequisite for *deeper interpretative learning* (Kolb & Kolb, 2013). During reflection, students not only become aware of their metacognitive processes but also learn to regulate their cognition (Bräuer, 2016; Taub et al., 2019). This applies even more to GBL. While experiential learning theory (Kolb & Kolb, 2013) refers to general experience-based learning, reflection in GBL is meaningful on two levels. First and foremost, reflection on the game and playing behavior can improve players' success in the game. Beyond that, transfer into the real life of students is an important learning outcome (Ke, 2016). On the one hand, it is important to compare game behavior with behavior in certain real-life situations, especially when a serious game is supposed to model financial decision situations. The determinant bases that can be derived from this can be valuable for young people. On the other hand, it is also about reflecting the opportunities and limits of this complexity-reduced modeling through the game to prevent incorrect concepts with regard to economic relationships and to avoid biases (Büchler & Quarg, 2014; Lusardi & Mitchell, 2014). Although the importance of reflection, e.g., through prompts, is uncontroversial, it is still unclear how this can be used (e.g., in a generic or direct way) to promote learning in a given GBL setting (Taub et al., 2019; Zumbach et al., 2020).

2.2.2 Serious Games and Game Mechanics

While it is possible to use an off-the-shelf game for learning purposes, there are so-called serious games with a well-thought-out learning goal (Graesser, 2017), on which the design of game elements such as the design of incentives, identity design, narratives, or the selection and design of game mechanics (Pawar & Tam, 2019) is based. Because the focus in off-the-shelf games is entertainment and engagement, game elements are designed accordingly. In a serious game, entertaining elements can distract from the actual learning goal and therefore have to be avoided when they do not serve a specific learning purpose (Jacob & Teuteberg, 2017). In regard to investigating the effects of serious games, a value-added approach is preferred due to methodological and theoretical reasons (Loh et al., 2015a). In this case, the effects of a basic version of the game are compared with the effects of an extended version. The extended version includes an additional element, e.g., a game mechanic or a narrative (Mayer, 2014).

Game mechanics are the main building blocks of game activities (Plass et al., 2012; Sicart, 2008) and therefore deserve special attention in game development. Nevertheless, there is only a small body of research on this design factor, although it has a major impact on game dynamics and learning effects (Pawar et al., 2019). To ensure the learning effect through a supplementary game mechanic, it must be provided that the corresponding mechanics are congruent with the learning content and are not distracting (Pawar et al., 2019; Zhonggen, 2019). Ideally, game activities and learning activities align or are even identical (Plass et al., 2012). In this case, they are no longer just game mechanics but so-called *learning mechanics* (Plass et al., 2016). Regarding simulating the effects of dealing with financial decisions, this should be represented by a game mechanic that involves dealing with scarce resources and considering changing (economic) conditions (Kaiser & Menkhoff, 2018). In contrast to game mechanics where the course of the game is predominantly random—as in a game of dice or roulette, for example—there are game mechanics where the success of the game is more directly connected to the strategic decisions of the players, e.g., in chess. To increase perceived learning success, central game mechanics should take this into account, increase the decision-making scope for players, and link the success of the game as closely as possible to game decisions.

2.2.3 Game-Based Learning and Financial Education

Meta-analyses in the field of financial education refer to the potential of experiential learning to make one's own actions tangible and, in the upper secondary level, to take future life goals into account (Amagir et al., 2017; Kaiser & Menkhoff, 2016, 2018). Both of these aspects of experiential learning could potentially be supported through GBL. There has also been a plea for "just-in-time" financial education (Fernandes et al., 2014) to ensure that the subjective significance of the content was conveyed to the real life of the students by aligning the content with student motivation and interest and thereby facilitating the transfer of what has been learned (Kaiser & Menkhoff, 2018; Totenhagen et al., 2015).

Numerous digital and analog educational games to promote financial literacy have been developed in recent years. According to our own count, there are more than 70 analog and digital games within the economic or financial domain in either English or German language. In addition to a different content focus and different gaming activities, the providers also vary. However, there is little empirical evidence about the effectiveness of these games in the area of financial literacy in general as well as information regarding the influence of certain design elements (Hainey et al., 2016). There have been some evaluations in this domain, but not all yet meet strict scientific criteria.

Although serious game evidence in the financial literacy area is still very sparse, much is already known about its general potential. Using a media-comparison approach (Mayer, 2014), it was suggested that GBL might be more effective in regard to knowledge acquisition and its retention period (Boyle et al., 2016; Riopel et al., 2019; Wouters et al., 2013) as well as providing higher motivation and interest development during the learning process (Clark et al., 2016; Connolly et al., 2012; Larson, 2020; Wouters & van Oostendorp, 2017; Zhonggen, 2019). In particular, increases in affective activation and learning engagement have been emphasized (Zhonggen, 2019) as important indicators of higher interest (Renninger & Hidi, 2011).

2.2.4 Interest as Part of Financial Literacy and Its Role in Learning

In line with several definitions of financial literacy, domain-specific interest can be seen as a substantial component (Koh, 2016; Weinert, 2001). Financial literacy is also defined as a competence incorporating five distinct content dimensions: money and payments, saving, loans, insurance, and monetary policy (Rudeloff, 2019; Schürkmann, 2017). Interest, as a *crucial motivational variable* (Hidi & Renninger, 2006), is an important predictor for attention, goal setting, and knowledge acquisition (Renninger & Hidi, 2016; Rotgans & Schmidt, 2017), since it influences the way and the frequency in which we interact with a certain context (Prenzel, 1986). In regard to interest in financial matters, studies have shown mixed results among young adults. There is evidence of a high level of interest in finance among young people (Greimel-Fuhrmann, 2018), but other studies have shown decreases in interest in finance and economic topics, especially for this age group (Kantar, 2019).

Especially with respect to assumed treatment effects, the distinction between situational (state) and individual interest (trait) has to be kept in mind (Reber et al., 2018; Renninger et al., 2014): While triggered situational interest can be considered simply an affective activation, a more developed situational interest as well as individual interest includes cognitive and emotional components, which are each related to a certain object (Hidi & Renninger, 2006). The cognitive dimension is defined as a high value-related valence, whereas the emotional dimension is defined as a high (positive) emotional experience. Both the cognitive and the emotional dimensions are connected to each other (Hulleman et al., 2010).

Following Krapp (2005), the development of interest can be explained by the basic needs of the theory of self-determination by Deci and Ryan (Deci et al., 2013; Ryan & Deci, 2017) involving social relatedness, perceived competence, and autonomy experience. Krapp (2005) links this concept to the person-object theory of interest (Prenzel, 1986). The role of basic needs with regard to the development of situational and individual interest in the learning process has been supported by several studies (Großmann & Wilde, 2018; Minnaert et al., 2011; Tsai et al., 2008). Regarding this learning process, Ryan and Rigby (2019) have suggested motivational effects of GBL. However, the role of basic needs in the learning process to promote intrinsic motivation, e.g., in GBL, could also be confirmed independent of person-object theory and plays an important role in measuring game experience (Johnson et al., 2018).

2.3 Development, Implementation and Evaluation of the GBL Environment "Moonshot"

Based on the theoretical considerations outlined above, we developed a GBL environment ("Moonshot", see Fig. 2.1) to promote learners' interest in the financial domain (see Sect. 2.3.1). As we aim to analyze the effects of this game and its reflective environment, we describe the research design (see Sect. 2.3.2) of an upcoming empirical study.

2.3.1 Game-Based Learning Environment "Moonshot"

The development of the serious game "Moonshot" comprised a two-year process including several pilot phases that involved experts from various disciplines (e.g., domain-specific didactics, educational sciences, game and communication design). It is designed for upper secondary school students (age: 15 years and older) and can be played by groups of 3–5 players. Accompanying reflection tasks were developed. In principle, the game can also be played without these tasks. In the following sections, the game components, game mechanics, and game reflection are briefly described. In addition, challenges in game development are briefly described.

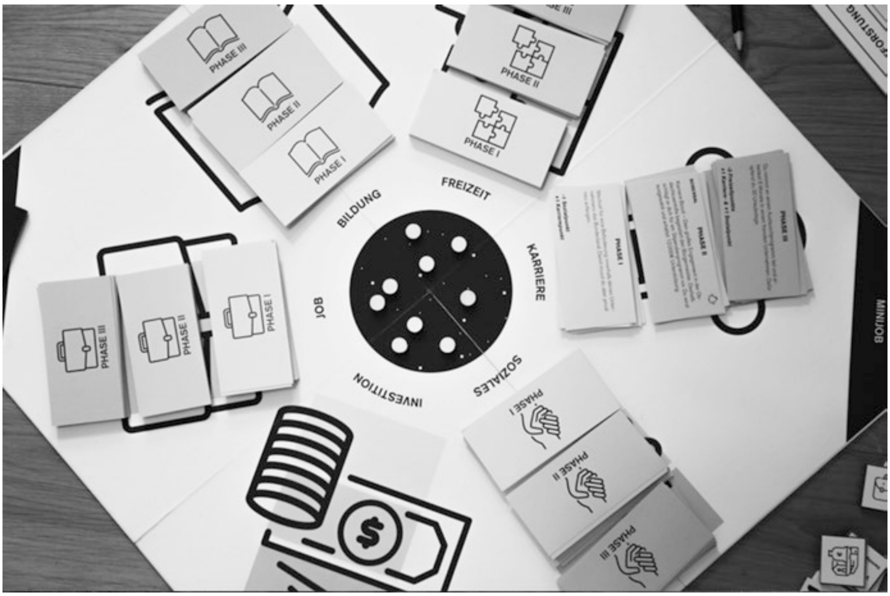


Fig. 2.1 Game "Moonshot". Photo © Susanna Grimm

2.3.1.1 Game Components of the Serious Game "Moonshot"

To make the game inviting to students, it starts with a so-called "life dream" that can be individually selected by each player at the beginning of the game (e.g., being a social media influencer or living in a self-sufficient manner on a farm). Every "life dream" can be achieved by making personal financial decisions while taking into account (a) changing economic conditions, (b) decisions of others, and (c) scarce resources. These "life dreams" were developed in such a way that they represent different value concepts and life plans and thus offer identification potential for students in different environments (Calmbach et al., 2016) to take into account the value-related valence for the game content by the players right from the beginning (Krapp & Ryan, 2002). All of these goals are comparable in their level of difficulty and allow the players to pursue different or even identical goals within the game, which also means realistic effects on cooperation and competition for existing resources.

The game goal can be achieved through three challenging game levels with increasing difficulty, each of which has different resource requirements. In every round of the game, there is a new economic and political situation that influences opportunities: change in interest rate, change in demand, environmental events, tax cuts, and others. Resources in exemplary areas of life must be taken into account: relationships, education, job and career, regeneration time, and finances. After one level has been completed, the next level can be started. The game is designed in such a way that players in one game can play with each other at the same time, even though they are at different levels, to make it more challenging and provide different opportunities to compete, cooperate, and catch up (Mayer, 2014).

All players have the opportunity to increase their income through gainful employment and financial investments, can take out loans, and insure themselves through different insurance opportunities. The rules are based on real conditions that have been reduced due to their complexity, e.g., changing interest rates are directly offered to the players as consumers and not through different commercial banks.

Thus, the area of finance is the focus of this game, and the game content and goals are aligned with the intended learning goal (Graesser, 2017; Klopfer et al., 2018; Plass et al., 2016). To bring it into connection with other areas of life, different resources (represented by different card stacks) must also be taken into account during the game. In addition to "Jobs" and "Investment," there are additional categories called "Education," "Social Affairs," "Career," and "Leisure" (see Table 2.1). Focusing on only one aspect of life (e.g., investment) is only successful to the extent that it corresponds to one's own life dream.

Apart from freely selectable possibilities to get closer to one's own game goal, card stacks contain the so-called individual "fates" in both positive and negative forms (e.g., (lottery) winnings, illnesses, or family and professional changes).

All options produce "costs" in different forms and amounts regarding time requirements, finances, and opportunity costs. These costs increase with each level of the game. During the game, the players keep track of their income and expenses

Table 2.1 Overview of categories

Category	Possible options
Jobs	Job offers with different salaries, depending on educational qualifications
Investment	More classic forms of investment with different profit and loss expectations, some of which can be anticipated by corresponding key figures
Education	Formal and informal educational opportunities
Career	Exemplary options for career advancement
Social	Exemplary options of civil society and voluntary work as well as individual family and friendship care
Leisure	Different forms of leisure activities and time-saving

as well as their game progress and monitor each other. This allows them to respond potentially early on changing circumstances (Mayer, 2014).

2.3.1.2 Direct and Generic Reflection

In the GBL environment, two reflection phases with two different standardized guidelines were implemented.

The basic version provides for a general, nonteacher-guided reflection (generic reflection): In the first phase, the players talk about their playing experience, and after the second phase of the game, they discuss the relationship to their lives. The first phase was to reflect on game decisions and the overall concept of the game so that in subsequent rounds, what has been learned can be tested directly in the game. Since the developed game has a high number of decision-making possibilities, it is intended to avoid overstraining and to create an experience of success for all participants (Ke, 2016).

In a second version, this objective is implemented by the teacher with the help of standardized instructional guidelines (direct reflection): After a first game phase, students' insights into promising game decisions were collected, categorized, and discussed. This should make the problem-solving ability within the game more efficient for the players (Kolb, 2015; Pawar et al., 2019) and increase their competence experience (Ryan & Deci, 2000). The topics to be discussed here are not limited to solutions according to the game logic but focus on individual reasons for game decisions to avoid cognitive biases in financial decision-making (Loerwald & Stemmann, 2016). The second phase of reflection focuses on the transfer of the playing experience to the reality of the students' lives. The references to reality, which were limited due to the simulation, are worked out to support the value-related valence for the game content (Krapp & Ryan, 2002). The final step is the design of a personal "(real)life dream" and the necessary budgeting in partial steps. Beyond the intervention, the aim here is to promote further engagement with the topic of finance as an important indicator of individual interest development (Renninger & Hidi, 2016).

2.3.1.3 Varying Game Mechanics to Influence Perceived Basic Needs Experience

Two versions of the game were designed (see Table 2.2): In the first version (treatment I), different opportunities are randomly presented to the players, whereas in the second version (treatment II), limited time resources were added that the players could use at their own discretion to perform an action (e.g., to invest in education) and to achieve their goals. This simulates the use of scarce resources and links individual game decisions more closely to the achievement of the game goal to support the competence experience (Ryan & Deci, 2000). The resulting greater freedom of choice was also intended to promote the autonomous experience (Aprea et al., 2018; Ryan & Deci, 2017). The economic conditions determine the number of limited resources in the category fields for which the players compete.

If categories relevant to the players are currently not available—because other players have already used up the resources in a certain round—there are two additional categories that are available at any time without limit: mini-jobs and advanced training courses. They are not associated with any risk but have a low return. Using only these categories cannot lead to victory, but it does guarantee the players' ability to act until the next economic scenario begins. Based on the person-object theory of interest, it was assumed that this play experience will be perceived as more relevant to the students' lives (Krapp, 2005).

2.3.1.4 Challenges During Game Development

Based on the defined game and learning goals, different game versions were tested and discarded. A central challenge was to balance realistic representation and appropriate complexity for the target group. Many pieces of information in text form

Table 2.2 Differences in strategic decisions according to the game mechanic

	Strategic decisions	Random events
Treatment I: Basic game, using dice (random)	• Taking out a loan • Dealing with an "offer" on playing card: Accept, exchange, or sale	• Economic situation (e.g., tax increase) • Fate (e.g., illness, winning in the lottery) • Decisions about resource category (e.g., job, leisure)
Treatment II: Advanced game, using an additional strategic game mechanic	• Taking out a loan • Analysis of available information on open cards • Deciding on a category, depending on the time budget, available resources, and individual game objective • Dealing with an "offer" on playing card: Accept, exchange or sale	• Economic situation (e.g., tax increase) • Fate (e.g., illness, winning in the lottery)

(e.g., on life goals or investment options) were thus significantly reduced or transferred into symbolic representations. The game mechanics in treatment II should also serve to represent the learning goals more adequately. The decision for an analog variant also brings, in addition to many advantages, such as a haptic gaming experience and a more direct interaction with other players—a few challenges—such as fewer control options for adhering to game rules or correct calculation paths. To counter this, peer control mechanisms were introduced, and it was ensured that minor rule violations did not contradict the intended learning goals. It became clear that not all content dimensions could be considered equally to keep the complexity and clarity appropriate. While money and payment transactions, savings, and loans were considered in a differentiated manner, insurance (through fates and the choice between three different insurance policies) and monetary policy (through changes in key interest rates) are less represented.

2.3.2 Research Design

2.3.2.1 Hypotheses

For the upcoming main study (2020/21), four treatment groups in the GBL environment "Moonshot" will be established and tested within the research design (see Fig. 2.2). The following two questions will be addressed. (1) How do specific game mechanics influence the basic needs experience of the players so that their interest

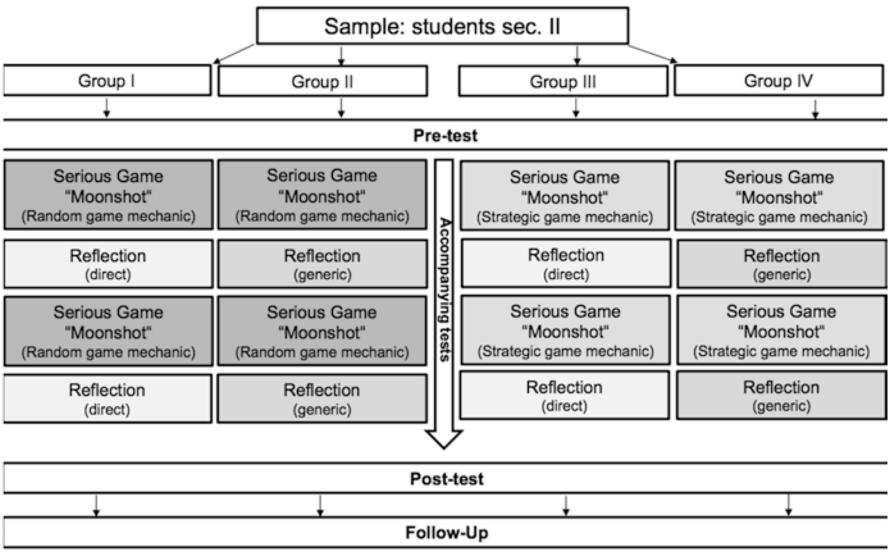


Fig. 2.2 Research design to test the effects of different game mechanics and reflections in the GBL environment "Moonshot"

in the financial domain increases? (2) How can the design of reflection phases support this learning goal? The experiment consists of a 2 × 2 group design. All four groups will play the game "Moonshot." Two groups will play the game with a game mechanic that chooses the opportunities on a random basis (I and II), whereas the two other groups (III and IV) will play the game with a strategic game mechanic. Furthermore, two groups with different game mechanics will reflect freely on their game experience as well as on the role of the game experience in their personal life ("generic reflection"; II and IV), whereas the other two groups ("direct reflection"; I and III) will reflect with the help of specific tasks given by the teacher. Thus, the following groups will be compared: group I (random game mechanic; direct reflection), group II (random game mechanic; generic reflection), group III (strategic game mechanic; direct reflection), and group IV (strategic game mechanic; generic reflection).

This group design will allow us to test several hypotheses regarding the effects of different game mechanics as well as reflection phases on the financial literacy of students in the upper secondary level. The following hypotheses will be tested:

(H1) In groups with strategic game mechanics (groups III and IV), the autonomy experience will be higher than in groups with random game mechanics (groups I and II).
(H2) In groups with strategic game mechanics (groups III and IV), the competence experience will be higher than in groups with random game mechanics (groups I and II).
(H3) In groups with strategic game mechanics (groups III and IV), the situational interest (state) will be higher than in groups with random game mechanics (groups I and II).
(H4) In groups with strategic game mechanics (groups III and IV), the value-related valence will be higher than in groups with random game mechanics (groups I and II).
(H5) In groups with direct reflections (groups II and IV), the value-related valence will be higher than in groups with generic reflections (groups I and III).
(H6) In the group with strategic game mechanics and direct reflections (group III), the individual interest (trait) will increase more strongly than in groups with no strategic game mechanics and/or direct reflection phases (groups I, II, and IV).

2.3.2.2 Sample and Procedure

The aim is to conduct a randomized controlled field trial (randomization by class; for an overview, see Fig. 2.2). The entire intervention will take place at schools and last 270 min., including the surveys. The playing time will involve two 60-min. periods, the reflection phases will last 90 min., and completion of the questionnaire will take 60 min. Based on power analyses using the statistic program G*Power (Faul et al., 2007), an optimal sample size of at least 300 students will be aimed at validating small to medium effect sizes for the 2×2 experimental control group design with repeated measures described above. To achieve this, five school classes for each treatment group will be tested.

One week before each intervention, relevant variables are collected by a pretest, and the program is explained to the students. Due to the different technical resources of the schools, all surveys will be paper-based.

The investigator-in-charge will be involved in all courses and will be supported by research assistants. The entire program during the quasi-experiment will follow a standardized procedure, which is provided by guidelines and standardized materials that accompany the game and reflection.

The intervention starts with a brief introduction explaining the game rules and measurement of emotional states. During the first 60-min. game time, data on emotional activation as a subset of interest (Renninger & Hidi, 2011) will be collected by continuous state sampling (Csikszentmihalyi & Larson, 2014). Basic needs experience and value-based valence will be measured directly after each game phase. After reflection phases, this happens again, but there is no continuous state sampling. After the second period of reflection, a final measurement of the dependent variables will be made, this time including planned changes in behavior. The survey will end with a follow-up two weeks after the intervention. Here, individual interest (trait) and actual engagement with finances will be measured again.

2.3.2.3 Instruments

To measure the development of situational and individual interest as well as basic needs experience, a questionnaire will be used. The questionnaire contains relevant control variables for the assessment of individual condition factors, socioeconomic backgrounds, and institutional framework conditions that are collected with existing and established scales (for an overview, see Table 2.3).

When selecting the dependent variables to be measured, the emphasis was placed on emotional and value-related valence concerning the game content, a general measurement of interest on the five content dimensions of financial literacy as well as the basic needs experience during and after play (for an overview, see Table 2.4). In addition, measurement of intended behavioral change was added as a supplement to have an indicator of change in individuals and not just situational interest (Renninger & Hidi, 2016).

Table 2.3 Extract on control variables measured in the pretest

Variable	Origin	Number of items
Attitudes, perceptions, and intentions toward serious games	Adapted according to Riemer and Schrader (2015)	16
Financial background and socialization	Adapted according to Rudeloff (2019)	5
Personal and socioeconomic factors	Age, gender, mother tongue, school, grades, parental education, and scope of employment	9

Table 2.4 Dependent variables

Variable	Origin	Number of items	Pretest	Accompanying	Posttest[a]	Follow-up
Value-related valence (state)	Adapted according to Prenzel et al. (2001)	6		x	x	
Emotional activation (state)	Adapted according to Schallenberger (2005)	10	x	x		
Competence experience	Adapted according to Prenzel et al. (2001)	5		x	x	
Autonomy experience	Adapted according to Prenzel et al. (2001)	5		x	x	
Interest in the financial domain (trait)	Adapted according to content dimensions of financial literacy and scale for interest used in PISA (2015)	5	x		x	x
(intended) engagement with subject	Self-developed, based on Renninger and Hidi (2016)	9	x		x	x

[a]After game and reflection phases

To control the quality of each intervention, the teacher rates the quality after the intervention is finished in a class. The dependent variables are also controlled by measuring game engagement in the area of finance by collecting the players' accounting to count actual game decisions in the finance category; furthermore, the individual game progress is tracked (Klopfer et al., 2018).

2.4 Outlook and Expected Implications

In this chapter, the game "Moonshot" was presented and discussed with regard to its potential as a serious game to foster financial literacy. Furthermore, a research design to analyze the effects of different game mechanics, especially on interest in the financial domain, was introduced.

On the basis of theoretical considerations, it was explained that game mechanics in particular must be taken into account in the development of games, as these form the core of game activity. On this basis, it was argued that in a serious game focusing on financial literacy, the strategic use of scarce resources as well as (economic) real-life conditions should be simulated by game mechanics. By linking the success of the game more closely to individual game decisions and actions, the aim is also to promote upper school students' experience of competence and autonomy.

Furthermore, reflection phases were included as an essential component of GBL environments (Taub et al., 2019). In the case of the GBL environment presented here, the value-related valence is to be promoted by instructional reflection on the relationship between the life of the player and the game decisions, since this is where a transfer to the students' own life is initiated.

Testing the hypotheses outlined above will provide needed empirical evidence on the development and implementation of serious games within schools to foster students' financial literacy as well as other learning goals in different school subjects. In this regard, discussing promising methods for teaching and learning as well as advancing the well-founded use of GBL methods could be major implications of this study.

References

Amagir, A., Groot, W., van den Maassen Brink, H., & Wilschut, A. (2017). A review of financial-literacy education programs for children and adolescents. *Citizenship, Social and Economics Education, 49*(2), 204717341771955. https://doi.org/10.1177/2047173417719555

Aprea, C., Schultheis, J., & Stolle, K. (2018). Instructional integration of digital learning games in financial literacy education. In T. A. Lucey & K. S. Cooter (Eds.), *Financial literacy for children and youth* (pp. 69–88). Peter Lang.

Boyle, E. A., Hainey, T., Connolly, T. M., Gray, G., Earp, J., Ott, M., … Pereira, J. (2016). An update to the systematic literature review of empirical evidence of the impacts and outcomes of computer games and serious games. *Computers & Education, 94*, 178–192. https://doi.org/10.1016/j.compedu.2015.11.003

Bräuer, G. (2016). *Das Portfolio als Reflexionsmedium für Lehrende und Studierende (2., erweiterte Auflage). Kompetent lehren: Band 6*. Verlag Barbara Budrich; UTB GmbH. Retrieved from http://www.utb-studi-e-book.de/9783838546322

Büchler, J.-P., & Quarg, S. (2014). Managementsimulationen als korporativer Lernprozess zur Rationalitätssicherung. In S. Schwägele, B. Zürn, & F. Trautwein (Eds.), *ZMS-Schriftenreihe* (*Planspiele - Erleben, was kommt: Entwicklung von Zukunftsszenarien und Strategien*) (Vol. 5, pp. 33–68). Books on Demand.

Calmbach, M., Borgstedt, S., Borchard, I., Thomas, P. M., & Flaig, B. B. (2016). *Wie ticken Jugendliche 2016?: Lebenswelten von Jugendlichen im Alter von 14 bis 17 Jahren in Deutschland. s.l.* Springer. Retrieved from http://www.doabooks.org/doab?func=fulltext&rid=19074

Clark, D. B., Tanner-Smith, E. E., & Killingsworth, S. S. (2016). Digital games, design, and Learning: A systematic review and meta-analysis. *Review of Educational Research, 86*(1), 79–122. https://doi.org/10.3102/0034654315582065

Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education, 59*(2), 661–686. https://doi.org/10.1016/j.compedu.2012.03.004

Crookall, D. (2015). Engaging (in) gameplay and (in) debriefing. *Simulation & Gaming, 45*(4–5), 416–427. https://doi.org/10.1177/1046878114559879

Csikszentmihalyi, M., & Larson, R. (2014). Validity and reliability of the experience-sampling method. In M. Csikszentmihalyi (Ed.), *Flow and the foundations of positive psychology: The collected works of Mihaly Csikszentmihalyi* (pp. 35–54). Springer Netherlands. https://doi.org/10.1007/978-94-017-9088-8_3

Deci, E. L., Ryan, R. M., & Guay, F. (2013). Self-determination theory and actualization of human potential. In D. McInerney, H. Marsh, R. Craven, & F. Guay (Eds.), *Theory driving research: New wave perspectives on self processes and human development* (pp. 109–133). Information Age Press.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175–191. https://doi.org/10.3758/bf03193146

Fernandes, D., Lynch, J. G., & Netemeyer, R. G. (2014). Financial literacy, financial education, and downstream financial behaviors. *Management Science, 60*(8), 1861–1883. https://doi.org/10.1287/mnsc.2013.1849

Förster, M., Happ, R., Walstad, W. B., & Asarta, C. (Eds.). (2018). *Empirische Pädagogik\: 32 (3/4), 2018. Financial literacy of students and young adults: Determinants and impacts*. Verlag Empirische Pädagogik.

Graesser, A. C. (2017). Reflections on serious games. In P. Wouters & H. van Oostendorp (Eds.), *Advances in game-based learning. Techniques to improve the effectiveness of serious games* (pp. 199–212). Springer.

Greimel-Fuhrmann, B. (2018). Ist es (un)möglich, finanziell gebildet zu sein? In K. Büchter, M. Fischer, F. Gramlinger, H.-H. Kremer, & T. Tramm (Eds.), *(Chairs), bwp@ Österreich spezial: Wirtschaftspädagische Forschung und Impulse für die Wirtschaftsdidaktik. Beiträge zum 12. Österreichischen Wirtschaftspädagogikkongress*.

Großmann, N., & Wilde, M. (2018). Promoting interest by supporting learner autonomy: The effects of teaching behaviour in biology lessons. *Research in Science Education*. Advance online publication*, 50*(5), 1763–1788. https://doi.org/10.1007/s11165-018-9752-5

Hacker, J. S. (2019). *The great risk shift: The new economic insecurity and the decline of the American dream (expanded & fully revised)* (Second ed.). Oxford University Press.

Hainey, T., Connolly, T. M., Boyle, E. A., Wilson, A., & Razak, A. (2016). A systematic literature review of games-based learning empirical evidence in primary education. *Computers & Education, 102*, 202–223. https://doi.org/10.1016/j.compedu.2016.09.001

Hermeier, B., Heupel, T., & Fichtner-Rosada, S. (Eds.). (2019). *FOM-Edition, FOM Hochschule für Oekonomie & Management. Arbeitswelten der Zukunft: Wie die Digitalisierung unsere Arbeitsplätze und Arbeitsweisen verändert*. Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-23397-6

Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist, 41*(2), 111–127. https://doi.org/10.1207/s15326985ep4102_4

Hoblitz, A. (2015). *Spielend Lernen im Flow: Die motivationale Wirkung von Serious Games im Schulunterricht (1. Aufl. 2015)*. Springer Fachmedien Wiesbaden.

Hulleman, C. S., Godes, O., Hendricks, B. L., & Harackiewicz, J. M. (2010). Enhancing interest and performance with a utility value intervention. *Journal of Educational Psychology, 102*(4), 880–895. https://doi.org/10.1037/a0019506

Jacob, A., & Teuteberg, F. (2017). Game-Based-Learning, Serious Games, Business Games und Gamification - Lernförderliche Anwendungsszenarien, gewonnene Erkenntnisse und Handlungsempfehlungen. In S. Strahringer & C. Leyh (Eds.), *Edition HMD. Gamification und Serious Games: Grundlagen, Vorgehen und Anwendungen* (pp. 97–112). Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-16742-4_8

Johnson, D., Gardner, M. J., & Perry, R. (2018). Validation of two game experience scales: The player experience of need satisfaction (PENS) and game experience questionnaire (GEQ). *International Journal of Human-Computer Studies, 118*, 38–46. https://doi.org/10.1016/j.ijhcs.2018.05.003

Kaiser, T., & Lutter, A. (2015). Empirische Forschung zu financial literacy.: Zugänge - Befunde - Desiderata. *Zeitschrift Für Didaktik Der Gesellschaftswissenschaften, 6*(2), 77–95.

Kaiser, T., & Menkhoff, L. (2016). Does financial education impact financial behavior, and if so, when? *SSRN Electronic Journal*. Advance online publication. https://doi.org/10.2139/ssrn.2753510.

Kaiser, T., & Menkhoff, L. (2018). Active learning fosters financial behavior: Experimental evidence. *SSRN Electronic Journal*. Advance online publication. https://doi.org/10.2139/ssrn.3208637

Kantar TNS (2019). *Finanzaffinität, Finanzwissen und Anlageverhalten der Deutschen: Ergebnisse einer repräsentativen Meinungsumfrage im Auftrag des Bundesverbandes deutscher Banken*. Retrieved from https://bankenverband.de/media/files/2019_07_30_U_Finanzkultur_SSh1.pdf

Ke, F. (2016). Designing and integrating purposeful learning in game play: A systematic review. *Educational Technology Research and Development, 64*(2), 219–244. https://doi.org/10.1007/s11423-015-9418-1

Kerres, M., Bormann, M., & Vervenne, M. (2009). Einzelbeiträge 2009. *MedienPädagogik: Zeitschrift Für Theorie Und Praxis Der Medienbildung, 2009*(Occasional Papers), 1–16. https://doi.org/10.21240/mpaed/00/2009.08.25.X

Klopfer, E., Haas, J., Osterweil, S., Rosenheck, L., & Macklin, C. (2018). Resonant games: Design principles for learning games that connect hearts, minds, and the everyday. In D. The John & C. T. Macarthur (Eds.), *Foundation series on digital media and learning*. The MIT Press.

Koh, N. K. (2016). Approaches to teaching financial literacy: Evidence-Based practices in Singapore schools. In C. Aprea, K. Breuer, E. Wuttke, N. K. Koh, P. Davies, B. Greimel-Fuhrmann, & J. S. Lopus (Eds.), *International handbook of financial literacy* (pp. 499–513). Singapore: Springer.

Kolb, A. Y., & Kolb, D. A. (2013). Experiential learning theory: A dynamic, holistic approach to management learning, education and development. In C. V. Fukami & S. J. Armstrong (Eds.), *The Sage handbook of management learning, education, and development* (pp. 42–68). SAGE Publications.; Credo Reference. https://doi.org/10.4135/9780857021038.n3

Kolb, D. A. (2015). *Experiential learning: Experience as the source of learning and development* (Second ed.). Pearson Education.

Krapp, A. (2005). Basic needs and the development of interest and intrinsic motivational orientations. *Learning and Instruction, 15*(5), 381–395. https://doi.org/10.1016/j.learninstruc.2005.07.007

Krapp, A., & Ryan, R. M. (2002). Selbstwirksamkeit und Lernmotivation: Eine kritische Betrachtung der Theorie von Bandura aus der Sicht der Selbstbestimmungstheorie und der pädagogisch-psychologischen Interessentheorie. In *Selbstwirksamkeit und Motivationsprozesse in Bildungsinstitutionen* (pp. 54–82). Beltz.

Larson, K. (2020). Serious games and gamification in the corporate training environment: A literature review. *TechTrends, 64*(2), 319–328. https://doi.org/10.1007/s11528-019-00446-7

Loerwald, D., & Stemmann, A. (2016). Behavioral finance and financial literacy: Educational implications of biases in financial decision making. In C. Aprea, K. Breuer, E. Wuttke, N. K. Koh, P. Davies, B. Greimel-Fuhrmann, & J. S. Lopus (Eds.), *International handbook of financial literacy* (pp. 25–38). Springer. https://doi.org/10.1007/978-981-10-0360-8_3

Loh, C. S., Sheng, Y., & Ifenthaler, D. (Eds.). (2015a). *Advances in game-based learning. Serious games analytics: Methodologies for performance measurement, assessment, and improvement.* Springer.

Loh, C. S., Sheng, Y., & Ifenthaler, D. (2015b). Serious games analytics: Theoretical framework. In C. S. Loh, Y. Sheng, & D. Ifenthaler (Eds.), *Advances in game-based learning. Serious games analytics: Methodologies for performance measurement, assessment, and improvement* (pp. 3–29). Springer. https://doi.org/10.1007/978-3-319-05834-4_1

Lusardi, A., & Mitchell, O. S. (2014). The economic importance of financial literacy: Theory and evidence. *Journal of Economic Literature, 52*(1), 5–44. https://doi.org/10.1257/jel.52.1.5

Mayer, R. E. (2014). *Computer games for learning: An evidence-based approach*. The MIT Press.

Minnaert, A., Boekaerts, M., Brabander, C. de, & Opdenakker, M.-C. (2011). Students' experiences of autonomy, competence, social relatedness and interest within a CSCL environment in vocational education: The case of commerce and business administration. Vocations and Learning, 4(3), 175–190. https://doi.org/10.1007/s12186-011-9056-7.

Pawar, S., Tam, F., & Plass, J. L. (2019). Emerging design factors in game-based learning: Emotional design, musical score, and game mechanics design. In J. L. Plass, R. E. Mayer, & B. D. Homer (Eds.), *Handbook of game-based learning* (pp. 347–366). The MIT Press.

Peters, M., Hülsken-Giesler, M., Dütthorn, N., Hoffmann, B., Jeremias, C., Knab, C., & Pechuel, R. (2018). Mobile Learning in der Pflegebildung. In C. de Witt (Ed.), *Handbuch mobile learning* (pp. 971–992). Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-19123-8_45

PISA (2015). *Results (Volume IV)* (2017): OECD Publishing. https://doi.org/10.1787/9789264270282-en

Plass, J. L., Homer, B. D., Hayward, E. O., Frye, J., Huang, T.-T., Biles, M., … Perlin, K. (2012). The effect of learning mechanics design on learning outcomes in a computer-based geometry game. In S. Göbel (Ed.), *LNCS sublibrary. SL 3, Information systems and application, incl. Internet/Web and HCI: Vol. 7516* (E-learning and games for training, education, health and sports: 7th International Conference, Edutainment 2012 and 3rd International Conference, GameDays 2012, Darmstadt, Germany, September 18–20, 2012, Proceedings) (Vol. 7516, pp. 65–71). Springer. https://doi.org/10.1007/978-3-642-33466-5_7

Plass, J. L., Homer, B. D., & Kinzer, C. K. (2016). Foundations of game-based learning. *Educational Psychologist, 50*(4), 258–283. https://doi.org/10.1080/00461520.2015.1122533

Plass, J. L., Mayer, R. E., & Homer, B. D. (Eds.). (2019). *Handbook of game-based learning*. The MIT Press.

Prenzel, M. (1986). *Grundzüge einer pädagogischen Interessentheorie: Principles of an educational concept of interest*. Beltz.

Prenzel, M., Kramer, K., & Drechsel, B. (2001). Selbstbestimmt motiviertes und interessiertes Lernen in der kaufmännischen Erstausbildung - Ergebnisse eines Forschungsprojekts. *Zeitschrift Für Berufs- Und Wirtschaftspädagogik*, 37–61.

Reber, R., Canning, E. A., & Harackiewicz, J. M. (2018). Personalized education to increase interest. *Current Directions in Psychological Science, 27*(6), 449–454. https://doi.org/10.1177/0963721418793140

Renninger, K. A., & Hidi, S. (2011). Revisiting the conceptualization, measurement, and generation of interest. *Educational Psychologist, 46*(3), 168–184. https://doi.org/10.1080/00461520.2011.587723

Renninger, K. A., & Hidi, S. (2016). *The power of interest for motivation and engagement*. Routledge Taylor & Francis Group.

Renninger, K. A., Hidi, S., & Krapp, A. (2014). *The role of interest in learning and development*. Taylor and Francis. Retrieved from http://gbv.eblib.com/patron/FullRecord.aspx?p=1619118

Riemer, V., & Schrader, C. (2015). Learning with quizzes, simulations, and adventures: Students' attitudes, perceptions and intentions to learn with different types of serious games. *Computers & Education, 88*, 160–168. https://doi.org/10.1016/j.compedu.2015.05.003

Riopel, M., Nenciovici, L., Potvin, P., Chastenay, P., Charland, P., Sarrasin, J. B., & Masson, S. (2019). Impact of serious games on science learning achievement compared with more conventional instruction: An overview and a meta-analysis. *Studies in Science Education, 55*(2), 169–214. https://doi.org/10.1080/03057267.2019.1722420

Rotgans, J. I., & Schmidt, H. G. (2017). The relation between individual interest and knowledge acquisition. *British Educational Research Journal, 43*(2), 350–371. https://doi.org/10.1002/berj.3268

Rudeloff, M. (2019). Der Einfluss informeller Lerngelegenheiten auf die Finanzkompetenz von Lernenden am Ende der Sekundarstufe I. *Economics Education and Human Resource Management*. https://doi.org/10.1007/978-3-658-25131-4

Ryan, R. M., & Deci, E. L. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness*. The Guilford Press.

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology, 25*(1), 54–67. https://doi.org/10.1006/ceps.1999.1020

Ryan, R. M., & Rigby, C. S. (2019). Motivational foundations of game-based learning. In J. L. Plass, R. E. Mayer, & B. D. Homer (Eds.), *Handbook of gamebased learning* (pp. 153–176). Cambridge, MA: The MIT Press.

Schallenberger, U. (2005). *Kurzskalen zur Erfassung der Positiven Aktivierung, Negativen Aktivierung und Valenz in Experience Sampling Studien (PANAVA-KS).: Theoretische und* *methodi-sche Grundlagen, Konstruktvalidität und psychometrische Eigenschaften bei der Beschreibung intra- und interindividueller Unterschiede.* Forschungsberichte aus dem Projekt „Qualität desErlebens in Arbeit und Freizeit" (No. Nr. 6). Retrieved from http://www.psychologie.uzh.ch/institut/angehoerige/emeriti/schallberger/schallberger-pub/PANAVA_05.pdf

Schürkmann, S. (2017). *FILS: Financial Literacy Study: Validierung und Analyse einer schülerorientierten Financial Literacy. Dissertation, Universität Siegen, 2017. Schriftenreihe zur Ökonomischen Bildung: BAND*. De Gruyter Oldenbourg. https://doi.org/10.1515/9783110555622

Sicart, M. (2008). Defining game mechanics. *Game Studies, 8*(2).

Taub, M., Bradbury, A. E., Mudrick, N. V., & Azevedo, R. (2019). Self-regulation and reflection in game-based learning. In J. L. Plass, R. E. Mayer, & B. D. Homer (Eds.), *Handbook of game-based learning* (pp. 239–262). The MIT Press.

Totenhagen, C. J., Casper, D. M., Faber, K. M., Bosch, L. A., Wiggs, C. B., & Borden, L. M. (2015). Youth financial literacy: A review of key considerations and promising delivery methods. *Journal of Family and Economic Issues, 36*(2), 167–191. https://doi.org/10.1007/s10834-014-9397-0

Tsai, Y.-M., Kunter, M., Lüdtke, O., Trautwein, U., & Ryan, R. M. (2008). What makes lessons interesting? The role of situational and individual factors in three school subjects. *Journal of Educational Psychology, 100*(2), 460–472. https://doi.org/10.1037/0022-0663.100.2.460

Weinert, F. E. (Ed.). (2001). *Beltz-Pädagogik. Leistungsmessungen in Schulen (Dr. nach Typoskript)*. Weinheim.

Wouters, P., van Nimwegen, C., van Oostendorp, H., & van der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games. *Journal of Educational Psychology, 105*(2), 249–265. https://doi.org/10.1037/a0031311

Wouters, P., & van Oostendorp, H. (2017). Overview of instructional techniques to facilitate learning and motivation of serious games. In P. Wouters & H. van Oostendorp (Eds.), *Advances in game-based learning. Techniques to improve the effectiveness of serious games* (pp. 1–16). Springer. https://doi.org/10.1007/978-3-319-39298-1_1

Wuttke, E., Seifried, J., & Schumann, S. (Eds.). (2016). *Economic competence and financial literacy of young adults. Status and challenges*. Verlag Barbara Budrich.

Zhonggen, Y. (2019). A meta-analysis of use of serious games in education over a decade. *International Journal of Computer Games Technology, 2019*, 1–8. https://doi.org/10.1155/2019/4797032

Zumbach, J., Rammerstorfer, L., & Deibl, I. (2020). Cognitive and metacognitive support in learning with a serious game about demographic change. *Computers in Human Behavior, 103*, 120–129. https://doi.org/10.1016/j.chb.2019.09.026

Chapter 3
Game Design in Financial Literacy: Exploring Design Patterns for a Collaborative and Inclusive Serious Game from Different Perspectives

Jessica Paeßens and Esther Winther

3.1 Game-Based Learning as an Approach for Inclusion[1]

The National Decade of Literacy and Basic Education in Germany aims to improve literacy and basic skills in areas, which are relevant to everyday life such as health, finance, and nutrition (Bundesministerium für Bildung und Forschung [Federal Ministry of Education and Research], 2015). Basic skills in reading and writing are regarded as an individual antecedent for social participation (Abraham & Linde, 2018; Sting, 2005). The literacy and basic numeracy skills of everyday life are understood as literacy in the narrower sense. The broader understanding of the term also includes the handling of knowledge (Sting, 2005). According to the Level One study, which measures adult literacy at different levels of competence, 6.2 million German-speaking adults between the ages of 18 and 64 living in Germany have reading and writing difficulties. The percentage of adults with reading and writing difficulties in the total population is thus 12 percent. Despite a low literacy rate, 62.3 percent of these adults are gainfully employed, and 76 percent have received a school diploma in their educational biography (Grotlüschen et al., 2019).

The concept of basic education is a broader concept than literacy work (Kastner, 2016). In addition to the fostering of reading and writing skills (literacy), basic education includes in particular the learning fields of media/computer literacy,

[1] The manuscript was written through project funding. The project "CurVe II—Curriculum and Professionalization in Financial Literacy" is funded by the Federal Ministry of Education and Research. The project is described in Mania and Tröster (2016) and Tröster and Bowien-Jansen (2020).

J. Paeßens (✉) · E. Winther
Universitätsstraße 3, 45141 Essen, Germany
e-mail: Jessica.Paessens@uni-due.de

C. Aprea, D. Ifenthaler (eds.), *Game-based Learning Across the Disciplines*, Advances in Game-Based Learning, https://doi.org/10.1007/978-3-030-75142-5_3

health literacy, food literacy, financial literacy, civic literacy, and basic foreign language skills (Abraham & Linde, 2018; Mania & Tröster, 2018; Tröster & Schrader, 2016). Mania and Tröster (2014) understand basic financial education as part of basic economic education. The necessity of financial literacy can be explained on the one hand by the economic and financial crises taking place at the macro-level (Aprea et al., 2012). On the other hand, the high per capita indebtedness of private households, precarious employment, complex financial services, and the need for private provision can be observed at the micro-level (Remmele et al., 2013). Mania and Tröster (2018) postulate that new groups of learners for basic education can be reached through other content areas. With thematic content areas such as finance, politics, and health at the level of basic education, it should be possible to reach new participants. The action- and lifeworld-oriented topic ensures a learning transfer into everyday life and maintains the motivation for learning in basic education. Further developments of the content of basic education will enable new strategies, actors, and places of learning (Mania & Tröster, 2018). In addition, basic education in finance enables both social participation (Mania & Tröster, 2015) and employability by increasing autonomy, self-determination, trust, and feelings of value (Engartner, 2016). Basic education is contextualized in lifelong learning (Abraham & Linde, 2018). Basic education is thus also understood as an instrument of labor market integration (Mania & Tröster, 2015). The addition of general content relevant to the world of work and life in literacy work is necessary to strengthen the learning motivation of the less literates (Huck & Schäfer, 1991). While literacy has been discussed in Germany for some time, research on the design of learning settings at the basic education level can still be expanded. The scientific knowledge on courses of basic financial literacy is less extensive. There are a small number of basic education courses that teach financial literacy (Mania & Tröster, 2018). Existing courses are more likely to address school education or vocational education and training.

Literacy and basic education courses are offered by civic associations, prisons, and adult education centers (Volkshochschulen). Courses include formats such as literacy courses, preparatory courses for obtaining school diplomas, literacy courses prior to integration courses, or open learning cafes (Mania & Thöne-Geyer, 2019). Löffler and Korfkamp (2016) refer to the target group-specific (rather negative) learning experiences that are associated with complex demands on teachers when planning and designing literacy and basic education courses. National and international studies show that teaching–learning processes of adults in literacy and basic education receive little attention (LEO, Grotlüschen et al., 2019; PIAAC, OECD, 2009). The findings of the AlphaPanel also indicate that there is little evidence of learning progress in literacy courses (von Rosenbladt & Lehmann, 2013). The assessment of the written language competence of participants with diagnostic procedures is rejected by course teachers (Bonna, 2015). Because the target group is often learning disabled, lives precariously, has low self-confidence, and needs to learn, how to learn (von Rosenbladt & Lehmann, 2013).

Overall, participants in literacy courses are often learners with specific learning impairments, concrete learning disabilities, and without educational socialization (von Rosenbladt & Lehmann, 2013). Thus, the target group of literacy courses

Table 3.1 Gbl in inclusive literacy courses

Success patterns for literacy classes	Gbl as an inclusive approach
(Re-)start of learning	Reduction of access barriers
Discover the fun of learning	Motivation of learners
Receiving suggestions for everyday life and work	Reaching other groups of learners
Knowledge transfer in private/professional context	Development of social bonding structures

requires an instructional setting that is internally differentiated and inclusive. This contribution argues that learners who cannot go through typical learning processes can be integrated via a serious game (SG). Game-based learning (gbl) offers various advantages that are shown in Table 3.1, which are comparable to the success criteria of basic education courses (Abraham & Linde, 2018).

Given these advantages of gbl in basic education courses, the aim of this contribution is (1) to identify the design principles from teaching practitioners in financial literacy learning settings, (2) to structure it based on central learning theories in SG, and (3) to discuss it in a context of increasing collaboration requirements. In the first step, the recommendations from practice for practice based on a document analysis are grouped into eight principles for game design. In a second step, the game "Curve," developed by the literacy/basic education practice, will be structured along the content and instructional characteristics of SG (Castell & Jenson, 2003). In a third step, the identified principles for designing inclusive learning settings in basic education are intertwined with the design elements of the inclusive SG to develop the SG theoretically as an intervention for fostering collaborative problem-solving (CPS; Fiore et al., 2017; OECD, 2017) skills. Due to changing market and work situations, new collaboration requirements arise for learners. Therefore, the collaboration will be fostered and assessed in the SG. The contribution thus addresses research desiderata but also stimulates the goal-oriented further development and design possibilities of game design in literacy in order to be able to react proactively to current developments.

3.2 Assumptions and Theoretical Derivations for Serious Games

For the analysis of the inclusive SG *Curve* regarding content and instructional characteristics of SG (Castell & Jenson, 2003), it is useful to first outline the theoretical background of SG. SG combines knowledge transfer with playful activity. In doing so, motivational factors of computer games are integrated with teaching-learning methods to aim at an active knowledge construction in authentic contexts. The field of application varies between training, enlightenment, recreation as well as didactic design possibilities (Blötz, 2015). If playful elements are used in SG in a reflective manner to impart knowledge, they increase the motivation and self-efficacy of the learners. This is possible if feedback mechanisms and individual learning processes (interests and learning pace of players) are considered in the conception of SG (Blötz, 2015). An SG can be characterized by the following criteria: (1) learning takes place casually in the game; (2) the game has rules; (3) winning is objective and possible; (4) in case of misconduct, achieved game points are not reduced; (5) games are played as intended; (6) games are less efficient in learning than other methods; and (7) teachers do not believe in games (Becker, 2017b). First, it is necessary to identify the game design in the SG *Curve,* and therefore the first research question (RQ1) is:

- RQ1: Which principles guide practitioners of basic education/literacy in designing learning settings in financial literacy?

SG links education and training with labor market skills and leisure activities. SG or simulations promote skills that will be required by employers in the future and are not taught adequately at school (Jackson Kellinger, 2017). In addition to the ability to solve problems, critical thinking, communication, and collaboration, especially in SG, the requirements for gamers include creativity and an innovative mindset. Players are characterized by the adoption of new identities and perspectives, their perception as problem solvers, and the understanding of mistakes as a learning opportunity (Gee, 2003). While playing, they test hypothesis-like developed game strategies to eliminate cognitive dissonance (van Eck, 2007). The learning approach in SG is based on constructivism. The idea is that learners construct knowledge through discovery learning (Bruner, 1961). Through the variety of game possibilities, trying out the game world, and direct feedback, learners in SG can learn from their mistakes and take risks (Gee, 2003; Prensky, 2001; Shaffer, 2006). The theory of situated cognition also requires that learning has to be embedded in an authentic context in order to explore contexts (Achtenhagen, 2002; Driscoll, 2005; Winther, 2010). SG should be designed in terms of content and instructional processes along with different approaches and theories for the specific design of learning support. The transfer of evident learning theories to SG can be found in Castell and Jenson (2003). Here, meta-analyses prove that the use of SG makes sense from a pedagogical point of view, since an increase in performance (Marzano, 2010), knowledge availability (retention), cognitive gains, and a better attitude toward learning content can be observed. This leads to the second research question (RQ2):

- RQ 2: Which design elements of gbl are implemented in the SG *Curve*?

The transfer of SG to real situations is particularly successful when the SG environment is moderately adapted to reality and real-world variables are limited for simplification (Gee, 2003; Grabe & Grabe, 2007). The ability of players to work in a team and communicate is promoted as they create affinity spaces (Gee, 2007) for exchange and establish a gaming culture based on experience. Collaboration is found both in the research by (1) educationalists Webb and Palincsar (1996) as the best form of learning (Squire, 2011) and in (2) game literature by Prensky (2006). Cooperation, esp. CPS, in groups or pairs, is called a twenty-first-century skill (Andrews et al., 2017; Graesser et al., 2018; von Davier & Halpin, 2013). When SG is played in dyads, participation, commitment, and learning outcomes are greater than when learners play alone (Schrier, 2007; Squire, 2011). Playing in dyads (1) promotes action–reflection through decision discussions, (2) verbalizes the intentions and thoughts of players, and (3) enables the sharing of problems within a game (Squire, 2011). Players describe playing in dyads as a way to share ideas and tasks, have small debates, remember information better, develop decision-making skills, and as a way to reflect (Schrier, 2007). This playing and collaboration within the SG encourage critical thinking, collaboration, and problem-solving skills. In other words, those skills are called future work skills (Davies et al., 2011). With a focus on inclusive teaching, teachers will be faced (in the future) with the challenge of teaching and promoting collaboration skills in the best possible way for all learners, regardless of their individual learning needs. This is the reason for a third research question (RQ3):

- RQ 3: To what extent can the practical and theoretical perspectives of designing an SG in financial literacy be intertwined to foster and assess CPS among learners?

The research questions are answered subsequently.

3.3 Designing a Serious Game in the Field of Financial Literacy

3.3.1 Design Principles from Teaching Practitioners

To answer the RQ1, which principles guide practitioners of basic education/literacy in designing learning settings in financial literacy, a document analysis (Lamnek & Krell, 2016; Rädiker & Kuckartz, 2018) was conducted. Here, publications available on the project website are used as documents. The analysis includes 35 German-language publications in journals, edited volumes, or monographs of the CurVe II project team. Thus, a broad spectrum of dissemination can be considered. The period covers the years 2016–2020; the number of published papers totales 2016 (10), 2017 (5), 2018 (5), 2019 (8), and 2020 (7). The documents are evaluated using content analysis (Mayring, 2015). To answer the research question, the recommendations were keyworded and categorized into eight principles in a first step of analysis (e.g., Deutsches Institut für Erwachsenenbildung [German Institute for Adult Education], 2019). In a final deductive analysis, all recommendations of the inductive categorization could be assigned to this scheme. The eight identified principles are presented in Table 3.2.

The identified design principles help teaching practitioners as well as learners. The design principles go back to the teaching–learning theory instructional approach of anchored instruction (Brown et al., 1989; Cognition and Technology Group at Vanderbilt [CTGV], 1997; The Cognition and Technology Group at Vanderbilt

Table 3.2 Identified design principles from practitioners in the field of financial literacy

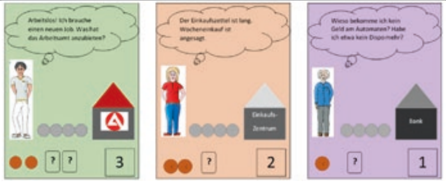
Design pattern	Description
Practical orientation	Materials should be usable in different settings by teachers with different teaching experiences.
Modularity	Materials should consist out of small and flexible units, which addresses the need, life circumstances and competences of low literate adults.
Openness and flexibility	Materials should be modifiable and supplemental and flexible regarding the needed time and different units.
Target group-spreading	Materials should be designed for different and heterogeneous target groups.
Learner orientation	Materials should be authentic and designed along realistic experiences, competencies, interests, and needs of low-literate adults.
Competence orientation	Materials should be built on a systematic competence model, developed along everyday requirements in different degrees of difficulties, and promote competence to act.
Connectivity and sustainability	Materials should be integrable into existing curricular/concepts in a different course.
Testing and trial	Materials should be theory-driven, tested by users (teaching practitioners and learners).

[CTGV], 1990). The approach emphasizes instructional ways to avoid inert knowledge in a particular way. To this end, learners are provided with narrative anchors that can be used to establish an everyday or real-life connection to specific learning content. The anchors make it easier for the learners to identify with the learning content, to experience it as relevant, and to transfer the acquired knowledge later in order to be able to recognize and solve further, similarly structured requirements on their own.

3.3.2 Game-Based Learning Design Elements Applied to "Curve"

To answer the RQ2, which design elements of gbl are implemented in the SG *Curve*, the designed SG is presented along with learning theories in Table 3.3. Here, the design elements are considered to complement each other to add pedagogical value.

Table 3.3 Applied gbl design elements, which foster learning in an SG in the field of financial literacy

Design elements to foster learning within an SG	Application in the SG *Curve*	Graphic implementation
Creating a storyline	The game takes fictional places at "Maisenbohn", where a fictional family "Mueller" life. The learners help one family member of the *Muellers* through different everyday tasks within financial topics, e.g., buying groceries at the supermarket	 Learners help a family member of the Mueller's (figure) to finish a financial task (in thoughts) at a specific place in Maisenbohn (house). During their walk through the village (grey dots) they will take part in financial quizzes. In these quizzes learners have to earn a specific amount of coins (orange dots) and get a specific amount of help at fields with question marks (?). The difficulty of the order for the learner/task of the family member varies between easy, middle, and hard (number in the square)
Setting goals	The game's final goal is to help one family member to get their task done. Therefore, the learners get an order, on which the task is described. Within the fulfillment of the specific order, learners have to solve calculating exercise or take part in a quiz about financial topics	
Providing a risk-reduced environment (Bransford et al., 2000)	The consequences of the taken decision within the game stay in the fictional village *Maisenbohn* and have no real-life consequences. The learners can improve their action with a next order or specific task of a family member	
Having a reward system (Skinner, 1953)	Learners will take part in quizzes while they guide their family members to fulfill the task a specific place (e.g. employment office). For a correct solution, they got coins, which are needed to complete an order	
Introducing knowledge when needed or relevant (Bransford et al., 2000)	The family member/learner is hiding to a specific building, where he can finish his task. During their walk, they get domain-relevant tips, e.g., at the public library or an advisory office	
Providing "scaffolding" (Vygotsky, 1978), or supports a student needs to learn something	The game provides hints in form of tips and there will be a video-based glossary	

(continued)

Table 3.3 (continued)

Design elements to foster learning within an SG	Application in the SG *Curve*	Graphic implementation
Employing "metacognition" (Bransford et al., 2000)	The game gives learners the ability to take on multiple roles. Family Mueller consists of eight different personas	 Family Mueller consists of eight stereotypic persons with different financial problems (in brackets) and a family dog. There is the mum Marie (e.g., retirement planning, cessation of alimony), her second husband Michael (e.g., buying a car) and their daughter Mona and her first son Max (e.g., opening a bank account, first payroll) from her first husband Thomas (e.g., becoming unemployed) and her parents Matilde (e.g., retirement) and Manfred (e.g., debts). Mustafa is a friend of Max and needs financial help as well (e.g., liability insurance, electricity billing, cell phone tariffs)
Inducing "flow" (Csikszentmihalyi, 1990), or a state of total engagement	The fictional family "Mueller" helps the learners to identify with the authentic problems. On the one side, learners are motivated to solve the problem for the family member and on the other side are keen to get more finical educated for their own real lives	
Providing "contrasting cases" (Bransford et al., 2000)	The order, which the learners have to fulfill for their family member to solve a task, is designed along with different sub-competence domains and differs in the degree of difficulty	

The SG *Curve* is supplemented by events that make it more difficult or easier to fulfill the game task. Events deal with positive aspects (e.g., winning a competition, selling clothes that have been sorted-out), negative aspects (e.g., additional payment of service charges, parking ticket for parking in a no-parking zone), or social aspects (e.g., calculating vacation costs, financing a bike wish). Overall, events provide game tension and can be solved individually or collaboratively

3.3.3 Linking Practitioners' Principles and Theory-Driven Game Design Elements to Foster Collaborative Problem-Solving

To answer RQ3, to what extent can the practical and theoretical perspectives of designing an SG in financial literacy be intertwined to foster and assess CPS among learners, it is first outlined why CPS is a new requirement in the twenty-first century. Due to changing market and work situations, new collaboration requirements are emerging overall. Ongoing digitization is changing the requirements for human–human and human–machine interaction. This also affects the less literates. Compared to individual work, collaboration offers advantages in terms of (1) more effective use of work; (2) a greater scope of knowledge, perspectives, and experience; and (3) more creativity based on the ideas of the group members (OECD, 2017). Collaboration does not achieve better results per se; what matters is the effectiveness of the collaboration. CPS is a type of collaboration that, in the educational context, refers to both the cognitive and the social dimensions of interaction (Griffin et al., 2015). The SG aims to foster their collaboration skills (social component of CPS) and their learning progress in financial literacy (cognitive component of CPS).

Barkley et al. (2014) briefly summarize theoretical background and scientific findings for collaborative learning in digital learning environments. They conclude that, like on-site learning, it is based on theoretical foundations of learner-centered teaching research and contributes to social constructivist learning research. Learners actively construct their knowledge and link it to previous knowledge and experience. Learners in digital learning environments acquire digital skills, such as the assessment of resources available online or effective online communication. It is believed that training enhances this effect and that effective communication is essential in collaborative processes. Furthermore, a digital learning environment with structure-giving elements can support learning novices until they can become active on their own. Scaffolding is important in digital learning environments from the perspective of teachers as it is the case with collaborative learning (Major, 2010, 2015). Digital learning environments offer numerous possibilities to collect and create knowledge (Barkley et al., 2014; Hillebrand, 1994; Reither & Vipond, 1989). Higher performing learners are more likely to benefit, while lower performing learners need support (Kirschner et al., 2006). This typical aptitude–treatment interaction (ATI) shows that there is no one optimal teaching method for all. This ATI is contrasted with the finding that weaker learners benefit from performance heterogeneous groups (e.g., for the field of mathematics see Fuchs et al. (1996)). For average learners, performance-homogeneous groups are more effective, while group composition has no effect on the best performing learners. The need for support and the individual performance in collaboration are therefore related.

The intertwining of practice and research perspectives thus takes place through the fostering of CPS. While the practice perspective mainly takes into account design principles that aim at the heterogeneity of the literacy/basic education setting, the gbl design elements bring constructivist learning theories into play.

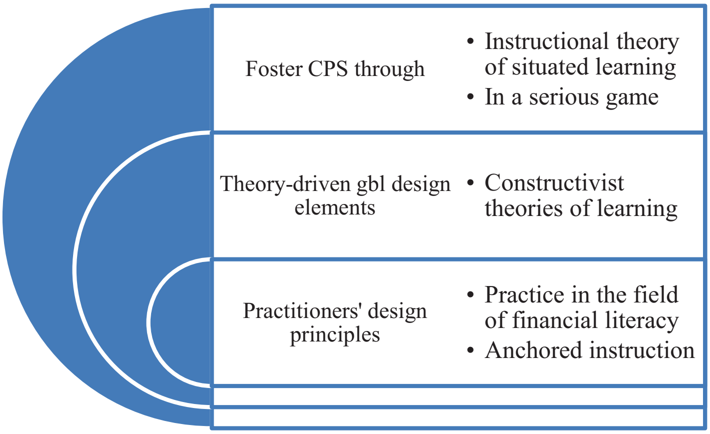


Fig. 3.1 Linking practitioners' principles along the anchored instruction approach and constructivist game design elements to foster CPS in situated learning settings within an SG

Figure 3.1 illustrates the intertwining of perspectives.

The fostering of CPS is linked to an instructional learning setting, the SG, which can be theoretically contextualized through the situated cognition approach: The interventions that address the social and the cognitive components of CPS and are situated in teaching-learning theory. From a constructivist or gbl research perspective, the central assumption is that knowledge is constructed by learners (Becker, 2017a; Webb et al., 1995). The design is based on the theory of situated cognition, in which anchored instruction can also be placed. Learning (and instruction) in this tradition are understood as active, constructive processes in a particular context of action. Knowledge emerges from the interaction between learners and situations under the following premises (Law & Wong, 1996; Resnick, 1991): thought and action can only be understood in contexts, learning is always situated, and knowledge is actively constructed by the perceiving subject, the learner, and constitutes shared knowledge. In the new moderately constructive instructional approach of situated learning, the aspect of situatedness and social interaction is combined with the results of empirical cognitive research. Knowledge acquisition in situated learning can be described based on process characteristics as active, self-directed, constructive, situational, and social. For this purpose, complex teaching-learning arrangements (Achtenhagen, 2002; Winther, 2006) have to be designed. The central principle of the learning theory conception is that learning can take place along narrative and new situations that are close to life or the professional field. This principle combines the principles of practice with those of gbl.

The practical implementation of the intervention should take place in a trialogue. The extension of a human-agent dialogue by another agent to a trialogue (conversational trialogues) improves learning and assessment (Graesser et al., 2017). Multiple agents have been used in various learning environments (including Betty's Brain (Biswas, 2010), iSTART (Jackson & McNamara, 2013), or Operation ARIES!

(Forsyth et al., 2013; Halpern et al., 2012), in various assessments (including trialogues in Zapata-Rivera et al., 2015, tetralogues with two agents and two humans Liu et al., 2016). The scientific literature focuses on the different configurations of trialogues to understand how trialogues can be used productively for learners, topics, deeper learning, and assessments (Cai et al., 2014; von Davier et al., 2017; Zapata-Rivera et al., 2015). As trialogue design criteria, Graesser et al. (2017) elaborate exemplary criteria for assessing CPS. Application in learning and assessment environments varies. The AutoTutor that was used in the Center for the Study of Adult Literacy helps over 16-year-olds to improve their reading skills (Graesser et al., 2015). In the assessment development, in addition to low literacy, learners' self-concept is taken into consideration by enhancing motivation and self-esteem through two design criteria. The design criteria are presented in Table 3.4 and adapted to the SG *Curve*.

Hence, the proposal of fostering CPS is equally connectable to current assessments of CPS. Currently developed assessments measure collaboration by performance in cooperative games and simulations. Assessments are implemented in interactive two-person games or simulations (Griffin, 2017; Hao et al., 2017), in

Table 3.4 Design elements to assess and foster cognitive and social component of CPS in an SG

Design element to foster CPS	Applied to the SG *Curve*	Fostering CPS
Two agents talk with each other and they will ask a yes-/no-question to the learner	Icebreaker questions for learners with little prior knowledge can be realized through additional video sequences. The video can visualize a discussion about the situation of the financial task from a family member of the Mueller's with a nonplaying character (e.g., an uncle). The financial problem is the order that the learner has to fulfill successfully. The video can end with a yes-/no-questionnaire, which will be scored automatically. The questionnaire addresses the understanding of the problem and integrate at the same time design principles from the teaching practice and from the gbl in a form that the learning goals derive from the competence model, the storyline fits to family Mueller and a real-life problem is offered to the learners, which have to be solved during the game	Foster cognitive component of CPS • Task regulation • Knowledge building
A playful competition between peer-agent and expert-agent motivates the learner as a viewer	The game integrates different events (negative, positive, social). When a player enters a specific field on the game board, he has to pull an event card. The social events cards could offer an additional video sequence (via QR-code), where non-playing characters (e.g., an aunt of family Mueller) addresses social elements like participation (e.g., the aunt presents a part of the solution and asks the learner to complete the task), perspective taking (e.g., the aunt tells different opinions from her friends and ask the learner to collect different ideas from their group) or social regulation (e.g., the aunt shows her strengths and weaknesses and ask the learner to recognize his strengths and weaknesses)	Foster social component of CPS • Participation • Perspective taking • Social regulation

multi-player games (Zhu & Bergner, 2017), or in problem-solving contexts in which collaboration is carried out with a human agent (Graesser et al., 2017). Collaboration skills are also measured in automated tutoring systems in which dialog data (Graesser et al., 2017; Griffin, 2017; Olsen et al., 2017) or eye-tracking data (Olsen et al., 2017) are evaluated.

3.4 Impact of Serious Games in Financial Literacy

Financial literacy teaches basic knowledge of money and payment transactions to secure one's own existence and to cope with everyday monetary issues, which are becoming increasingly complex (Aprea et al., 2012; Mania & Tröster, 2014). To enable teachers to professionalize financial literacy and establish it as a component of literacy and basic education, this research highlights the importance of SG. SG is an instructional instrument with which the low-literate persons who cannot go through typical learning processes can be integrated. The SG Curve is an educational innovation in the field of financial literacy. On the one hand, the cognitive needs of financial literacy and, on the other hand, the learning-promoting potential of gbl (cognitive + social dimension) are combined to enable participatory involvement (social dimension) in society. The analysis of the development of learning settings shows that practitioners are guided by eight principles, and theoretical gbl criteria can be applied to the SG Curve. The practical and theoretical results have been developed along the design-based research (DBR; Reeves, 2006) approach. This is primarily focused on generating theories to solve authentic problems. The findings show that practitioners are good instructional designers. Learning materials, which are designed with instructional theories, support the teaching-learning processes in basic education courses. Thus, the DBR approach is an appropriate and adequate research paradigm when it comes to developing inclusive SG. As scientists within DBR take the initiative to trigger new design processes, this paper proposes that inclusive SG to be extended to incorporate CPS. Since the SG is inclusive and developed along gbl design elements, the two components of CPS are proposed for fostering. As a result, an agent-based trialogue is proposed that embeds cognitive and social components of CPS into the game story via additional personas.

References

Abraham, E., & Linde, A. (2018). Alphabetisierung/Grundbildung als Aufgabengebiet der Erwachsenenbildung. In R. Tippelt & A. V. Hippel (Eds.), *Handbuch Erwachsenenbildung/Weiterbildung* (sixth ed., pp. 1297–1320). Springer VS.

Achtenhagen, F. (2002). Reality and complex teaching-learning environments. In K. Beck (Ed.), *Teaching-learning processes in vocational education* (pp. 197–211). Lang.

Andrews, J., Kerr, D., Mislevy, R., von Davier, A., Hao, J., & Liu, L. (2017). Modeling collaborative interaction patterns in a simulation-based task. *Journal of Educational Measurement, 54*(1), 54–69. https://doi.org/10.1111/jedm.12132

Aprea, C., Arn, C., Boldrini, E., Cattaneo, A., Motta, E., & Sroka, A. (2012). Digitale Technologien als Tools zur Förderung der Konnektivität des Lernens in Schule und Betrieb. In U. Faßhauer, B. Fürstenau, & E. Wuttke (Eds.), *Schriftenreihe der Sektion Berufs- und Wirtschaftspädagogik der Deutschen Gesellschaft für Erziehungswissenschaft (DGfE)* (*Berufs- und wirtschaftspädagogische Analysen - aktuelle Forschungen zur beruflichen Bildung*) (pp. 61–73). Barbara Budrich.

Barkley, E., Major, C., & Cross, P. (2014). *Collaborative learning techniques: A handbook for college faculty* (second ed.). Jossey-Bass.

Becker, K. (2017a). Digital game pedagogy: Teaching with games. In K. Becker (Ed.), *Advances in game-based learning. Choosing and using digital games in the classroom: A practical guide* (pp. 63–97). Springer International Publishing. Imprint: Springer.

Becker, K. (2017b). Digital game-based learning: Learning with games. In K. Becker (Ed.), *Advances in game-based learning. Choosing and using digital games in the classroom: A practical guide* (pp. 25–61). Springer International Publishing.; Imprint: Springer. https://doi.org/10.1007/978-3-319-12223-6_2

Biswas, G. (2010). Measuring self-regulated learning skills through social interactions in a teachable agent environment. *Research and practice in technology-enhanced learning (RPTEL), 5*, 123–152.

Blötz, U. (2015). *Berichte zur beruflichen Bildung. Planspiele und Serious Games in der beruflichen Bildung: Auswahl, Konzepte, Lernarrangements, Erfahrungen - aktueller Katalog für Planspiele und Serious Games 2015 (5., überarbeitete Auflage)*. BIBB Bundesinstitut für Berufsbildung; W. Bertelsmann Verlag GmbH & Co. KG.

Bonna, F. (2015). Berufliche Zukunftsvorstellungen Langzeitarbeitsloser. In A. Grotlüschen & D. Zimper (Eds.), *Literalitäts- und Grundlagenforschung* (pp. 301–317). Waxmann.

Bransford, J., Brown, A., & Cocking, R. (2000). *How people learn*. National Academy Press.

Brown, J., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32–42.

Bruner, J. (1961). The act of discovery. *Harvard Educational Review, 31*, 21–32.

Bundesministerium für Bildung und Forschung (2015, September, Dekade für Alphabetisierung ausgerufen: Bund und Länder wollen in den nächsten zehn Jahren die Lese- und Schreibfähigkeiten von Erwachsenen deutlich verbessern. Retrieved from https://www.bmbf.de/de/dekade-fuer-alphabetisierung-ausgerufen-1194.html

Cai, Z., Feng, S., Baer, W., & Graesser, A. (2014). Instructional strategies in trialog-based intelligent tutoring systems. In R. Sottilare, A. Graesser, X. Hu, & B. Goldberg (Eds.), *Design recommendations for intelligent tutoring systems: Adaptive instructional strategies* (Vol. 2, pp. 225–235). Army Research Laboratory.

Castell, S. de, & Jenson, J. (2003). Serious play. Journal of Curriculum Studies, 35(6), 649–665. Retrieved from http://files.eric.ed.gov/fulltext/EJ1073819.pdf

Cognition and Technology Group at Vanderbilt. (1997). *The Jaspers project: Lessons in curriculum, instruction, assessment, and professional development*. Erlbaum.

Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience*. Harper & Row.

Davies, A., Fidler, D., & Gorbis, M. (2011). Future work skills. Palo Alto. Retrieved from Institute for the Future for the University of Phoenix Research Institute website: http://www.iftf.org/uploads/media/SR1382A_UPRI_future_work_skills_sm.pdf

Deutsches Institut für Erwachsenenbildung (2019). Curriculum Finanzielle Grundbildung. Retrieved from https://www.die-bonn.de/curve/content/PDF/Curriculum_Finanzielle_Grundbildung_zur%20webansicht.pdf

Driscoll, M. (2005). *Psychology of learning for instruction (3rd)*. Pearson.

Engartner, T. (2016). Ökonomische Grundbildung. In C. Löffler & J. Korfkamp (Eds.), *UTB: Vol. 8683. Handbuch zur Alphabetisierung und Grundbildung Erwachsener* (pp. 436–445). Münster, New York.

Fiore, S. M., Graesser, A., Greiff, S., Griffin, P., Gong, B., Kyllonen, P., … Davier, A. von (2017). *Collaborative problem solving: Considerations for the national assessment of educational progress*: National Center for education statistics; Alexandria VA. Retrieved from http://158.64.76.181/handle/10993/31897

Forsyth, C., Graesser, A., Pavlik, P., Cai, Z., Butler, H., Halpern, D., & Millis, K. (2013). Operation ARIES!: Methods, mystery, and mixed models: Discourse features predict affect in a serious game. *Journal of Educational Data Mining, 5*(1), 147–189. Retrieved from https://eric.ed.gov/?id=EJ1115374

Fuchs, L. S., Fuchs, D., Karns, K., Hamlett, C. L., Dutka, S., & Katzaroff, M. (1996). The relation between student ability and the quality and effectiveness of explanations. *American Educational Research Journal, 33*(3), 631–664.

Gee, J. (2003). *What videogames have to teach us about learning and literacy*. Palgrave Macmillan.

Gee, J. (2007). *Good videogames + good learning*. Peter Lang.

Grabe, M., & Grabe, C. (2007). *Integration technology for meaningful learning*. Houghton Mifflin.

Graesser, A., Baer, W., Feng, S., Walker, B., Clewley, D., Hayes, D., & Greenberg, D. (2015). Emotions in adaptive computer technologies for adults improving learning. In S. Tettegah & M. Gartmeier (Eds.), *Emotions, technology, design and learning: Communication, for with and through digital media* (pp. 1–35). Elsevier.

Graesser, A., Dowell, N., & Clewley, D. (2017). Assessing collaborative problem solving through conversational agents. In A. von Davier, M. Zhu, & P. Kyllonen (Eds.), *Methodology of educational measurement and assessment. Innovative assessment of collaboration* (pp. 65–80). Springer International Publishing.

Graesser, A., Fiore, S., Greiff, S., Andrews-Todd, J., Foltz, P., & Hesse, F. (2018). Advancing the science of collaborative problem solving. *Psychological Science in the Public Interest: A Journal of the American Psychological Society, 19*(2), 59–92. https://doi.org/10.1177/1529100618808244

Griffin, P. (2017). Assessing and teaching 21st century skills: Collaborative problem as a case study. In A. von Davier, M. Zhu, & P. Kyllonen (Eds.), *Methodology of educational measurement and assessment. Innovative assessment of collaboration* (pp. 113–134). Springer International Publishing.

Griffin, P., Care, E., & Harding, S.-M. (2015). Task characteristics and calibration. In P. Griffin & E. Care (Eds.), *Educational assessment in an information age. Assessment and teaching of 21st century skills: Methods and approach* (pp. 133–182). Springer Netherlands.

Grotlüschen, A., Buddeberg, K., Dutz, G., Heilmann, L., & Stammer, C. (2019). LEO 2018 - Leben mit geringer Literalität: Pressebroschüre. Hamburg. Retrieved from http://blogs.epb.uni-hamburg.de/leo

Halpern, D., Millis, K., Graesser, A., Butler, H., Forsyth, C., & Cai, Z. (2012). Operation ARA: A computerized learning game that teaches critical thinking and scientific reasoning. *Thinking Skills and Creativity, 7*(2), 93–100. https://doi.org/10.1016/j.tsc.2012.03.006

Hao, J., Liu, L., Davier, A. von, & Kyllonen, P. (2017). Initial steps towards a standardized assessment for collaborative problem solving (CPS): Practical challenges and strategies. In A. von Davier, M. Zhu, & P. Kyllonen (Eds.), *Methodology of educational measurement and assessment. Innovative assessment of collaboration* (pp. 135–156). : Springer International Publishing.

Hillebrand, R. (1994). Control and cohesion: Collaborative learning and writing. *The English Journal, 83*(1), 71. https://doi.org/10.2307/820964

Huck, G., & Schäfer, U. (1991). Funktionaler Analphabetismus in der Bundesrepublik Deutschland: Sachstandsbericht.

Jackson, G. T., & McNamara, D. S. (2013). Motivation and performance in a game-based intelligent tutoring system. *Journal of Educational Psychology, 105*(4), 1036–1049. https://doi.org/10.1037/a0032580

Jackson Kellinger, J. (Ed.). (2017). *Advances in game-based learning. A guide to designing curricular games: How to "game" the system*. Springer International Publishing.

Kastner, M. (2016). *Alphabetisierung und Basisbildung für Erwachsene* (Dossier erwachsenenbildung.at).

Kirschner, P., Sweller, J., & Clark, R. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 41*(2), 75–86. https://doi.org/10.1207/s15326985ep4102_1

Lamnek, S., & Krell, C. (2016). *Qualitative Sozialforschung. 6. Vol*. Weinheim.

Law, L.-C., & Wong, K.-M. P. (1996). Expertise und instructional design. In H. Gruber & A. Ziegler (Eds.), *Expertiseforschung: Theoretische und methodische Grundlagen* (pp. 115–147). VS Verlag für Sozialwissenschaften. https://doi.org/10.1007/978-3-663-12111-4_7

Liu, L., Hao, J., Davier, A. von, Kyllonen, P., & Zapata-Rivera, J.-D. (2016). A tough nut to crack. In M. Mosharraf, S. Ferrara, & Y. Rosen (Eds.), Advances in higher education and professional development. Handbook of research on technology tools for real-world skill development (pp. 344–359). Hershey, PA: . https://doi.org/10.4018/978-1-4666-9441-5.ch013.

Löffler, C., & Korfkamp, J. (Eds.). (2016). *UTB: Vol. 8683. Handbuch zur Alphabetisierung und Grundbildung Erwachsener*. Waxmann.

Major, C. (2010). Do virtual professors dream of electric students? University faculty experiences with online distance education. *Teachers College Record, 112*(8), 2154–2208.

Major, C. (2015). *Teaching online and instructional change: A guide to theory, research, and practice*. John Hopkins University Press.

Mania, E., & Thöne-Geyer, B. (2019). Die Auswahl von Lerninhalten in der Alphabetisierung und Grundbildung: Spannungsfelder an der Schnittstelle von Programmplanung und Angebotsentwicklung. In *Hessischer Volkshochschulverband e.V.* (*Hessische Blätter für Volksbildung 02/2019: Programmplanung - Programmforschung*) (Vol. 69, pp. 151–158). wbv Media.

Mania, E., & Tröster, M. (2014). Finanzielle Grundbildung - Ein Kompetenzmodell entsteht. In *Hessischer Volkshochschulverband e.V.* (*Hessische Blätter für Volksbildung 02/2014: Grundbildung*) (Vol. 60, pp. 136–145). wbv Media.

Mania, E., & Tröster, M. (2015). Finanzielle Grundbildung: Konzepte, Förderdiagnostik und Angebote. In A. Grotlüschen & D. Zimper (Eds.), *Literalitäts- und Grundlagenforschung* (pp. 45–59). Waxmann.

Mania, E., & Tröster, M. (2016). Lernangebote im Bereich Finanzielle Grundbildung. *DIE-Zeitschrift für Erwachsenenbildung, 23*(I), 41–44.

Mania, E., & Tröster, M. (2018). Finanzen, Politik und Gesundheit als notwendige Inhalte der Grund-/Basisbildung. Stand, Bedarfe und Herausforderungen. *Magazin Erwachsenenbildung.at, 12*(33), 1–10.

Marzano, R. (2010). Using games to enhance student achievement. *Educational Leadership, 67*(5), 71–72.

Mayring, P. (2015). *Qualitative Inhaltsanalyse: Grundlagen und Techniken (12., überarb. Aufl.)*. Beltz.

OECD. (2009). *PIAAC problem solving in technology-rich environments: A conceptual framework*. OECD. https://doi.org/10.1787/19939019

OECD. (2017). *PISA 2015 results (volume V): Collaborative problem solving*. OECD. https://doi.org/10.1787/9789264285521-en

Olsen, J., Aleven, V., & Rummel, N. (2017). Exploring dual eye tracking as a tool to assess collaboration. In A. von Davier, M. Zhu, & P. Kyllonen (Eds.), *Methodology of educational measurement and assessment. Innovative assessment of collaboration* (pp. 157–172). Springer International Publishing.

Prensky, M. (2001). *Digital game-based learning*. McGraw-Hill.

Prensky, M. (2006). *Don't bother me mom - I'm learning!* Paragon House.

Rädiker, S., & Kuckartz, U. (2018). *Analyse qualitativer Daten mit MAXQDA*. Text, Audio und Video.

Reeves, T. (2006). Design research from a technology perspective, 86–109.

Reither, J., & Vipond, D. (1989). Writing as collaboration. *College English, 51*(8), 855. https://doi.org/10.2307/378091

Remmele, B., Seeber, G., Speer, S., & Stoller, F. (2013). Ansprüche an und Grenzen von ökonomischer Grundbildung. In *Ansprüche an und Grenzen von ökonomischer Grundbildung*. wbv Media. https://doi.org/10.3278/6004343w041

Resnick, L. B. (1991). Shared cognition: Thinking as social practice. In L. B. Resnick, J. M. Levine, & S. D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 1–20). American Psychological Association. https://doi.org/10.1037/10096-018

Schrier, K. (2007). Reliving history with "reliving the revolution": Designing augmented reality games to teach the critical thinking of history. In D. Gibson, C. Aldrich, & M. Prensky (Eds.), *Games and simulations in online learning: Research and development frameworks* (pp. 250–269). Information Science Publishing.

Shaffer, D. (2006). *How computer games help children learn*. Palgrave Macmillan.

Skinner, B. (1953). *Science and human behavior*. The Free Press.

Squire, K. (2011). *Video games and learning: Teaching and participatory culture in the digital age*. Teachers College Press.

Sting, S. (2005). Literacy versus Schriftlichkeit. In J. Ecarius & B. Friebertshäuser (Eds.), *Literalität, Bildung und Biographie: Perspektiven erziehungswissenschaftlicher Biographieforschung* (pp. 18–38). Verlag Barbara Budrich.

The Cognition and Technology Group at Vanderbilt. (1990). Anchored instruction and its relationship to situated cognition. *Educational Researcher, 19*(6), 2–10. https://doi.org/10.3102/0013189X019006002

Tröster, M., & Bowien-Jansen, B. (2020). Grundbildung über die Lebensspanne - Ideen für die Angebotsentwicklung. In B. Schmidt-Hertha, E. Haberzeth, & S. Hillmert (Eds.), *Lebenslang lernen können: Gesellschaftliche Transformationen als Herausforderung für Bildung und Weiterbildung* (first ed., pp. 187–201). wbv Media.

Tröster, M., & Schrader, J. (2016). Alphabetisierung, Grundbildung, Literalität: Begriffe, Konzepte, Perspektiven. In C. Löffler & J. Korfkamp (Eds.), *UTB: Vol. 8683. Handbuch zur Alphabetisierung und Grundbildung Erwachsener* (pp. 42–58). Münster, New York.

Van Eck, R. (2007). Building artificially intelligent learning games. In D. Gibson, C. Aldrich, & M. Prensky (Eds.), *Games and simulations in online learning: Research and development frameworks* (pp. 271–307). Information Science Publishing.

von Davier, A., & Halpin, P. (2013). *Collaborative problem solving and the assessment of cognitive skills: Psychometric considerations. Research report no. RR-13-41*. Educational Testing Service.

von Davier, A., Zhu, M., & Kyllonen, P. (Eds.). (2017). *Methodology of educational measurement and assessment. Innovative assessment of collaboration*. Springer International Publishing. https://doi.org/10.1007/978-3-319-33261-1

von Rosenbladt, B., & Lehmann, R. H. (2013). Grade der Schriftbeherrschung und subjektiver Lernerfolg bei Teilnehmenden an Alphabetisierungskursen. *Zeitschrift für Erziehungswissenschaft, 16*(1), 55–77. https://doi.org/10.1007/s11618-013-0342-z

Vygotsky, L. (1978). *Mind in society*. Harvard University Press.

Webb, N., & Palincsar, A. S. (1996). Group processes in the classroom. In D. C. Berliner & R. C. Calfee (Eds.), *Handbook of educational psychology* (pp. 841–873). Macmillan Library Reference USA.

Webb, N., Troper, J., & Fall, R. (1995). Constructive activity and learning in collaborative small groups. *Journal of Educational Psychology, 87*(3), 406–423. https://doi.org/10.1037/0022-0663.87.3.406

Winther, E. (2006). *Motivation in Lernprozessen: Konzepte in der Unterrichtspraxis von Wirtschaftsgymnasien. Wirtschaftswissenschaft*. Deutscher Universitäts-Verlag. https://doi.org/10.1007/978-3-8350-9304-1

Winther, E. (2010). *Kompetenzmessung in der beruflichen Bildung*. W. Bertelsmann Verlag.

Zapata-Rivera, D., Jackson, G., & Katz, I. (2015). Authoring conversation-based assessment scenarios. In R. Sottilare, A. Graesser, X. Hu, & K. Brawner (Eds.), *Design recommendations for intelligent tutoring systems* (Vol. 3, pp. 169–178). Army Research Laboratory.

Zhu, M., & Bergner, Y. (2017). Modeling collaboration with social network models. In A. von Davier, M. Zhu, & P. Kyllonen (Eds.), *Methodology of educational measurement and assessment. Innovative assessment of collaboration* (pp. 303–314). Springer International Publishing.

Chapter 4
Development and Pilot Testing of a Financial Literacy Game for Young Adults: The Happy Life Game

Andrea Maria Pfändler

4.1 Introduction

The effective promotion of financial literacy (or financial competence)[1] has become increasingly important in the international debate over the past two decades. Numerous German and international studies have revealed that young people, in particular, lack financial literacy and practical skills when it comes to handling finance-related issues. They often overestimate their competencies in this domain (FINRA, 2016; Kaminski & Friebel, 2012; Union Investment, 2017). While Fürstenau and Hommel (2019) found that informal learning situations via the internet without sound prior knowledge have no positive effect on financial competence, internationally relevant literature shows that targeted teaching situations can have a positive effect on the financial literacy levels of students (Walstad, 2010, p. 353; Asarta, 2014, p. 49; Cameron, 2014, p. 17; Tang & Peter, 2015, p. 129; Bover et al., 2018; Bruhn et al., 2018; Frisancho, 2018). By contrast, there were only a few studies that found teaching financial literacy had no impact on the students' levels of financial literacy (Mandell & Schmid-Klein, 2009; Peng et al., 2007).

[1] The terms are not used uniformly. Financial literacy, financial capability, and financial education are sometimes used as synonyms, and in other cases one subsumes the other. In this chapter, financial literacy and financial competence are used as synonyms. A competence-oriented view of financial literacy is preferred, and financial knowledge is only a precondition to develop financial competence, which leads to adequate financial decision making and financial behavior.

A. M. Pfändler (✉)
Goethe University of Frankfurt, Frankfurt, Germany

Wilhelm-Merton-Schule, Frankfurt, Germany
e-mail: pfaendler@econ.uni-frankfurt.de

C. Aprea, D. Ifenthaler (eds.), *Game-based Learning Across the Disciplines*, Advances in Game-Based Learning, https://doi.org/10.1007/978-3-030-75142-5_4

In recent years, numerous interventions to promote financial literacy have been put into practice. In a meta-analysis, Kaiser and Menkhoff (2018a), Kaiser & Menkhoff, 2018b) found that such interventions have a far greater effect on financial knowledge than financial behavior. Fernandes (2014) question the long-term learning effect of teaching financial literacy. They discovered that the learning effect of interventions of different duration (24, 18, 12, and 6 h) is the same after 24 months. Lusardi and Mitchell (2014) see the reasons for this in the low quality and motivation of the teachers teaching personal finance. Furthermore, they state that the financial literacy programs are still not tailored well enough to the respective target groups. Other studies show that the positive correlation between financial literacy and good financial decision-making is significantly influenced by other individual factors, such as an increased affinity for numbers (Erner & Oberste, 2016), mathematical competencies (Cole et al., 2015), motivation to deal with personal finances (Bucher-Koenen & Lusardi, 2011), and patience (Hastings & Mitchell, 2011). Therefore, each of these competencies needs to be promoted individually. In particular, it was found that training young people to be more patient and exercise better self-control leads to lasting positive effects (Alan & Ertac, 2018; Lührmann et al., 2018). The increased acquisition of financial experience that comes from having a bank account and a higher income, combined with the socioeconomic status of the family of origin, also have an impact on financial literacy (Förster et al., 2019; Lusardi et al., 2009; Sohn et al., 2012; Zhan et al., 2006).

A further explanation for the lower effectiveness of these financial literacy programs in the long-term could be the lack of applicability and relevance of the material in the period immediately following instruction, which decreases the likelihood of retention (Renkl, 1996). On the one hand, it is assumed that things are more likely to be retained in memory if they are associated with strong emotions (Sembill, 2010). On the other hand, some emotions can be an additional obstacle to rational financial decisions, namely attachment (property, real estate), aversion (fear of loss), ignorance, delusion and confusion, envy and jealousy, and pride (Gonzales & Byron, 2010, p. 55). As a result, adequate handling of these emotional states is necessary and should be trained to allow youth to make meaningful financial decisions—in addition to imparting financial knowledge.

Furthermore, the promotion of financial literacy must be holistic and multidimensional if it is to have a sustainable impact (Smith et al., 2015). According to Hira (2012), such a program should address the required values and attitudes required to make long-term responsible financial decisions and to encourage reflection, yet should be simple and realistic. The inclusion of a game as a part of an intervention could be helpful to overcome the shortcomings of traditional financial literacy programs. Boyle et al. (2016) found positive effects on cognitive, physiological, affective, and social skills of both entertaining computer games and serious games. Moreover, board games are effective teaching tools (Berland & Lee, 2011; Gobet et al., 2004; Shanklin & Ehlen, 2007; Shanklin & Ehlen, 2017; Treher, 2011; Yoon et al., 2014). Games kindle emotions such as curiosity, frustration, and fun (Kim, 2012), and make learning possible through trial and error, failure and success, and through practice, experience, and reflection (Buckley et al., 2016). Since games can be played repeatedly and thus lead to experimentation, initial failure is not final, but rather the first step to success (Lee & Hammer, 2011). This has the potential to increase motivation, which can be seen as a key determinant of learning (Brophy, 2013). These findings could explain the boom of serious games, gamification, and physical and analog learning games in recent years.

For a game to be successful at increasing an individual's financial competence and financial literacy, it has to simulate the financial context in a way similar to how young adults are required to manage their money. Furthermore, its design should be motivating enough so it can be played with pleasure. With this in mind, the board game here presented has been developed based on the following assumptions:

1. The game characters live in an industrialized country and lead an average, middle-class life.
2. The game is based on the comprehensive competencies model for financial literacy (Aprea & Wuttke, 2016).
3. It takes a holistic approach in that not only knowledge is taught but also decision-making competency is promoted.
4. The emotional–motivational facets play a central role.
5. While financial well-being plays an important role, it is not the sole determinant of success as the winner is the happiest player, not the richest in financial terms. This implies that to become the happiest player, you need to make sound and reflected financial decisions.

The research objective presented in this chapter is the development and the pilot testing of a financial literacy board game, which can be used solely or in combination with other tools to foster financial literacy.

This chapter is structured as follows: Section 2 contains the relevant theoretical foundations. After presenting important definitions, the latest research results in the fields of financial literacy (Sect. 4.2.1), happiness research in relation to money (Sect. 4.2.2), and game-based learning (Sect. 4.2.3) will be illustrated. Taking the theoretical foundations into account, the development of the game is described and the methods and results of the pilot testing are presented (Sects. 4.3 and 4.4). Finally, the results are discussed, limitations are specified, and an outlook for future research is presented (Sect. 4.5).

4.2 Theoretical Foundations

4.2.1 Financial Literacy

4.2.1.1 Concept, Underlying Definitions, and Competency Model

In academic literature, there is a wide range of concepts surrounding financial literacy (Davies 2015; Kaminski & Friebel, 2012; Remmele & Seeber, 2012; Schlösser et al., 2011; Retzmann, 2011; Aprea & Leumann, 2016), and there exist several competency models for different target groups and educational contexts.[2] Only the most important concepts, terms, and definitions deemed relevant for this article will be examined here.

Financial literacy is defined by the OECD as "the knowledge and understanding of financial concepts, and the skills, motivations and confidence to apply such knowledge and understanding to make efficient decisions across range of financial contexts, to improve financial well-being of individuals, and to enable participation in economic life" (OECD, 2014, p. 33). It is "a combination of awareness, knowledge, skill, attitude, and behavior necessary to make sound financial decisions and ultimately achieve individual financial well-being" (OECD, 2017, p. 50). Financial literacy can thus be compared with the concept of competence. Based on Weinert's definition of competencies, they "are the cognitive abilities and skills available in or learnable by individuals to solve specific problems, as well as the associated motivational, volitional and social willingness and ability to use problem-solving in variable situations successfully and responsibly" (Weinert, 2001, p. 27).

As financial literacy focusses more on basic education like "money and transactions," "planning and managing finances," or "risk and reward" (OECD, 2017, p. 50), this concept is criticized for referring more to knowledge than the application of this knowledge and for disregarding the relevance of motivation, emotion or attitudes (Rudeloff, 2019, p. 53). In contrast, competence emphasizes motivation, emotion, and attitudes within a holistic approach and refers to more complex issues (Fürstenau & Hommel, 2019, p. 3).

According to Aprea and Wuttke (2016), financial literacy is "the potential that enables a person to effectively plan, execute, and control financial decisions" (p. 402). In their competence-oriented working model of financial decision-making, they have adopted Weinert's definition of competence. The authors argue that intellectual activities (e.g., reasoning and decision-making) depend partially on the person and his /her individual characteristics and partly on his/her individual situation and environment. These activities can be subdivided into a planning phase, an execution phase, and a control phase. As an outcome of this process, the person gains a new mental attitude and motivation by developing knowledge and skills, and the person shows an observable performance (Aprea & Wuttke, 2016, p. 401). By repeating the process, earlier decision processes and their decision outcomes affect subsequent processes and decision outcomes (referred to as a decision product in the model). Accordingly, financial literacy can change a person's financial behavior.

[2] (1) Basic education (Finanzielle Grundbildung) (Mania & Tröster, 2015), (2) financial education (Finanzielle Bildung) (Retzmann & Seeber, 2016), (3) basic education (Ökonomische Grundbildung) (Remmele et al., 2013) and (4) general economic education (Ökonomische Allgemeinbildung) (Seeber et al., 2012).

4.2.1.2 Spheres of Activity and Central Competences

For young adults, the spheres "money and transactions, planning and managing finances, risk and rewards, and financial landscape" (OECD, 2017, p. 50) are relevant for managing their personal finance issues. Manz (2011) specifies the spheres of financial literacy as *earning and spending money, making debts, saving and investing, and dealing with risk*. In an interview-based study, Aprea et al. (2015) broke this down even further and found the following individual cognitive competence facets: *Earning money, planning and dealing with money issues in everyday life, spending money, dealing with debt, and avoiding excessive indebtedness, wealth-creation, and retirement savings, and managing risks with insurance policies*. A similar breakdown of important individual financial decisions in private life and their interdependencies was found in a multidimensional expert survey on the topics relevant to the target group *Young Adults on the Road to Financial Independence*, (Pfändler, 2021): *Earning and spending money* (budgeting including money earned/money spent calculations as well as saving), *taking on debt* (including various forms of debt such as overdraft facilities or real estate financing, interest and repayment, and over-indebtedness), *identifying, taking on and covering risks* (by defining insurance concepts for the most serious life risks and differentiating between relevant and less relevant insurance policies), *saving and investing* (with a focus on investing money in securities, identifying asset classes and investment forms with regard to the relationship between risk and return, interest rates, and changes in value).

In addition to these cognitive competencies, there are non-cognitive competencies with respect to emotion, motivation, and volition relevant for financial decisions (Aprea et al., 2015, p. 13). Manz (2011) emphasizes that *mathematical skills, discipline,* and *intuitive cleverness* are relevant for being successful regarding financial matters. Furthermore, the abilities of *structuring information, self-motivation, openness, decision-making ability, (self-)reflection, information exchange within the peer group, mutual support,* and *patience* are crucial as well (Pfändler, 2021).

4.2.2 Findings of Happiness Research in Relation to Money

Happiness research is helpful in understanding why people spend money. "General happiness is, philosophically, a sense of well-being which in turn has been defined either as a complete and lasting satisfaction with life-as-a-whole, or as a preponderance of positive over negative feelings" (Kamann et al., 1984, p. 91).

Regarding the connection between happiness and money, Jebb et al. (2018) showed that globally, people are the happiest in terms of how they evaluate their life and emotional well-being when they receive a solid middle income. In the sense of Maslow's pyramid of needs, money is associated with security and thus is a basic need (Howell et al., 2013). Financial well-being is important to sustaining current and anticipating desired living standards and financial freedom (Brüggen et al., 2017).

In addition to income and wealth, this also includes work and the quality thereof, work-life balance, health status, education and skills, social connections, civic engagement and governance, environmental quality, personal security, and subjective well-being (OECD, 2011, p. 6). Within the context of the phrase *money can't buy happiness,* the question is often raised whether or not spending on events to gain positive experiences can increase subjective well-being and personal happiness (Pchelin & Howell, 2014).

According to Haidt (2018), the living conditions of a person and his or her voluntary activities add up to a fixed, personally individual target value (p. 130). This implies that each person has an individual level of happiness that is influenced by his or her living conditions and actions.

There is a variety of factors that have a positive or negative effect on the feeling of happiness. In their research, Kumar et al. (2014) have found that anticipating a (positive) experience makes people happier than anticipating a new possession. Furthermore, one of the most important life conditions with regard to the feeling of happiness is the intensity and number of relationships a person maintains (Baumeister & Leary, 1995; Myers, 2000). With regard to living conditions, constant noise can cause stress and reduce the quality of life, and thus the feeling of happiness (Glass & Singer, 1972). Other investigations have shown that people do not get entirely used to a longer commute to work, which is generally associated with stress (Koslowsky et al., 1995). Also, a lack of control and the inability to make decisions for oneself affects people's living conditions negatively (Langer & Rodin, 1976).

What if you use your money to create these situations that have been found to be relevant to happiness? Will that make you happy? One argument in favor of this is that if people can spend money to live in a quieter and more prosperous area closer to their workplace, they reduce stress (Firebaugh & Schroeder, 2009). They could have more leisure time and can build and maintain more positive relationships with other people. According to Haidt (2018), spending money on simple and functional appliances or cars makes people happier than saving and investing the rest of the money in high-priced consumer goods for later consumption (p. 140). Demonstrative consumption can thus be seen as a zero-sum game since the acquisition of increasingly expensive status symbols by one person devalues the possessions of another and vice versa (Haidt, 2018, p. 141). *Keeping up with the Joneses*—the comparison of income within the peer group—can make people unhappy (Harris, 2008).

In contrast, spending money on things that put you in the flow state, i.e., the temporary and subjective feeling of deep happiness combined with high commitment can make people happy (Cziksentmihalyi, 1990). Flow can come from hobbies or enjoyable work, challenging and voluntary physical activities, mental activity in the form of thinking or remembering, philosophical considerations, communication, writing, or diversified work. According to the author, the following prerequisites are necessary to attain this state (Cziksentmihalyi, 1990, p. 304):

1. tasks with a reasonable chance of completion
2. the ability of full concentration on the activity
3. clear goals

4. immediate feedback
5. deep but effortless involvement that removes from awareness the frustrations and worries of everyday life
6. sense of control over our actions
7. no concern for the self
8. alteration of the concept of time, hours can pass in minutes and minutes can feel like hours.

These findings would seem to indicate that spending on hobbies, further education, or other activities should be high to achieve a high balance of happiness. There is also another relationship between happiness and money, e.g., people feel happy when they donate money or spend their money on other people (Dunn et al., 2008). Children have a positive influence on the life satisfaction of parents if the parents do not experience a noticeable deterioration in their material circumstances after the birth of their children, according to Blanchflower and Clark (2019). However, people who get into financial difficulties as a result of having children are less happy than before.

In summary, it can be assumed that money alone does not make people happy, but indirectly money can make people happy as a certain amount necessary to create security, freedom, and pleasant living conditions.

4.2.3 Game-Based Learning

4.2.3.1 State of Research

Game-based learning can be implemented in analog or physical (non-computer simulation games, board simulation games) or digital settings (computer simulation games), i.e., video games or apps (Geuting, 2000). This gamification of learning is defined by Landers (2014) as "the use of game elements, including action language, assessment, conflict/challenge, control, environment, game fiction, human interaction, immersion, and rules/goals, to facilitate learning and related outcomes" (p. 757).

By using special learning games, students can experience motivation and engagement in complex learning situations where problems are solved, decisions are made, and metacognitive thinking is required. This in turn leads to changes in attitudes, behavior, and skills (Ifenthaler et al., 2012; Kim et al., 2009; McClarty et al., 2012; Mishra & Foster, 2007). Furthermore, they receive constant feedback via a score or changes in the game world that enables them to monitor their progress (Prensky, 2001). Game-based learning is understood as the use of games for teaching and learning purposes (Wilson et al., 2013). It focuses on interactive problem-solving to reach a specific objective by using required competencies where the learners receive timely feedback on previously uncertain game results to promote learning (Eseryel et al., 2014). It can be used as an assessment tool as well (Ifenthaler et al., 2012;

Shute & Ke, 2012). In comparison with digital games, analog games, especially board games, are often much simpler and more transparent in terms of game mechanics and the associated links (Zagal et al., 2006). The decision-making and the execution speed of a game move are higher in physically tangible games than in screen-based games or exclusively virtual versions (Esteves et al., 2013).

Several reviews and meta-studies have shown the positive effects of game-based learning. In an evaluation by Boyle et al. (2016), games are seen as a way to change behavior via unintentional learning opportunities. Hamari (2014) has also identified positive effects from gamification. Granic et al. (2014) summarized the cognitive (e.g., attention), motivational (e.g., resilience in the face of failure), emotional (e.g., mood management), and social (e.g., prosocial behavior) benefits. Moreover, Wouters et al. (2013) state that games are more effective in terms of learning and retention than other teaching methods.

The studies also identified shortcomings of learning with games. Boyle et al. (2016) noted that the primary outcome of learning-focused games was knowledge acquisition, whereas entertainment games achieved a broader range of affective behavior change, perceptual and cognitive, and physiological outcomes. According to Wouters et al. (2013), games for learning are not more motivating than conventional instruction methods. They also found that students only learned more using games in comparison to conventional instruction methods when the gameplay was supplemented by other instruction methods, when multiple training sessions were involved, and when players were working in groups. Furthermore, Hamari (2014) claimed that the effects of gamification greatly depend on the context of usage and the individual user. In other words, not all learning games are interesting and motivating for every player. Expectation also played a role. Motivation dropped in particular when learners went into a game expecting a gaming experience offering problem-solving within a complex system, but came to realize they dealing with nicely packaged teaching material that failed to create a context they could identify with and did not succeed at creating a flow state (Granic et al., 2014). In some cases, learners recognizing that they were playing a learning game led to resistance against the game (Remmele, 2017). Finally, based on data on 9343 games taken from BoardGameGeek.com, Koehler et al. (2016) came to the conclusion that learning games were rated as less entertaining than traditional games. They surmised this could be because the design of good education is different from the design of a good game.

That being said, positive learning effects have been achieved through the use of computer games and board games—within the framework of intervention studies—in the domains of pharmacology (Karbownik et al., 2016), marketing (Ross, 2013), information literacy (Greifender & Markey, 2008; Wilson et al., 2017), physics and astronomy (Cardinot & Fairfield, 2019), and in the learning of abstract scientific concepts such as quantum mechanics, relativity and nano-biology (Chiarello & Castellano, 2016).

In the field of financial literacy, too, there are various analog and digital games and intervention studies, e.g., Credit Union Island in the Teen Grid of Second Life

3D[3] (learning objective: budgeting, saving, how to deal with loans and investing in a house) (Elliott, 2009; Liu et al., 2011), The Stock Market Game (learning objective: promoting investment decisions and mathematical knowledge) (Harter & Harter, 2010; Hinojosa et al., 2010), Cashflow 101 (learning objective: training of investment and saving behavior with the aim of living on passive income only) (Sánchez-Macías et al., 2018), Finance Mission Heroes in which financial-eating robots must be actively combated (learning objective: earning, spending and saving money) (Aprea et al., 2018).

Other examples of educational games in the financial sector are W2 Finance ABC from the Schufa education initiative[4] (learning objective: basic financial knowledge), Visa's Financial Soccer and Financial Football[5] (Learning objective: basic financial knowledge), Piggy Bank Game,[6] (Learning objective: earning money), D2D's Celebrity Calamity Game[7] (learning objective: budgeting, avoiding overindebtedness, see Aprea & Schultheis, 2019). But there are no intervention studies in which the educational use of these games has been tested. Regarding the game Isle of Economy[8] (learning objective: general economic competences and financial literacy), the study showed that the learning effects, and especially with regard to motivation, were rather low (Remmele, 2017).

Based on this review, it would appear that a financial literacy game that covers all relevant competencies needed by young adults and does so in an authentic, interesting, and motivating way, does not yet seem to exist. In the following section, this paper will outline the theoretical foundations of a workable concept and competency model of financial literacy, the findings of happiness research in relation to money, and the principles and mechanics of game-based learning, which would be relevant to developing such a game.

4.2.3.2 Principles, Mechanics, and Elements of Game-Based Learning

According to Perotta (2013) and Eseryel et al. (2014), there are several interdependent principles or concepts and mechanisms (or processes) that are important in

[3] *Second Life* (released in 2003) is a virtual 3D world with virtual figures, which was developed by *Linden Lab* for use in various games for people over 16 years. There are no further documents or entries online about the Financial Literacy Game and its further use. In Germany, the platform came into disrepute due to a lack of youth protection (young people worked virtually in brothels and earned Linden Dollars) and criminal activities (child pornography). For more details see https://secondlife.com/

[4] For more details see https://www.schufa.de/ueber-uns/presse/pressemitteilungen/finanz-abc.jsp

[5] For more details see https://www.visa.co.in/dam/VCOM/download/corporate/media/Visa_FinancialSoccer_FactSheet_012915_v8.pdf

[6] For more details see https://mymoneyrain.com/piggybank

[7] For more details see https://www.thesolutionsjournal.com/article/video-games-teach-financial-skills-to-women/

[8] For more details see https://www.teacheconomy.de/planspiele/isle-of-economy/

game-based learning. There is (1) intrinsic motivation (see Ryan & Deci, 2000), which manifests itself through voluntariness and self-determination when playing. When a game awakens a player's intrinsic motivation, learning is accompanied by (2) intense enjoyment, fun, and authenticity, and can lead to flow (see Cziksentmihalyi, 1990). The learning processes should exhibit (3) authenticity. That means that they are concrete, coherent, and goal-oriented in a way that allows the player to experience (4) autonomy and self-control. The passion and interest in the subject matter resulting from this (5) experimental learning lead the learner to become more and more immersed in the subject matter.

Based on self-determination theory, motivation consists of three basic needs: autonomy, competence, and connectedness (see Ryan & Deci, 2000). When these needs are satisfied, intrinsic motivation arises, leading to a qualitatively higher commitment, and thus to learning processes. Experiencing self-efficacy and the belief in achieving the desired results, in turn, leads to higher motivation (Bandura, 1997). According to Cziksentmihalyi (1990), individuals can reach a state of flow, a state characterized by optimal experience, if (1) they believe that they are approaching the envisaged goal, (2) this is signaled to them by feedback, and (3) the achievement of the goal is not associated with uncertainty and the associated challenges correspond to their abilities and skills (Schell, 2012, p. 194). Commitment can be represented by indicators like effort, persistence, and perseverance arises when the motivational factors interest, autonomy, competence, connectedness, and self-efficacy are demanded in the context of a task (Ryan & Deci, 2000).

Given the abovementioned principles, an effective game would implement the following mechanisms (Perotta, 2013; Shute & Ke, 2012, p. 46). Complex decisions must be made based on (1) *clear rules*, and (2) *objectives* of the game need to be *clear and challenging*—but not too challenging (Cziksentmihalyi, 1990)—for the learner. The game should take place in a (3) *fictional setting* or a *compelling background* and should contain (4) *progressive difficulty levels*. (5) *Interaction and control* should exist although there should be a (6) degree of *uncertainty and unpredictability* combined with (7) *immediate and constructive feedback*. Finally, it is important that the players feel a sense of cohesion and belonging through the (8) *shared experience*.

A game basically consists of the elements mechanics, story, aesthetics, and technology (Schell, 2012, p. 93). The mechanics of the game are the processes and rules of the game as explained in the section above. They determine what the game's goal is and how the players can achieve it. The story of the game comprises the sequence and events (actions) during the game, whereas the aesthetics of the game are responsible for the sensory perception of the game. Technology is the medium through which the aesthetics are transported, the mechanics come into play, and the story is told.

It is based on these principles, mechanics, and elements that the development and pilot testing of the *Happy Life Game* will be presented in the following chapter.

4.3 Methodology

4.3.1 Development of the Happy Life Game

4.3.1.1 Requirements for the Specific Game Design

Based on the theoretical foundations, the following requirements can be postulated for a good game design that fosters financial literacy in young adults. (1) The decision-making process of the competency model as well as the concrete competencies and their interdependencies (see Sect. 4.2.1.2) should have a clear practical manifestation in the game. (2) The game principles need to be implemented by adequate mechanics as explained above (see Sect. 4.2.3.2). (3) The game has to be challenging but not too challenging for the target group. (4) In particular, it has to be designed in a manner that allows the target group—the *late Millennials* and the early born of *Generation Z*[9]—to be enthusiastic and excited about playing it (Schell, 2012, p. 167). This could be achieved by stimulating a situation in which the players envision a possible future. (5) Additionally, a credible connection between money and happiness (see Sect. 4.2.2) is key to game authenticity as the target group sees life as "a journey to find their purpose in life, a pursuit of happiness" (Tan et al., 2015, p. 9). In particular, being healthy, both physically and mentally (94%), as well as having a good relationship with one's family (92%) and friends (91%) contributes mostly in their opinion but having enough money to make life comfortable (86%) is very important for them, too (Broadbent et al., 2017, p. 30).

4.3.1.2 Aim of the Game and Game Structure

Happiness and well-being are seen by the target group as reasons for spending money. Happiness is operationalized in the *Happy Life Game* by giving players the goal of accumulating as many happiness points as possible in the course of their play-life. The players can only earn happiness points if they are careful with their finances, especially in their younger years. In other words, by not spending too much at the beginning of the game, their income increases through further rounds, they build up savings and investments and can take out necessary insurance policies early on. This framework balances rewards for good against setbacks for bad financial choices, thus encouraging responsible financial behavior. In addition to the happiness points collected (e.g., for pleasant shared experiences or goods and services that make life easier, see Sect. 4.2.2), earned money and assets are converted into happiness points at the end of the game, as wealth increases financial security and thus the probability of continuing to live happily after retirement. However, you receive fewer happiness points when converting at the end of the game than you

[9] Millennials are those born between the early 1980s and the late 1990s, Generation Z are those born afterwards.

would have earned from happiness-enhancing extra spending during the game. Players are in competition with each other but without the possibility of consciously hindering one another.

4.3.1.3 Story, Aesthetics, and Technology

The story of the game covers the years of life from young adulthood, employment to retirement age. Corresponding decision-making situations with financial consequences are implemented on this path of life. This period of time, the *Path of Life*, is depicted on the game board in different game field colors (see Figs. 4.1 and 4.2): Green for payday, blue for income earned by securities, e.g., stocks and bonds, and rental income, yellow for extra expense fields and cards, orange for property fields and cards, and grey for event fields and cards. Further education (pink) and the birth of a child (delicate pink) lead to both higher spending and higher happiness (by gaining happiness points). Unemployment, which means the player must sit out three rounds, has been designed in alarming red. The technique itself is simple as it consists only of a game board, different cards, game pieces, and 6-sided and 12-sided dice.

Fig. 4.1 Happy Life Game (own illustration)

Fig. 4.2 Game board of the Happy Life Game (own illustration)

4.3.1.4 Game Mechanics

The game board represents the path of life and consists of six connected semicircles (see Fig. 4.2). Each player receives start-up money at the beginning of the game. For the rest of the game, the players are financially autonomous and have to design their earning and spending independently from each other, i.e., plan and make permanent financial decisions. This includes the long-term increase of income through further education, conscious decisions for or against spending money, investing in the capital market or buying real estate, taking out loans, and insurance policies against undesirable life events. Each player has to keep track of these activities on an earning/spending and an asset portfolio sheet. Furthermore, the players are constantly confronted with decisions such as rewards by spending more on education or investing in securities or real estate to generate higher future monetary income; or spending their money in the present time and acquiring immediate happiness points. As the players are not able to foresee future events, they are always being faced with realistic life decisions.

In the *Happy Life Game*, each move consists of financial planning, decision-making, and repeated decisions being reviewed. The players can revise their decisions from move to move. They have to apply their financial knowledge to different situations with the goal of improving their financial competence (see Sect. 4.2.1).

Expensive losses can also come about, and the only way to protect against these is to take out the right insurance policy or to have enough money or/and liquid assets. Stocks, bonds, and real estate investments may increase or decrease in value at the end of each semicircle (when the first player lands on or passes the field *Marktveränderungen,* see Fig. 4.2). Additional costs in the form of mandatory expenses (e.g., car repair, broken smartphone) or optional expenses, which increase the player's happiness (e.g., holidays, candlelight dinner) are incurred when players land on the extra expense field. In addition, players may unexpectedly become unemployed, resulting in a loss of income. Players receive happiness points due to the birth of a child but may also face permanently higher future expenses, which is determined by a throw of the dice after landing on a specific field. The worst-case scenario for players is private bankruptcy, i.e., they no longer have any assets and have exhausted their overdraft to the maximum amount of three months' salary. In this case, the player has to sit out several rounds and loses happiness points. Afterward, the player reenters the game with a balance of zero at the beginning of the next semicircle. At the end of the game, when all players have reached the retirement field, the money and assets they have accumulated are converted into happiness points and added to the happiness points they earned during the game.

In addition to throwing the dice, there are two ways that gameplay is advanced. Firstly, there are real estate, event cards, and extra-expense cards. Secondly, there are chance-based, recurring market changes. The probability of falling asset prices is slightly lower than that of rising prices, which takes into account that over the last 70 years asset prices have, on average, shown positive trend growth (Claessen, 2017).

In addition, a snowball system as per Friese (2010) has been integrated into the game, i.e., early saving and investment, as well as the deferral of rewards all result in income that the player can then invest again (compound interest effect) or spend. Players are usually quite uncertain when making their early decisions about which real estate, bonds, or stocks to invest in. As the values of these investments fluctuate independently later in the game, this can be equated with a large element of chance (implementation of lotteries). The only way to hedge against these risks is to achieve sufficient diversification in terms of portfolio selection (Markowitz, 1952).

4.3.2 *Pilot Testing of the* Happy Life Game

4.3.2.1 Criteria of Game Evaluation

Annetta (2010) and Aprea and Schultheis (2019) provide suitable criteria for evaluating a serious game. According to Annetta (2010), a game requires six central characteristics to enhance motivation and sustained commitment of the player and to fulfill didactic purposes. The first is *identity*, which means that the player quickly identifies with the game and perceives himself as a unique individual in this new environment. It is a prerequisite for achieving complete *immersion* in the game without experiencing real consequences. The *interactivity* of the players, the *increasing complexity*, and the direct feedback by evaluating the actions through *informed teaching* lead to a deeper involvement in the game. The focus of a serious game should be *instructional learning*. On the one hand, this requires the fulfillment of the previous elements, on the other, the content must also be meaningful for the learner and draw on his or her previous knowledge to address long-term memory. In this sense, Annetta (2010) argues from a constructivist's point of view, claiming that to generate new knowledge, serious games must be structured in a way that game experiences can be linked to existing ones. Ideally, the players are not consciously aware of this learning process, resulting in implicit learning.

Aprea and Schultheis (2019) likewise summarize six design principles of game design. They partially overlap with those of Annetta's (2010). Firstly, situatedness *(Situiertheit)*, can be compared to characteristic identity. Furthermore, goal and rule orientation *(Ziel- und Regeloriertierung)* in connection with a transparent goal, an increasing challenge *(zunehmende Herausforderung)* in the course of the game, the easy learnability of the game mechanics *(Erlernbarkeit der Spielmechanismen)*, especially linked to the examination of the game content, social interaction possibilities *(Soziale Interaktionsmöglichkeiten)* of the players as well as direct control *(Kontrolle)* connected with the experience of autonomy and competence are mentioned.

The evaluation of a game is possible during and after playing (Eseryel et al., 2011, p. 164). The assessment during the game refers to the gameplay itself, while the assessment after the game focuses on the impact and the results. Eseryel et al. (2011) differentiate between external and internal assessment. The external assessment is carried out through interviews outside the game process, the internal assessment takes place in the context of the game and—at least in the case of digital games—does not lead to an interruption of the game flow (Eseryel et al., 2011). Dynamic feedback within game-based learning environments is mentioned to be a reliable and valid assessment tool. Ifenthaler et al. (2012) differentiate between game scoring, i.e., the points achieved or the time required, external assessment, e.g., through surveys before, during, and after the game, and embedded assessment of game-based learning, i.e., feedback implemented through clickstreams.

Since the *Happy Life Game* is an analog board game, embedded assessment is hardly possible. For this reason, the pilot study focused on the usability assessment as its main objective. Game scoring has not yet been examined in detail. As a result, the pilot study is largely based on external assessment.

4.3.2.2 Sample

Testing was done with five young adults (18–27 years, target group of the game). This was a sufficiently high number to identify most of the usability problems. It is unlikely that using more testers would lead to better findings as saturation has already occurred (Jacobsen & Meyer, 2019, p. 189; Sarodnick & Brau, 2011, p. 174). The test persons played the game in three rounds. In the first two rounds with one respondent and the interviewer, in the third round, there were three respondents and one interviewer. The interviewer explained the game and played it along at the beginning of each round.

The average age was 26 years (min = 24; max = 27), the sample consisted of two female and three male participants. With regard to the highest educational qualifications attained, one participant possessed an intermediate school leaving certificate (Realschulabschluss), two had the general higher education entrance qualification (Abitur), one had a Bachelor's, and one a Master's degree. Two test persons were doing an apprenticeship while the remainder were students.

4.3.2.3 Usability Testing

The pilot study was conducted in December 2019. The evaluation materials, as well as the procedure, were pilot-tested in advance with two additional test persons belonging to the target group. The methodology proposed of Moreno et al. (2012)—a Serious Game Usability Evaluator (SeGUE)—was chosen for testing as it takes into account the specifics of serious games. It is a structured approach that records and categorizes events and the player's reactions. The trigger for coding an event is the emergence of a problem or the display of a negative or positive reaction. Events are coded using event category definitions provided by Moreno et al. (2012). In addition to the positive, negative, and neutral information, greater detail on the specific form of the emotional reaction is coded, linked in each case to an interface/design area.

The SeGUE categories are further divided into interface and game design. Interface comprises six subcategories with items like content, user interface, and technical errors. Game design includes the subcategories like game flow and functionality. Examples of emotional reactions and states shown by the users could be learning, reflecting, satisfied/excited, pleasantly frustrated, frustrated, confused, annoyed, unable to continue (fatal), nonapplicable, or suggestion/comment. Each of the reactions is assigned a negative, neutral, or positive valence. In this application of SeGUE for the pilot study, the category N/A (non-applicable) was added to cover events that could not be accurately assigned to an existing category.

The Thinking-Aloud method (Ericsson, 1993) was employed to collect data during the game rounds. This method is suitable for detecting usability problems and also provides insights into whether a test person is captivated by the game (Knoll, 2018).

Furthermore, a questionnaire consisting of two parts was used to record the test subjects' perceptions of the factors such as playability and learnability immediately after the game. Since the flow experience is suitable for assessing playability (Procci, 2012), the first 10 items of the first section of the questionnaire formed the 7-step short scale by Rheinberg (2003), which showed reliability of $0.8 < \alpha < 0.9$ in previous tests (Rheinberg & Vollmeyer, 2003). Based on the performed factor analysis, the first section forms the scale *Flow* (items 1–10) which can be additionally divided into two sub-scales *Absorbedness* (items 1,3,6,10) and *Smooth automated progression* (items 2,4,5,7,8,9).

The second section consists of self-developed items with a 7-step Likert scale and items with open answer options which refer to *Concern and Fear* (items 11–12) as well as U*sability, Playability*, and *Learnability* (items 13–22). Items 14–15

(Request and Ability) have been used for the level of requirements and items 16–17 for the players' subjective learning effect (*Learnability*). Items 18–20 concentrated on playability in terms of the concept of *Fun*. With item 21, reasons why the game was not fun, and 22, general suggestions for improvement (usability) were obtained from users. The reliability of the scales was determined with Cronbach's Alpha (αc). For the two scales *Concern* and *Request and Ability* the Spearman-Brown-Coefficient (αs) was additionally determined. In addition, demographic and socio-economic data of the test persons were collected. The participants filled out the questionnaire directly after ending the game.

4.4 Results

Using the SeGUE method, 202 events were identified. Of those, 67 (33.2%) were classified as negative, 62 (30.7%) as positive and 73 (36.1%) as neutral events. Regarding the type, 102 (50.5%) related to the interface and 100 (49.5%) to the design of the game. The negative events were mostly annoyance and confusion with the layout or the user interface, content, and game flow, e.g., when the players had to pay standard expenses and overdraft interest or when they had to sit out several rounds due to unemployment. Among the positive events, the reactions to the game flow stand out, especially satisfaction and excitement such as increases in asset values aftermarket adjustments or extra spending that brought happiness points. The neutral events came mainly from comments on the layout/user interface, content, and functionality. Furthermore, there werwe no technical errors or events that interrupted the game flow. With regard to the negative and neutral events, there were suggestions for improving usability, such as swapping two fields on the game board and removing various small ambiguities in the game instructions. These could be easily addressed. Figure 4.3 (Results of SeGue) gives an overview of the assigned events.

With regard to the questionnaire, the following evaluation results were obtained (Table 4.1).

The results show that the scales *Flow*, including the subscales *Absorbedness* and *Smooth automated progression*, and *Fun* are highly rated—considering values above the mean value of four. Average values were obtained for the scales *Request and Ability* (3.9) and *Learnability* (3.8), whereas the scales *Concern* (2.6) and *Level of difficulty* (2.8) resulted in values below average.

The answers to the open question (item 17) revealed a greater awareness for circumstances that could impact the player's financial situation in real life ("Ich wurde sensibilisiert für Dinge, die im Leben passieren können, und welche Auswirkungen sie auf die eigene finanzielle Situation haben."). The participants also stated that they had learned, which factors can influence financial decisions ("Ich habe gelernt, welche Faktoren bei finanziellen Entscheidungen eine Rolle spielen können."), that it is necessary to take precautions against unexpected negative events ("Man muss echt vorsorgen, falls etwas Unerwartetes eintrifft.") and the

		Interface			Design		N/A	Total	
		Content	Layout/UI	Technical Error	Gameflow	Functionality			
Negative	Annoyed	8	1		11	3		23	67
	Confused	10	23		3	5		41	
	Frustrated		1		2			3	
	Unable to continue							0	
Positive	Pleasantly frustrated	1			5	2		8	62
	Reflecting				8	3		11	
	Satisfied/excited	1	2		14	3		20	
	Learning	4	7		6	6		23	
Neutral	N/A		2		2	1		5	73
	Suggestion/Comment	15	27		9	17		68	
Total		39	63	0	60	40		202	
		102			100		0		

Fig. 4.3 Results of SeGUE

importance of insurance ("Versicherungen sind so wichtig!"). They also became aware of the influences of chance and luck ("Der Einfluss von Zufall und Glück ist heftig.").

Taking into account the answers to item 21, the participants stated that the game simulation led them to think about their own choices in life and they recognized situations relevant to their own during the course of the game ("Man fängt an, sich während des Spielens über seinen eignen Lebensweg Gedanken zu machen und identifiziert sich dabei ein wenig mit dem Spielverlauf."). They also found themselves getting emotionally involved and found the game exciting and also very entertaining, especially when they were successful ("Man wird quasi emotional mitgerissen. In dieser Hinsicht, ist es sehr spannend, aber auch sehr unterhaltsam, wenn man Erfolge vorweisen kann."). They rated the game as something new compared to other board games ("Verglichen mit anderen "typischen" Brettspielen war es etwas Neues.") and found the game fun ("Macht Spaß, besonders das Durchdenken von Alternativen!").

The answers on *Usability* (item 22) pointed ways to make the game even more realistic, e.g., introducing the opportunity to throw the dice in case of unemployment. The participants rated the situation as unrealistic that they would not be able to take any action while unemployed ("Bei Arbeitslosigkeit sollte man zwar keine Einnahmen mehr bekommen, aber dennoch die Möglichkeit haben zu Würfeln. Es ist unrealistisch, dass man bei Arbeitslosigkeit gar keine Handlungsmöglichkeit mehr hat."). One participant criticized the game design ("Ein anderes Design des Spielbretts wäre schöner.") and the layout of the forms used during game ("Die Übersichtlichkeit der Zettel ist verbesserungswürdig.").

Table 4.1 Results of the questionnaire ($n = 202$ assigned events)

Test person	Flow	Absorbed-ness	Smooth automated progression	Concern	Level of difficulty	Request and Ability	Learn-ability	Fun	Graduation degree
	Item 1–10	Item 1, 3, 6, 10	Item 2, 4, 5, 7, 8, 9	Item 11, 12	Item 13	Item 14, 15	Item 16	Item 18–20	
	M	M	M	M	M	M	M	M	
1	4.7	4.75	4.67	4.5	2	3	6	7	Bachelor
2	6.1	5.5	6.5	1	1	4	5	6	Master
3	5.3	5.25	5.33	2	5	4.5	4	6	Abitur
4	6	6.5	5.67	3	2	4.5	1	6.67	Realschule
5	4.8	4.5	5	2.5	4	3.5	3	6	Abitur
Mean	5.38	5.3	5.43	2.6	2.8	3.9	3.8	6.33	
SD	0.58	0.696	0.63	1.16	1.47	0.58	1.72	0.42	
Reliability αc	0.874	0.811	0.843	0.729		0.824		0.90	
αs				0.928		0.866			

4.5 Discussion, Limitations, and Conclusion

In this study, a board game was developed to convey relevant financial literacy competencies to young adults. In particular, the game was designed to promote mathematical and decision-making competencies in accordance with the competency model of Aprea and Wuttke (2016).

In addition, the game design considered the findings of happiness research in its evaluation of choices about how to appropriately spend money. This may appear contradictory to the premise of financial literacy as the supposed pursuit of happiness of the target group could be seen as one driving force behind excessive consumption. Nevertheless, studies have shown that being happy in their lives and being able to look back on a happy life are defining characteristics of the youth cohort in question (Sect. 4.3.1). For this reason, the objective of the game was not to maximize money, but happiness points, which in turn requires responsible use of money.

An important message conveyed by the game rules was that one should not buy too much happiness because that will undermine the financial basis for security and pleasant living conditions and the player's situation will no longer be financially viable. For a person of the target group, it could be important to become aware of these factors as they relate the feeling of happiness, to balance them out, and to learn how this could be achieved through an adequate implementation of financial literacy. A game can make these interrelationships tangible—and thus learnable—which an intervention based purely on financial literacy focused on financial knowledge cannot do.

Although digital serious games are a trend, using a board game to foster financial literacy competencies brings several advantages. Firstly, the interdependencies between the facets of financial literacy are clearer and more transparent. Secondly, a player has more time for reflection between the moves and can observe and discuss the strategies of the other players. Finally, the players have to calculate their money transactions and have to structure their cashflows independently.

The results of the pilot study show that the average test person attained a flow state while playing the game. They had fun and dealt actively with relevant financial literacy objects in a stimulating state of high concentration, absorption, motivation, and commitment. Furthermore, they could name subjective learning effects in retrospect. These facts permit the interpretation that the game is a very good fit for the target group.

Nevertheless, there are some limitations. Although saturation was achieved, the sample was rather small and the participants were well-educated (Abitur, Realschule). Additionally, the game still has to be tested with younger students (18–25 years) and groups having lower levels of education (Hauptschulabschluss; no graduation). The piloting also revealed some opportunities for improvement which will be included in a second edition.

The game strongly reduced the number of investment opportunities within the most diverse asset classes and the most diverse products within these, as well as the most diverse forms of financing. It did the same regarding the abundance of different insurance policies and the different ways of accessing credit in real life. Nor can every eventuality in life be represented. Personal tragedies such as divorce or the death of a partner were ignored in the design.

As the game was designed to increase financial literacy, it would additionally be important to test the game's effectiveness at doing just that. In a further study, the learning effects will be tested by means of an intervention study. Keeping in mind that long-term learning effects strongly decrease over time (see Sect. 4.1), the study will capture financial knowledge and financial behavior at three points in time (before playing the game, shortly after, and a longer period after the intervention). This approach will allow better conclusions on whether the game is suitable for a long-term and sustainable promotion of financial literacy.

References

Alan, S., & Ertac, S. (2018). Fostering patience in the classroom: Results from randomized educational intervention. *Journal of Political Economy, 126*(5), 1865–1911. https://doi.org/10.1086/699007

Annetta, L. (2010). The "I's" have it: A framework for serious educational game design. *Review of General Psychology, 14*(2), 105–112. https://doi.org/10.1037/a0018985

Aprea, C., & Leumann, S. (2016). Financial Literacy aus Sicht von Lehrpersonen an beruflichen Schulen in der Schweiz. *Zeitschrift für ökonomische Bildung Nr, 4*, 36–64.

Aprea, C., & Schultheis, J. (2019). Entwicklung und Validierung eines Schmas zur Evaluation von Serious Games im Kontext von Financial Literacy. In E. Wittmann, D. Frommberger, & U. Weyland (Eds.), *Jahrbuch der berufs- und wirtschaftspädagogischen Forschung 2019* (pp. 91–108). Opladen.

Aprea, C., Schultheis, J., & Stolle, K. (2018). Instructional integration of digital learning games in financial literacy education. In T. L. Cooter (Ed.), *Financial Literacy for Children and Youth* (pp. 69–88). Lang. https://doi.org/10.1787/9789264208094

Aprea, C., & Wuttke, E. (2016). Financial literacy of adolescents and young adults: Setting the course for a competence-oriented assessment instrument. In C. Aprea, E. Wuttke, K. Breuer, N. K. Koh, P. Davie, B. Greimel-Fuhrmann, & L. J. S (Eds.), *International handbook of financial literacy* (pp. 397–414). Springer.

Aprea, C., Wuttke, E., Leumann, S., & Heumann, M. (2015). Kompetenzfacetten von Financial Literacy: Sichtweisen verschiedenerAkteure. In J. Seifried, S. Seeber, & B. Ziegler (Eds.), *Jahrbuch der berufs- und wirtschaftspädagogischen Forschung 2015* (pp. 11–22). Verlag Barbara Budrich.

Asarta, C. J. (2014). The features and effectiveness of the keys to financial success curriculum. *International Review of Economics, 16*, 39–50. https://doi.org/10.1016/j.iree.2014.07.002

Bandura, A. (1997). *Self-efficacy*. W.H. Freeman & Company.

Baumeister, R., & Leary, M. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin, 117*(3), 497–529. https://doi.org/10.1037/0033-2909.117.3.497

Berland, M., & Lee, V. (2011). Collaborative strategic board games as a site for distributed computational thinking. *International Journal of Game-Based Learning, 1*(2), 65–81. https://doi.org/10.4018/ijgbl.2011040105

Blanchflower, D., & Clark, A. (2019). Children, Unhappiness and Family Finances: Evidence from One Million Europeans. *NBER Working Paper No.* w25597. doi: https://doi.org/10.3386/w25597.

Bover, O., Hospido, L., & Villanueva, E. (2018). The impact of high school financial education on financial knowledge and choices: Evidence from a randomized trial in Spain. *IZA Discussion Papers, No. 11265*, 1–40. https://doi.org/10.2139/ssrn.3116054

Boyle, E., Hainey, T., Conolly, T., Gray, G., Earp, J., Ott, M., Lim, T., Ninaus, M., Ribeiro, C., & Pereira, J. (2016). An update to the systematic literature review of empirical evidence of the impacts and outcomes of computer games and serious games. *Computers & Education, 94*, 178–192. https://doi.org/10.1016/j.compedu.2012.03.004

Broadbent, E., Gougoulis, J., Lui, N., Pota, V., & Simons, J. (2017). *What the world's young people think and feel*. Generation Z. Retrieved from https://www.varkeyfoundation.org/media/4487/global-young-people-report-single-pages-new.pdf

Brophy, J. (2013). *Motivating students to learn*. Routledge. https://doi.org/10.4324/9780203858318

Brüggen, E. C., Hogreve, J., Holmlund, M., Kabdayi, S., & Löfgren, M. (2017). Financial Well-being: A conceptualization and research agenda. *Journal of Business Research, 79*, 228–237. https://doi.org/10.1016/j.jbusres.2017.03.013

Bruhn, M., Souza Leao, L. D., Legovini, A., Marchetti, R., & Zia, B. (2018). The Impact of High School Financial Education: Evidence from a Large-scale Evaluation in Brazil, Experimental Evidence from Peru. *IDB Working Papers Series No. IDB-WP-871*, 1–52. doi: https://doi.org/10.1257/app.20150149

Bucher-Koenen, T., & Lusardi, A. (2011). Financial literacy and retirement planning in Germany. *Journal of Pension Economics and Finance, 10*(4), 565–584. https://doi.org/10.1017/S1474747211000485

Buckley, P., Doyle, E., & Doyle, S. (2016). Game on! Students' Perceptions of gamified learning. *Educational Technology & Society, 20*(3), 1–10. https://doi.org/10.1016/j.compedu.2010.09.001

Cameron, M. P. (2014). Factors associated with financial literacy among high school students in New Zealand. *International Review of Economics Education, 16*, 12–21. https://doi.org/10.1016/j.iree.2014.07.006

Cardinot, A., & Fairfield, J. (2019). Game-based learning to engage students with physics and astronomy using a board game. *International Journal of Game-Based Learning, 9*(1), 42–57. https://doi.org/10.4018/IJGBL.2019010104

Chiarello, F., & Castellano, M. (2016). Board games and board game design as learning tools for complex scientific concepts: Some experiences. *International Journal of Game-Based Learning, 6*(2), 1–14. https://doi.org/10.4018/IJGBL.2016040101

Claessen, S. K. (2017). Asset prices and macroeconomic outcomes: a survey. *BIS Working Papers No 676*. doi: https://doi.org/10.2139/ssrn.3079156.

Cole, S., Paulson, A., & Shastry, G. (2015). High school curriculum and financial outcomes: The impact of mandated personal finance and mathematics courses. *The Journal of Human Resources, 51*, 656–698. https://doi.org/10.3368/jhr.51.3.0113-5

Cziksentmihalyi, M. (1990). *Flow: The psychology of optimal experience*. Harper & Row.

Davies, P. (2015). Towards a framework for financial literacy in the context of Democracy, *Journal of Curriculum Studies, 47*(2), 300–316.

Dunn, E., Aknin, L., & Norton, M. (2008). Spending money on others promotes happiness. *Science, 319*, 1687–1688. https://doi.org/10.1037/xge0000082

Elliott, S. (2009). Boosting financial literacy a click at a time. Ohio University Outlook: Retrieved from https://www.ohio.edu/outlook/08-09/February/359.cfm

Ericsson, K. A. (1993). *Protocol analysis: Verbal reports as data*. MIT Press.

Erner, C. G.-M., & Oberste, M. (2016). Financial literacy of high school students: Evidence from Germany. *The Journal of Economic Education, 47*(2), 95–105. https://doi.org/10.1080/00220485.2016.1146102

Eseryel, D., Ifenthaler, D., & Ge, X. (2011). Alternative assessment strategies for complex problem solving in game-based learning environments. In K. P. D. Ifenthaler (Ed.), *Multiple perspectives on problem solving and learning in the digital age* (pp. 159–178). Springer. https://doi.org/10.1007/978-1-4419-7612-3_11

Eseryel, D., Law, V., Ifenthaler, D., Ge, X., & Miller, R. (2014). An investigation of the interrelationships between motivation, engagement, and complex problem solving in game-based learning. *Journal of Educational & Society, 17*(*1*), 42–53. https://doi.org/10.1016/j.learninstruc.2010.08.004

Esteves, A., Hove, E. v., & Oakley, I. (2013). Physical games or digital games? Comparing support for mental projection in tangible and virtual representations of a problem-solving task. Conference: Proceedings of the 7th International Conference on Tangible*,* Embedded and Embodied Interaction. doi:https://doi.org/10.1145/2460625.2460651.

Fernandes, D. L. (2014). Financial literacy, financial education and downstream financial behaviors. *Management Science, 60*(8), 1861–1883. https://doi.org/10.1287/mnsc.2013.1849

FINRA Investor Education Foundation. (2016). Financial Capability in the United States.

Firebaugh, G., & Schroeder, M. (2009). Does your neighbor's income affect your happiness? *AJS, 115*(3), 805–831. https://doi.org/10.1086/603534

Förster, M., Happ, R., & Walstad, W. (2019). Relations between young adults'. *Empirical Research in Vocational Education and Training, 11*(2), 1–21. https://doi.org/10.1186/s40461-019-0077-z

Friese, F. (2010). Schneeballsysteme. In M.-A. Casasola Merkle, C. Conrad, F. Friese, A. Meyer, H. Poehl, & A. Wetter (Eds.), *Spiele entwicklen 2010* (pp. 80–98).

Frisancho, V. (2018). The impact of school-based financial education on High School students and their teachers: Experimental evidence from Peru. *IDB Working Papers series No.* IDB-WP-871, 1–52. doi:https://doi.org/10.18235/0001056.

Fürstenau, B., & Hommel, M. (2019). Developing financial competence about mortgage loans by informal learning using banks' online calculators. *Empirical Research in Vocational Education and Training, 11*, 1–33. https://doi.org/10.1186/s40461-019-0085-z

Geuting, M. (2000). Soziale Simulation und Planspiel in pädagogischer Perspektive. In D. Herz & A. Blätte (Eds.), *Simulation und Planspiel in den Sozialwissenschaften* (pp. 15–61). Lit.

Glass, D., & Singer, J. (1972). Behavioral aftereffects of unpredictable and uncontrollable aversive events: Although subjects were able to adapt to loud noise and other stressors in laboratory experiments, they clearly demonstrated adverse after effects. *American Scientist, 60*(4), 457–465.

Gobet, F., Voogt, A. d., & Retschitski, J. (2004). *Moves in mind: The psychology of board games*. Psychologie Press. https://doi.org/10.4324/9780203503638

Gonzales, M., & Byron, G. (2010). *The mindful investor: How a calm mind can bring your inner peace and financial security*. Wiley.

Granic, I., Lobel, A., & Engels, R. C. (2014). The benefits of playing video game. *American Psychologist, 69*(1), 66–78. https://doi.org/10.1037/a0034857

Greifender, E., & Markey, K. (2008). Designing and testing a web-based board game for teaching information literacy skills and concepts. *Library Hi Tech, 26*(4), 663–681. https://doi.org/10.1108/07378830810920978

Haidt, J. (2018). Die Glückshypothese - was uns wirklich glücklich macht, 6. Auflage. In *Kirchzarten*.

Hamari, J. K. (2014). Does Gamification Work? —A Literature Review of Empirical Studies on Gamification. *Proceedings of the 47th Hawaii International Conference on System Sciences*. doi:https://doi.org/10.1109/HICSS.2014.377.

Harris, M. (2008). Keeping up with the Joneses: A field study of the relationships among. *Journal of Applied Psychology, 93*(3), 665–673. https://doi.org/10.1037/0021-9010.93.3.665

Harter, C., & Harter, J. (2010). Is financial literacy improved by participation in a stock market game. *Journal for economic Educators, 10*(1), 21–32.

Hastings, J., & Mitchell, O. (2011). *How financial literacy and impatience shape retirement wealth.* NBER Working Paper 16740. doi: https://doi.org/10.3386/w16740.

Hinojosa, T., Miller, S., Jung, P., Miezio, K., Carlson-Oehlers, V., & Cohen, B. (2010). The Impact of The Stock Market Game on Financial Literacy and Mathematics Achievement: Result as from a National Randomized Controlled Trial. *Conference Abstract Template* (pp. 1–9). Society for Research on Educational Effectiveness. doi: https://doi.org/10.2307/2291629.

Hira, T. (2012). Promoting sustainable financial behaviour: Implications for education and research. *International Journal of Consumer Studies, 36*, 502–507. https://doi.org/10.1111/j.1470-6431.2012.01115.x

Howell, R. T., Kurai, M., & Tam, L. (2013). Money buys financial security and psychological need satisfaction: Testing need theory in affluence. *Social Indicators Research: An International and Interdisciplinary Journal for Quality-of-Life Measurement, 110*(1), 17–29. https://doi.org/10.1007/s11205-010-9774-5

Ifenthaler, D., Eseryel, D., & Ge, X. (2012). Assessment for game-based learning. In D. Ifenthaler, D. Eseryel, & X. Ge (Eds.), *Assessment in game-based learning. Foundations, innovations, and perspectives*. Springer. https://doi.org/10.1007/978-1-4614-3546-4

Jacobsen, J., & Meyer, L. (2019). *Praxisbuch Usability & UX: Was jeder wissen sollte, der Websites und Apps entwickelt*. Rheinwerk Computing.

Jebb, A., Tay, L., Diener, E., & Oishi, S. (2018). Happiness, income satiation and turning points around the world. *Nature Human Behaviour, 2*, 33–38. https://doi.org/10.1038/s41562-017-0277-0

Kaiser, F.-J., & Kaminski, H. (2012). Methodik des Ökonomieunterrichts - Grundlagen eines handlungsorientierten Lernkonzepts mit Beispielen. Bad Heilbrunn.

Kaiser, T., & Menkhoff, L. (2018a). Does financial education impact financial literacy and financial behavior, and if so, when? *Policy Research Working Paper 8161*.

Kaiser, T., & Menkhoff, L. (2018b). Financial education in schools: A meta-analysis of experimental studies. CESifo Working Paper No. 7395, 1–35.

Kamann, R., Farry, M., & Herbison, P. (1984). The analysis and measurement of happiness as a sense of Well-being. *Social Indicators Research, 15*, 91–115. https://doi.org/10.1007/BF00426282

Kaminski, H., & Friebel, S. (2012). *Arbeitspapier "Finanzielle Allgemeinbildung als Bestandteil der ökonomischen Bildung"*. Institut für Ökonomische Bildung an der Universität Oldenurg.

Karbownik, M., Wiktorowska-Owczarek, A., Kowalczyk, E. K., Mokros, L., & Pietras, T. (2016). Board game versus lecture-based seminar in the teaching of pharmacology of antimicrobial drugs - a randomized controlled trial. *FEMS Microbiology Letters, 363*(*7*), fnw45. https://doi.org/10.1093/femsle/fnw045

Kim, B. (2012). Harnessing the power of game dynamics - why how to, and how not to gamify the library experience. *College & Research Libraries News, 73*(8), 465–469. https://doi.org/10.5860/crln.73.8.8811

Kim, B., Park, H., & Baek, Y. (2009). Not just fun, but serious strategies: Using meta-cognitive strategies in game-based learn-ing. *Computers & Education, 52*(4), 800–810. https://doi.org/10.1016/j.compedu.2008.12.004

Knoll, T. (2018). The think-aloud protocol. In P. M.-B. A. Drachen (Ed.), *Games user research* (pp. S189–S202). University Press. https://doi.org/10.1093/oso/9780198794844.003.0012

Koehler, M. J., Greenhalgh, S. P., & Boltz, L. O. (2016). Here We Are, Now Entertain Us! A Comparison of Educational and Non-Educational Board Games. *Conference Paper*, 567–572.

Koslowsky, M., Kluger, A., & Reich, M. (1995). *The plenum series on stress and coping. Commuting stress: Causes, effects, and methods of coping*. Plenum Press. https://doi.org/10.1007/978-1-4757-9765-7

Kumar, A., Killingsworth, M., & Gilovich, T. (2014). Waiting for merlot: Anticipatory consumption of experiential and material purchases. *Psychological Science Online First*, 1–8. https://doi.org/10.1177/0956797614546556

Landers, R. N. (2014). Developing a theory of gamified learning: Linking serious games and gamification of learning. *Simulations and Games, 45*(6), 752–768. https://doi.org/10.1177/1046878114563660

Langer, E., & Rodin, J. (1976). The effects of choice and enhanced personal responsibility for the aged: A field experiment in an institutional setting. *Journal of Personality and Social Psychology, 34*(2), 191–198. https://doi.org/10.1037/0022-3514.34.2.191

Lee, J., & Hammer, J. (2011). Gamification in education: What, how, why bother? *Academic Exchange Quarterly, 15*(2), 146–155.

Liu, C., Franklin, T., Shelor, R., Ozercan, S., Reuter, J., Ye, E., & Moriarty, S. (2011). A learning game for youth - financial literacy education in the teen grid of second life three-dimensional virtual environment. *American Journal of Business Education, 4*(7), 1–18. https://doi.org/10.19030/ajbe.v4i7.4670

Lührmann, M., Serra-Garcia, M., & Winter, J. (2018). The impact of financial education on Adolescents' intertemporal choices. CESifo Working Paper No. 4925, 1–20.

Lusardi, A., & Mitchell, O. (2014). The economic importance of financial literacy: Theory and evidence. *Journal of Economic Literature, 52*(1), 5–44. https://doi.org/10.1257/jel.52.1.5

Lusardi, A., Mitchell, O., & Vilsa, C. (2009). Financial Literacy Among The Young: Evidence and Implications for Consumer policies. *NBER Working Paper 15352*.

Mandell, L., & Schmid-Klein, L. (2009). The impact of financial literacy education on subsequent financial behavior. *Journal of Financial Counseling and Planning, 20*(1), 15–24.

Mania, E., & Tröster, M. (2015). Kompetenzmodell Finanzielle Grundbildung. Umgang mit Geld als Thema der Basisbildung. *Magazin Erwachsenenbildung.at, 25*, 1–10.

Manz, M. (2011). Financial education: Rolle und internationale Entwicklungen. *Die Volkswirtschaft, 6*, 57–60.

Markowitz, H. (1952). Portfolio selection. *Journal of Finance, 7*, 77–91.

McClarty, K., Orr, A., Frey, P., Dolan, R., Vassileva, V., & McVay, A. (2012). A literature review of gaming in education (research report). *Gaming in Education*.

Mishra, P., & Foster, A. (2007). The claims of games: A comprehensive review and directions for future research. In R. Carlsen, K. McFerrin, J. Price, R. Weber, & D. Willis (Eds.), *Proceeding of the 18th International Conference of the Society for Information Technology & Teacher Education*. Association for the Advancement of Computing in Education (AACE).

Moreno, P. J., Hsieh, Y., & Lester, W. (2012). Usability testing for serious games: Making informed design decisions with user data. *Advances in Human-Computer Interaction, 2012*(2), 1–14. https://doi.org/10.1155/2012/369637

Myers, D. (2000). The funds, friends, and faith of happy people. *American Psychologist, 55*(1), 56–67. https://doi.org/10.1037/0003-066X.55.1.56

OECD. (2011). Compendium of OECD Well-being indicators.

OECD. (2014). *PISA 2012 results. Students and money: financial literacy skills for the 21st century.*

OECD. (2017). *PISA 2015 (volume IV) – Students' financial literacy*. OECD Publishing.

Pchelin, P., & Howell, R. T. (2014). The hidden cost of value-seeking: People do not accurately forecast the economic benefits of experiential purchases. *The Journal of Positive Psychology*, 322–334. https://doi.org/10.1080/17439760.2014.898316

Peng, T. C., Bartholomae, S., Fox, J. J., & Cravener, G. (2007). The impact of personal finance education delivered in high school and college courses. *Journal of Family and Economic Issues, 28*(2), 265–284. https://doi.org/10.1007/s10834-007-9058-7

Perotta, C. (2013). Game-based learning: Latest evidence and future directions. In *NFER Research Programme: Innovation in Education*. NFER.

Pfändler, A. M. (2021). in preparation, Entwicklung eines kompetenzorientierten Curriculums zur Förderung von Financial Literacy. *Zeitschrift für ökonomische Bildung*.

Prensky, M. (2001). *Digital game-based learning*. McGraw-Hill.

Procci, K. C. (2012). Usability in serious games: A model for small development teams. *Computer Technology and Applications, 3*(4), 315–329.

Remmele, B. (2017). Playing against the game. *International Journal of Game-Based Learning*, 74–82. https://doi.org/10.4018/IJGBL.2017070107

Remmele, B., & Seeber, G. (2012). Integrative economic education to combine citizenship education and financial literacy. *Citizenship, Social and Economics Education, 11*(3), 189–201. https://doi.org/10.2304/csee.2012.11.3.189

Remmele, B., Seeber, G., Speer, S., & Stoller, F. (2013). *Ökonomische Grundbildung für Erwachsene. Ansprüche – Kompetenzen – Grenzen*. Wochenschau.

Renkl, A. (1996). Träges Wissen. *Psychologische Rundschau, 47*, 78–92.

Retzmann, T. (2011). *Finanzielle bildung in der Schule*. Mündige Verbraucher durch ökonomische Bildung.

Retzmann, T., & Seeber, G. (2016). Financial education in general education. In E. W. Carmela Aprea (Ed.), *International handbook of financial literacy* (pp. 9–24). Springer.

Rheinberg, F., & Vollmeyer, R. (2003). Flow-Erleben in einem Computerspiel unter experimentell variierten Bedingungen. *Zeitschrift für Psychologie / Journal of Psychology, 211*, 161–170. https://doi.org/10.1026//0044-3409.211.4.161

Rheinberg, F. V. (2003). Die Erfassung des Flow-Erlebens. In J. Stiensmeier-Pelster (Ed.), *Diagnostik von Motivation und Selbstkonzept (Tests und Trends N.F. Bd. 2)* (pp. 261–279). Hogrefe.

Ross, B. (2013). Effects of participation in a simulation game on marketing students' numeracy and financial skills. *Journal of Marketing Education, 35*(3), 259–270. https://doi.org/10.1177/0273475313482928

Rudeloff, M. (2019). *Der Einfluss informeller Lerngelegenheiten auf die Finanzkompetenz von Lernenden am Ende der Sekundarstufe I (Economics Education und Human Resource Management)*. Gabler Springer.

Ryan, R., & Deci, E. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and Well-being. *American Psychologist, 55*(1), 68–78. https://doi.org/10.1037/0003-066X.55.1.68

Sánchez-Macías, A., Azuara-Pugliese, V., & Martinez-Cerda, M. (2018). Estrategia Didáctica Basada En La Lúdica Para La Adquisición De Competencias Financieras En Estudiantes De La Licenciatura En Administración. *European Scientific Journal, 14*(7), 69–89. https://doi.org/10.19044/esj.2018.v14n7p69

Sarodnick, F., & Brau, H. (2011). *Methoden der Usability Evaluation: Wissenschaftliche Grundlagen und praktische Anwendung. Wirtschaftspsychologie in Anwendung*. Huber.

Schell, J. (2012). Die Kunst des Game Designs - Bessere Games konzipieren und Designen. .

Schlösser, H. J., Neubauer, M., & Tzanova, P. (2011). Finanzielle Bildung. *APuZ Aus Politik und Zeitgeschichte*, 21–27.

Seeber, G., Retzmann, T., Remmele, B., & Jongebloed, H. C. (2012). *Bildungsstandards der ökonomischen Allgemeinbildung. Kompetenzmodell – Aufgaben*. Wochenschau.

Sembill, D. (2010). Emotionen - Auslöser, Begleiter und Ziele individuellen und sozialen Handeln. In R. Nickolaus, G. Pätzold, H. Reinisch, & T. Tramm (Eds.), *Handbuch der Berufs- und Wirtschaftspädagogik* (pp. 80–84). Klinkhardt.

Shanklin, S., & Ehlen, C. (2017). Extending the use and effectiveness of the monopoly® board game as an in-class economic simulation in the introductory financial accounting course. *American Journal of Business Education, 10*(2), 75–80. https://doi.org/10.19030/ajbe.v10i2.9916

Shanklin, S. B., & Ehlen, C. R. (2007). The monopoly board game as an in-class economic simulation in the introductory financial accounting course. *Journal of College Teaching & Learning, 4*(11), 65–72. https://doi.org/10.19030/tlc.v4i11.1525

Shute, V., & Ke, F. (2012). Games, learning, and assessment. *Assessment in Game-Based Learning*, 43–58. https://doi.org/10.1007/978-1-4614-3546-4_4

Smith, T., Richards, K., & Shelton, V. (2015). Mindfulness in financial literacy. *Journal of Human Behavior in the Social Environment, 26*(2), 154–161. https://doi.org/10.1080/10911359.2015.1052914

Sohn, S.-H., Joo, S.-H., Grable, J. E., Lee, S., & Kim, M. (2012). Adolescents' financial literacy: The role of financial socialization agents, financial experiences, and money attitudes in shaping financial literacy among South Korean youth. *Journal of Adolescence, 35*(4), 969–980. https://doi.org/10.1016/j.adolescence.2012.02.002

Tan, L., Hasselt, W. v., & Collison, T. (2015). *The Pursuit of Happiness - Creating Meaningful Brand Experiences for Millenials*. Retrieved from https://www.zenithmedia.com/wp-content/uploads/2015/10/4_ThePursuitOfHappiness.pdf

Tang, N., & Peter, P. C. (2015). Financial knowledge acquisition among the young: The role of financial education, financial experience, and parents´ financial experience. *Financial Services Review, 24*, 119–137.

Treher, E. (2011). Learning with board games - tools for learning and retention. The learning key - transforming learning into action. Retrieved from https://thelearningkey.com/

Union Investment. (2017). Finanzbildung in Deutschland Wissensstand – Defizite – Handlungsfelder.

Walstad, W. B. (2010). The effects of financial education on the financial knowledge of high school students. *The Journal of Consumer Affairs, 44*(2), 336–357. https://doi.org/10.1111/j.1745-6606.2010.01172.x

Weinert, F. E. (2001). Leistungsmessungen in Schulen. Weinheim und Basel.

Wilson, A., Hainey, T., & Connolly, T. (2013). Using scratch with primary school children: An evaluation of games constructed to gauge understanding of programming concepts. *International Journal of Game-Based Learning, 3*(1), 93–109.

Wilson, S., Engler, C., Black, J., Yager-Elorriaga, D., Thompson, W., McConnell, A., … Terry, R. (2017). Game-based learning and information literacy: A randomized controlled trial to determine the efficacy of two information literacy learning experiences. *International Journal of Game-Based Learning, 7*(4), 1–21.

Wouters, P., van Nimwegen, C., van Oostendorp, H., & & van der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects. Journal of Educational Psychology, 1–17.

Yoon, B., Rodriguez, L., Faselis, C., & Liappis, A. (2014). Using a board game to reinforce learning. *The Journal of Continuing Education in Nursing, 45*(3), 110–111. https://doi.org/10.3928/00220124-20140224-14

Zagal, J. P., Rick, J., & Hsi, I. (2006). Collaborative games: Lessons learned from board games. *Simulation & Gaming, 37*(1), 24–40. https://doi.org/10.1177/1046878105282279

Zhan, M., Anderson, S., & Scott, J. (2006). Financial knowledge of the low-income population: Effects of a financial education. *Journal of Sociology and Social Welfare*, 53–74.

Chapter 5
Business Simulation Games: Three Cases from Supply Chain Management, Marketing, and Business Strategy

Scott J. Warren, Meranda Roy, and Heather A. Robinson

5.1 Introduction

Why are business games and simulations valuable tools for teaching and learning? Many analog business games and simulations were used in organizational training for decades before digital as evidenced by the hundreds captured in Horn's (1977) seminal book *The Guide to Simulation/Games for Education and Training*. Most games and simulations in this time were simulations developed for different business disciplines. These learning tools are often intended to give users the opportunity to practice complex cognitive tasks with low consequences for failure (Levant et al., 2016). Using simulations reduces the risk of negative consequences for learners while allowing them to repeatedly test different strategies and approaches and learn from mistakes (Johnson et al., 2016).

These basic learning affordances (Greeno, 1994; Robertson, 2011) of business games and simulations explain the value of different cognitive and psychomotor aspects of a digital tool and how they align to identified learning affordances in the field of educational gaming. However, whether business games and simulations are effective for teaching and training remains a challenging question due to limited research over the last several decades. Over the last 20 years, the field has enjoyed a significant increase in the availability of business games and simulations for K-12 and higher education students; unfortunately, research on these digital business training tools lags research on other educational games (Buil et al., 2020). The purpose of this chapter is to explore use cases of simulation games designed for business education and describe how they are expected to improve learning using

S. J. Warren (✉) · M. Roy · H. A. Robinson
University of North Texas, Denton, TX, USA
e-mail: scott.warren@unt.edu

C. Aprea, D. Ifenthaler (eds.), *Game-based Learning Across the Disciplines*, Advances in Game-Based Learning, https://doi.org/10.1007/978-3-030-75142-5_5

concepts of game, simulation, and learning affordance to better explain how to analyze these instructional tools to determine their value for business education settings.

5.2 Background

Business simulations allow users to apply theory and practice skills in a low-threat environment (Buil et al., 2020; Wolfe, 1993). Since business disciplines are rooted in the real world, simulation games model what the field understands about concepts such as consumer psychology, applied mathematics (e.g., accounting), organizational structuring, management, and law (Faria et al., 2009). Today's digital simulation games remain rooted in analog, in-person simulation games that preceded them as well as the business principles and practices they teach. It is therefore important to explain some of the primary business concepts that frame the design, rule sets, conflicts, and the value those simulations offer for learning transfer.

5.2.1 Core Business Concepts: Boundary of the Firm; Explore and Exploit, Creative Destruction

Three root concepts frame both the practices and broader conceptual frameworks of the business discipline (Barney & Hesterly, 2012; Yang et al., 2010); and therefore, underpin the interactions and goals of most simulation games, especially those used in higher education courses. Many business simulation games ask students to address one aspect (e.g., supply chain management) within a discipline, and to address tradeoffs that result from their simulated choices in response to presented consequences. The following concepts in the literature are a common focus, whether explicitly stated or not, of what students are expected to engage with in business simulation games.

5.2.1.1 Boundary of the Firm

The first concept is the boundary of the firm and explains the central purpose of business firms as organizations and why they provide an important social service in providing goods and services to individuals.

The study of firm boundaries originated with ideas put forth by Coase (1937, p. 1) who considered:

> The question of why we observe significant economic activity within formal organizations despite the economic argument that markets are the most powerful and effective mechanisms for allocating scarce environmental resources.

Coase explained that organized companies (i.e., firms) can transact business at lower costs despite having imperfect information from the markets. At the time Coase rejected the commonly accepted concept that for one business agent to do better, another must-do worse, making it a core conceit of business logic (Holmström & Roberts, 1998), leading to a need to employ game theory where we cannot know how our opponent will react in each situation (Bendle & Vandenbosch, 2014). This situation results because business actors must decide how to spend limited funds on advertising, renting workspace, buying needed resources from suppliers to make a product, hiring lawyers to write and enforce contracts, and many other activities that are cost-prohibitive for one person to encumber; therefore, an organized firm made up of many people acting in concert is a more secure way to do business. As such, business students must learn how to establish a firm boundary that allows their company to produce better, cheaper products than their competitors. Wernerfelt (1984) later identified that the goal of any business firm is to strategically manage scarce industrial and human resources more effectively, efficiently, and sustainably than their competitors to generate profit and maintain a competitive advantage over time (Oliver, 1997). As such, in business simulations, it is common to provide students with the task of developing a firm boundary in such a way that their simulated company provides a product at a lower cost to consumers than their competitors (Carenys & Moya, 2016). Using this view, business simulation games often require students to manage and/or explore to acquire scarce resources and exploit them to best effect for their company to survive against competitors.

5.2.1.2 Explore and Exploit

Another concept central to business logic is exploring the external environment (i.e., markets, physical world, etc.) and internal capabilities of an organization to discover valuable resources that can be exploited for the financial benefit of a firm (Levitt, 1965; Nielsen et al., 2018). Business educators teach students to observe and analyze potential markets for products, seeking to maximize profit by entering the right target market segment with the right product at the right time, exploiting demand, and matching current knowledge of consumer psychology (Ho et al., 2006; Stephen, 2016). Related educational practice in business classrooms provide students with opportunities to practice skills such as research on available markets, product development and pricing, segmentation, targeting, and survey research to best exploit the current environment and available corporate resources to best improve financial gain (Harrigan & Hulbert, 2011; Teece et al., 1997).

5.2.1.3 Creative Destruction

Creative destruction, because of industry changes over time, is a central feature of capitalism (Schumpeter, 1942). Maintaining an advantage against competitors is a goal of corporations, but the conflict to gain market share and grow profit through exploration of new products and markets can lead to strategic failures and, potentially, the financial collapse of a firm. However, the failure of a product in the market can lead to innovative approaches by an existing firm or allow entry of a new company that offers something that customers want to buy (Suddaby & Foster, 2017). Competition among businesses in the same market can lead to the perception that the firms are at war and, over time, corporate strategists employed analyses of environmental and competitive conflict to strategic planning, a view inherent in business simulation games (Pitkethly, 2006).

5.2.2 Business Framed as Interplay Between Conflict and Strategy

In business, participants recognize core concepts regarding what constitutes a game and play (Salen & Zimmerman, 2004):

- *Conflict driving activity*: In games, the conflict is generally rooted in an artificial situation that drives the play. Case studies on conflict analysis are often written to mirror the real world; thus, improving learning transfer to existing corporate contexts.
- *Interactive rule set*: In simulation games, the interactive rule set may be significantly abstracted from the real world due to logistical constraints with programming. In simulation games, the rule set is based on limited models of human behavior. Although, not always realistic it can provide a useful approximation for teaching. Business simulations portray business rules in accordance with the theoretical and practical frameworks of business (e.g., resource-based view of the firm) so students can understand the consequences of their decisions within a coherent rule set.
- *Win scenario*: Some business firms win, and others lose or simply perform less well than others based on decisions of the non-player characters or competing live players. These game aspects are combined with high fidelity of experience simulations, rather than high graphical fidelity tools, to provide learners with opportunities to apply and practice business concepts and skills and to illustrate how they work in a recognizable situation (Thavikulwat, 2004).

5.2.3 Learning Affordances and Uses of Business Simulation Games

The primary learning affordance of simulations in business disciplines is to provide practice applying knowledge and skills. Since most simulations have high fidelity to the real world where they are expected to transfer, learners can apply concepts and skills they are likely to encounter in work settings (Warren & Jones, 2017). For example, accurate presentation and interaction with operational principles, accounting calculations, marketing and sales concepts, and others are necessary to be successful in the workforce, which is a challenging development task and does not always occur effectively in business simulation games. The purpose of the chapter is therefore to provide example cases that can act as a guide to researchers and users for identifying and evaluating the central learning, simulation, and gaming aspects of business simulation games prior to adoption.

5.3 Methods

For the purpose of this chapter, we played and analyzed three available business simulation games. The simulations were chosen based on convenience and availability (e.g., no subscription-based fee) as well as the defined business activities (i.e., specific business disciplines) that students are expected to learn through practice. Simulations also needed accessible directions or other curricular materials that explained use. To qualitatively examine the business simulation game cases, we used an adapted procedure following steps from Zhang and Wildemuth's (Zhang & Wildemuth, 2009, in Ravitch & Mittenfelner Carl, 2016):

1. *Create or define the dataset.*

   At the outset, we had to define which simulation games we could review in-depth to examine their pedagogical, game, and simulation characteristics. Reviewed products were designed for collegiate business disciplines and did not include edutainment titles such as *Railroad Tycoon* due to a lack of explained pedagogical or content rigor. Most games examined for this chapter have expensive counterparts that can be purchased; however, we opted for low- or no-cost alternatives that are broadly available to faculty. We located 20 different business simulation games online; however, only seven were accessible for play, while others were simply described. To select the games that would be analyzed, the following choice criteria were used:

   (a) Playability: Is the game accessible to play?
   (b) Single business subject: Only one game per subject.
   (c) Ability: Do the analysts have enough knowledge and skills with the discipline and game requirements to successfully play it?

2. *Define the unit(s) of analysis.*

   The following units of analysis were chosen to provide readers and analysts with a view of the structural underpinnings of the simulation games so that they could be analyzed in terms of how well they aligned with the stated overall learning goals and outcomes.

   (a) *Educational purpose:* What was the design intention of the simulation game regarding its identified discipline?

(b) *Game structure:* What is the overall narrative and game play structure with the simulation that is used to contextualize student learning activities? These included (a) description of game intention (e.g., number of players, discipline, etc.), (b) simulated play characteristics, (c) artificial conflict, (d) interactive rules, and (e) win scenario.
(c) *Learning affordances:* What media, simulation characteristics, and other learning affordances exist in the game and how do they support student performance?
(d) *Overall expected value to business educators:* We provide an overall evaluation of the likely value that instructors and students will receive from integrating the business simulation into their curriculum and will note areas for improvement.

3. *Develop categories and coding schemes.*
   The etic set of codes used to organize and describe the resulting data stemmed from the units of analysis described in **step 2**. Since the etic codes were predefined, we did not use Zhang and Wildemuth's code testing step.
4. *Assessing coding consistency and drawing conclusions from coded data.*
   During this step, we analyzed the game documents, played the simulation games, and took notes focused on the etic, predefined categories.

The following section provides the outcomes of our analysis as a model that others may use for evaluating the learning and play components present in a business simulation game.

5.4 Findings: Example Business Education Use Cases

The first case, *SCM Game*, is a supply chain management (SCM) game offered to help students make decisions about resource allocation. The second case is called *Marketing Simulation Game*; it allows online or face-to-face team-based learning decision-making regarding market segmentation, targeting, and product choice. The third case is *The Founder*, a business strategy game, which simulated an internet startup and required players to make complex decisions about markets, product development, employee management, company location, and other common business choices.

5.4.1 Case 1: SCM Game*: Low Resolution, High Fidelity Supply Chain Management Practice*

Number of players: 1.
Business discipline: Supply chain and operations management.

Game format: Web browser.
Instructor responsibility for support: None.
Instructor access to learning outcomes: None.
Website: https://www.mbacrystalball.com/app/scm/scmmain.php

5.4.1.1 Educational Purpose

The overall goal of the *SCM Game* is to immerse students in the decision-making and mathematics activities common to supply chain decision management. Students are provided with a realistic context to prepare them for interactions with concepts, work activities, and cognitions they will be expected to perform in future work settings. Students practice the activities and receive visual and numeric feedback on their performance each time they practice with different expectations and data sets that simulate real-world practice.

5.4.1.2 Game Structure

Learners role-play as new employees on a probationary contract who must prove themselves by successfully completing activities common to supply chain management (Chopra & Meindl, 2010). The simulation game is made up of four central learning activities:

1. *Review the status of customer orders*: This mathematics activity requires students to observe and record the total demand for products as well as to calculate whether the inventory is enough to meet demand.
2. *Determine and enter production quantity into the system*: Using data collected in the first step, learners decide how much their simulated company should produce. Learners are also expected to calculate time delays to project on-time delivery to customers.
3. *Submit order decision*: Students practice the work of using supply chain logic to meet customer needs which includes repeating the order process until the supply chain system achieves successful equilibrium or until failure results at the end of the probation period.
4. *Review results for performance feedback*: The final screen presents numeric data and visual feedback to learners. Feedback on failed attempts is expected to help students improve performance on each next attempt.

A visual depiction of the game play process is included in Fig. 5.1.

When compared with the business operations activities described in Chopra and Meindl's (2010) text, the game activities mirror common supply chain practices, although simplified to accommodate learners new to the topic and practice of management.

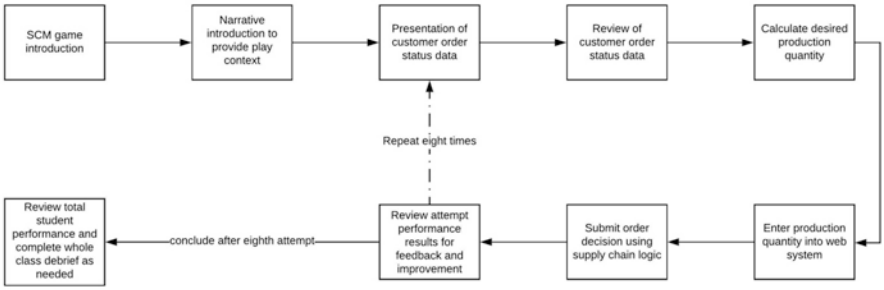


Fig. 5.1 SCM Game activity flowchart

5.4.1.2.1 Artificial Conflict

The *SCM Game*'s conflict is naturalistic and presents situations that mirror real-world contexts and problems, which the students may encounter in their future work. Directions are presented in straightforward text and graphics. Students are asked to observe information presented on the screen, complete the inferred math problems outside the game system, and input solutions into the simulation. Feedback is then presented to the student regarding the game play conflict relative to expected performance.

5.4.1.2.2 Interactive Rule Set

The interactive rule set provided by the simulation game is derived from supply chain management theory and mathematics procedures commonly outlined in textbook practice. Rule governing concepts including implied demand uncertainty, customer demand requirements, inventory, spoilage, transportation times based on distance, and other relevant ideas that govern play, practice, and performance. The rule set is used to frame the win/lose scenario that defines desired learner/player performance.

5.4.1.2.3 Win/Lose Scenario

The win-lose scenario is framed in terms of desired customer satisfaction metrics, so a score representing equilibrium is the player's performance target. Meeting that requirement indicates that they won the simulation game. A loss is coupled with performance feedback, so students can learn from their mistakes and improve over time.

5.4.1.3 Learning Affordances

Primary media affordances of the simulation game include text, visual images, and data visualizations. The primary means of communicating with learners are text directions and numeric data. Information needed to make decisions is presented visually and logically so learners can complete the needed mathematical calculations. Learning feedback comes primarily through visual graphs overlaid with related numeric outcomes presenting the results of student attempts.

5.4.1.4 Overall Value for Business Education

The free version of the simulation game provides single-line feedback on student performance, explaining the consequences of failing to meet customer demand and what number of units they should have produced. Students are provided with limited opportunities to practice simple supply chain calculations in a business context. The more advanced version allows unlimited attempts, which may improve student performance. While the realism and graphical fidelity are simple, the simulation game may provide business educators the opportunity to supplement textbooks and examination preparation with additional practice. This was a common approach in many described business simulation games and while this was designed for individual players, the next example allowed for team-based play.

5.4.2 *Case 2:* Marketing Simulation Game: *An Excel-Based Free to Play Tool*

Number of players: Flexible: one or more with up to ten teams.

Business discipline: Marketing.

Format: Multimedia, web browser (text), document downloads (MS Word & Excel, PDF).

Instructor responsibility for support: Significant tracking and management.

Instructor access to learning outcomes: All outcomes are in team spreadsheets.

Website: **https://www.greatideasforteachingmarketing.com/free-marketing-simulation-game/**

5.4.2.1 Educational Purpose

The overall purpose of this simulation game is to maximize profits by completing common marketing tasks such as identifying resources for target customers, determining the return on investment for marketing items, calculating marketing metrics, and more. Students use the marketing dashboard to allocate various resources and to complete required tasks. Bulleted learning objectives are common to marketing activities conducted by business professionals (Hooley et al., 2004). As noted in the game directions, the primary learning goal is to teach students how to determine what target market their company should compete in, a task called positioning.

5.4.2.2 Game Structure

The simulation game uses a combination of digital documents and web-based game play. By providing digital resources, the game structure makes it simpler for the professor to distribute them to students and teams, allows students to share documents and work together at a distance, and makes grading easier. The game provides students with a business problem (i.e., in what target market should their company compete based on data) that is introduced using directions posted on a website. The developer includes a visual map with cells that functions similarly to an analog game board, a general guide to game play, as well as an instructor guide that functions as a job aid for the simulation. The visual map is divided into four potential target markets color-coded by their level of attractiveness as follows: green (i.e., most attractive), yellow (i.e., average attractiveness), and red (i.e., not attractive) based on predicted demand for the company's products. Using other information provided in individual cells, students decide what products to develop and where to advertise them.

Learner teams have limited funds (5000 points). Each advertising decision can result in financial gain or loss for the company. Decisions for each round are captured on a sheet and the total number of points is captured during eight rounds of play. The general game process is presented in the following systemic diagram (Systemigram)—Fig. 5.2. Systemigrams are visualizations of complex systems to provide a narrative that more simply explains how a complex system is structured (Sauser & Boardman, 2015).

5.4.2.2.1 Artificial Conflict

The game conflict game is naturalistic and represents common business problems of deciding what products to develop and in what markets a company should compete to gain the most financial advantage. Conflict emerges because the learner has imperfect information similar to the experience of managers; therefore, students are faced with the common business problem of making decisions about how to best employ scarce resources to best effect for the company. Furthermore, real conflict arises as team members compete with one another to develop marketing strategies in line with their views while not knowing how competitor teams will choose to allocate their resources, and which will result in the highest profit.

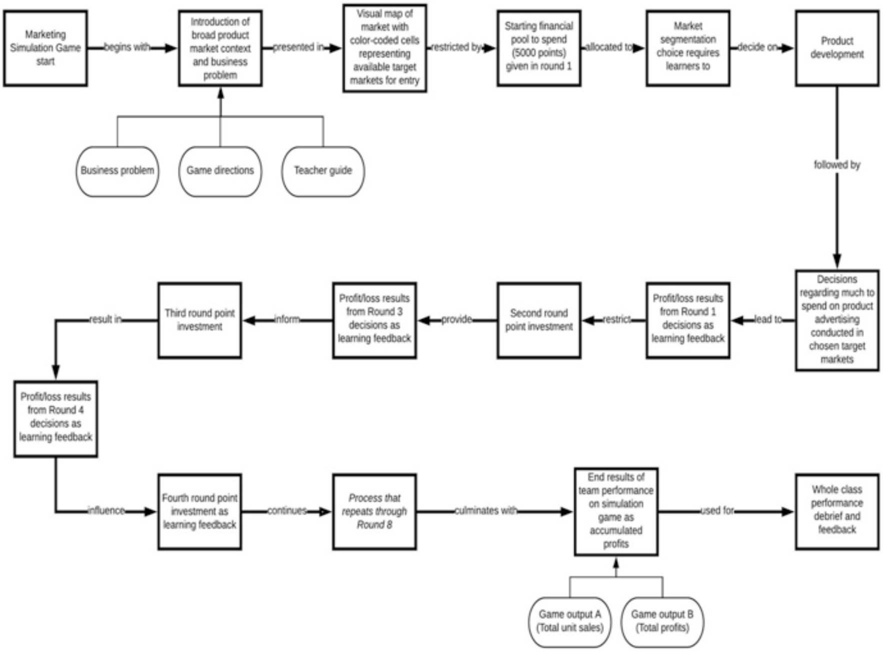


Fig. 5.2 Marketing simulation game depicted as a systemigram

5.4.2.2.2 Interactive Rule Set

The rule set for game play results from common marketing theory models (Hooley et al., 2004). Students in the simulation are required to learn about the product, position the product within the market, advertise products to consumers, and measure profit. Using information throughout the process, students also can reposition the product within existing markets or start the process over again with new a product. If a set of choices results in higher profit for a team's simulated company based on their success using the rule set, they likely internalized and learned the rule set and provided evidence, which they applied successfully.

5.4.2.2.3 Win/Lose Scenario

Competition among teams, representing separate companies, results in a win/loss scenario governed by which unit has the highest profit, which is not necessarily the same as the largest number of units sold. This situation results because the student's choice to produce lower priced products may result in more units sold but at a lower profit. Therefore, the team may lose the game because they yield lower profits despite selling significantly more products.

5.4.2.3 Learning Affordances

The simulation's primary media learning affordances (Greeno, 1994) include text to present game play context, business problem/conflict, and directions for learning from play. The directions give limited detail but are written in a language and conceptual complexity level appropriate to the target audience of undergraduate and early-stage MBA students. Furthermore, online video (i.e., audio-visual affordance) is used to provide text in an alternative modality that supports students with visual learning needs or preferences. Students are also provided with visual maps to contextualize practice and game play, as well as documents to apply what they have learned as part of measuring performance. These documents provide a cognitive organizational schema for their future business practice while also providing the instructor with evidence of student learning and information for performance feedback. The competition results also afford students with knowledge of how they performed against peers, mirroring how performance is judged in real-world corporate settings.

5.4.2.4 Overall Value for Business Education

As with the supply chain simulation, the marketing simulation game provides students with the opportunity to practice real-world business skills in a low-threat context. Because of the system that allows eight rounds of play, as well as reviewing their performance against peers using numeric outcomes representing financial outcomes, students can connect what they learn in the game to marketing cases they read in the textbook or assigned articles. The simulated practice, contextualized with educational media and play, should help reinforce what students learn and foster their ability to transfer what they learn to other relevant contexts. Additionally, the simulation is easy to implement due to the instructional videos on how to play the game, directions for how to use the digital documents, and an instructor's manual.

5.4.3 Case 3: The Founder: A Dystopian Business Simulator: A Realistic Start-Up Game

Number of players: Flexible: one or more with up to ten teams.
Business disciplines: Business strategy, research and development, and management.
Format: Browser.
Instructor responsibility for support: Significant tracking and management.
Instructor access to learning outcomes: All outcomes are in team spreadsheets.
Website: thefounder.biz

5.4.3.1 Educational Purpose

The simulation introduces students to the basic principles of starting up a new business with minimal resources. Common organizational behavior concepts are introduced through game play such as human resource selection and allocation, employee onboarding, market target, product development, and competition. Competitor businesses students play against are modeled on real-world internet startups that are now major technology companies such as Google (*Kougle*). Players encounter the concept of disruption from Schumpeter's (1942) creative destruction concept by competing against smaller competitors initially and then against these stronger companies as they grow. Students learn principles such as the business cycle (Schumpeter, 1927) and organizational forms through competitive play.

5.4.3.2 Game Structure

The Founder places students in the context of starting a business just after the end of the late 1990s dot-com bubble. As in the second case, players receive startup funds from a venture capitalist at the outset of the game. Players create a name and choose what kind of business they will start with (i.e., hardware products or information services) as part of their vertical business strategy, introducing the concept and providing examples of those company forms. Hardware products include gadgets or mobile devices while information services include e-commerce or social networks and players choose which type to start with at the outset, with options for combining types or expanding into new markets later. Players also choose which city to start in and each location provides different bonuses to game play (e.g., Boston provides +3 to employee engineering skills). Once the location is chosen, players choose a non-player character (NPC) cofounder who provides additional benefits to their play within natural competitive conflicts.

5.4.3.2.1 Artificial Conflict

Game conflict arises from simulated conflict between the player's startup company and competitors who each provide similar products or services with different attributes resulting from their size, available resources, organizational structure, and chosen employees. Players can overcome conflict by making better management choices than other companies when they face strategic paradoxes (Smith, 2014) such as insufficient resources to meet expected demands. However, as with game theory (Reiners & Wood, 2015), the players cannot know what choices their competitors will make regarding resource allocation, so they decide how to allocate resources based on knowledge of their own company's competitive advantages and the situation.

5.4.3.2.2 Interactive Rule Set

Game play in *The Founder* is complex and governed by rules enforced by an NPC board of directors who provide feedback on player performance using backgrounded rules that codify performance expectations tied to return on investment and product sales outcomes. Players start by creating a new product by combining different product types. Bonuses are given to player's companies based on whether combinations are deemed by the rules to be innovative; however, like in the real world, those rules may be unclear or hidden until the player encounters them. Players assign NPC employees to tasks that are responsive to the declared game play business expectations. The more skill points the employees contribute, the better the product or service. As the game progresses, players can unlock and purchase new product options using profits. The product that results must be designed based on quantity (i.e., how many in the market), the strength of the product versus others in the market, and how well it suffuses in the market. A competitor is assigned, and a difficulty level is associated with it. Upon product launch, students choose where to compete in the market based on how much money is available in a target segment per turn. Once the ten-turn market competition phase ends, the NPC mentor provides formative and summative feedback on how well the player performed against the competitive rules. The NPC explains how the product generates revenue based on business factors such as market share, communication costs, etc.

The more employees assigned to a product development task, the more rapid the new development. Figure 5.3 is a Systemigram that explains the broad activities flow process that players engage in using *The Founder* simulation game.

As companies become more successful, new challenges are introduced (e.g., server attacks) that require making decisions about how to allocate resources (e.g., harden servers) or suffer consequences (e.g., public/customer outrage), which can

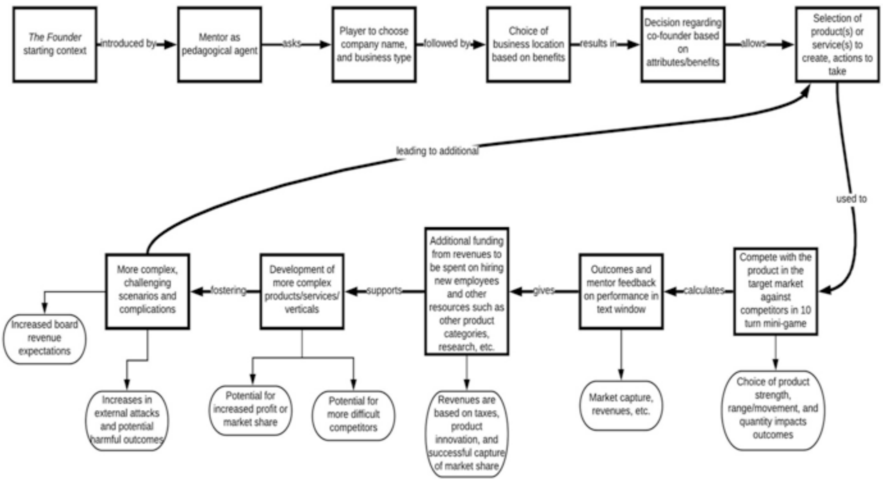


Fig. 5.3 The Founder's business simulation game activity flow

harm profits. Presenting such situations teaches players about trade-offs inherent in management decision-making. As players are more successful in building products, the complexity and challenge of managing the company and its products increase.

5.4.3.2.3 Win/Lose Scenario

The player competes against their previous highest profit scored in dollars. The player's performance is evaluated by the fictional board after the second year based on profit expectations (e.g., 12% profit growth for year three). Failure to meet the board's expectations for too long results in the player being fired from the company. Each time player meets expectations, the board raises those expectations for the following year, often far more than the previous target (e.g., increase target profit from $17,000 to $112,000).

Another win/loss scenario comes as students play on the market game board against simulated competitors and is based on the percentage of market share they achieve over ten turns. For example, with an initial product that took three months to create, our fictional company captured 21.74% of the market representing $28,800. The outcome included bonuses from locations, new products, economic health, social media influence, hype, and consumer spending. On the game board, players can also knock their competition out of the market, providing a significant bonus to the company's market share and revenue. There is no specified educational win or loss outcome unless the student or instructor sets an external profit goal or how many years the company survives. This outcome may be decided by either party, depending on the instructional goals. Significant learning should take place informally because of the failure against competitors and reflecting on past strategies and decisions. Determning whether learning took place in this case may require the creation of reflection activities so students can think about what they learned during the experience.

5.4.3.3 Learning Affordances

The simulation initially provides players with a simple visual depiction of their start-up apartment with workstations and their NPC co-founder moving through space. Displayed onscreen are the current month and year, available funds, board attitude (e.g., content), available player choices (e.g., New Task, View Tasks), and information about available company strength level regarding design, marketing, engineering, and productivity. The text provides basic information while mildly flashing symbols draw users' eyes to available tasks.

5.4.3.4 Overall Value for Business Education

Major benefits of *The Founder* are that students can play independently, and it models the complexity of starting up a new business. A challenge is that the simulation game does not come with specific instructor materials that support integration into the curriculum and it was not formally designed as an educational tool. However, an instructor could easily create debrief and reflection questions to guide discussion about student game play and for students to reflect on what they learned. These questions provide assessment evidence and diagnostic information about concepts students need more practice through repeated play before testing.

5.5 Discussion

The business simulation game cases analyzed for this chapter leveraged common learning affordances such as text, video, audio, multimedia, and simulated real-world practice to support instruction. Using technologies that have varying levels of complexity and fidelity of experience provides students with opportunities to practice the application of concepts and skills needed to successfully work in corporate firms (Anderson & Lawton, 2009). There are many available commercial simulations as well as some free-to-use or limited access products available online. The quality of the graphics varies, but most employ lower resolution graphics in favor of increased fidelity of experience likely to improve learning transfer to industry settings.

Our analysis of simulation games for supply chain and operations management, marketing, and business strategy highlighted the various tasks and available choices provided to users during their play experience. The *Supply Chain Game* was narrowly focused on teaching a single skill (i.e., determine production target). Such a product would be valuable for teaching a discrete skill during class time and to spur discourse or as independent work by students as practice in anticipation of examinations. By comparison, *The Founder* started with simple choices such as where to locate the business and what product, to begin with; however, the complexity of decisions and consequences rapidly increased as the game progressed. The *Marketing Simulation Game* simulated likely real-world tasks to provide modeling needed to support transfer from the simulation game to future business settings where they will apply them.

The more realistic the simulated activities and outcomes (i.e., fidelity of experience) in the game, the more instructors should expect the transfer to the business contexts where students are expected to work in the future. It is this preparedness from the use of such simulations that provides their primary educational value and justifies investment in their use. However, all simulation games should be evaluated independently by instructors to determine their quality prior to curriculum integration. It would also be beneficial to locate empirical research in support of the simulation to increase the likelihood it will provide students with a valuable learning experience.

5.5.1 Limitations of Business Simulations Games

A significant limitation of business simulation games is that they are not as complex as real-world applications. Therefore, as with other simulations, the fidelity of experience may not be high enough to allow successful transfer to real-world practice and other contexts. Some of the reviewed games included overly broad contexts that lacked sufficient detail to scaffold learning successfully, because students may not see clear connections between the game play and other contexts without significant debrief by the instructor. If a simulation game provides a model that is not sufficiently complex, students may draw inappropriate conclusions and strategies for applying business principles. This outcome may harm a student's future success if they apply lessons that worked in the simulation game but do not work in real practice. It will be important to ensure that any business simulation game includes models of business practice that are accurate relative to real practice. This inclusion may be complicated if the designer(s) lacks experience with a corporate application. This challenge may be overcome by including subject matter experts working currently in the target discipline, including graduates of the program, to inform a successful design. Ensuring that course materials include classroom debriefings regarding student simulation game experiences is important to fostering transfer to classroom and work contexts outside of the digital space (Jaye et al., 2015).

5.5.1.1 Opportunities for Research

An obstacle to using business simulation games is a dearth of published academic research on their effectiveness for supporting students as they learn concepts in business courses. When evidence of efficacy is presented on websites, it is often presented as anecdotal quotes from past or existing customers. Further research into the educational value of available business simulations regarding learning efficacy and real-world transfer to work contexts is needed.

5.5.1.2 Challenges to Research

With publicly available simulation games, conducting formal research should not be difficult. However, with commercial games, the cost to purchase and study them may be prohibitive and limit possibilities for future study. Furthermore, private companies may not want the structure and efficacy of their products published as it may harm their perceived competitive advantage against rivals selling similar games or reduce sales.

5.6 Conclusion

While games and simulations have a long history of use for training in business disciplines, research on their efficacy and theory development to explain their value remains limited, so there is much work to be done. However, the three cases presented in this chapter may act as a guide to illustrate how we may analyze and determine the intended pedagogical value of a simulation game used to support learning topics related to business. These tools range from simple (e.g., *SCM game*) in terms of the number required management activities and choices at around 20 to highly complex (e.g., *The Founder*) with potentially thousands of simulated choices. As such, the instructor's choice of the game depends on an instructor's learning objectives. Not all learning outcomes require extreme levels of detail; however, if a simulation game fails to provide sufficient fidelity of experience, learning transfer may be limited. We believe that simulation games provide learners with safe, repeatable practice, which can help students apply business concepts and skills independently or with instructor guidance that has benefits that outweigh readings, quizzes, and analog problem-solving activities. Significant systematic study still needs to be done to test the efficacy of existing available products. It is this research and analysis that provides researchers with opportunities to determine and disseminate important knowledge regarding the value of these learning technologies.

References

Anderson, P. H., & Lawton, L. (2009). Business simulations and cognitive learning. *Simulation & Gaming, 40*(2), 193–216. https://doi.org/10.1177/1046878108321624

Barney, J., & Hesterly, W. (2012). *Strategic management and competitive advantage: Concepts and cases* (4th ed.). Pearson.

Bendle, N., & Vandenbosch, M. (2014). Competitor orientation and the evolution of business markets. *Marketing Science, 33*(6), 781–795. https://doi.org/10.1287/mksc.2014.0863

Buil, I., Catalán, S., & Martínez, E. (2020). Engagement in business simulation games: A self-system model of motivational development. *British Journal of Educational Technology, 51*(1), 297–311. https://doi.org/10.1111/bjet.12762

Carenys, J., & Moya, S. (2016). Digital game-based learning in accounting and business education. *Accounting Education, 25*(6), 1–53. https://doi.org/10.1080/09639284.2016.1241951

Chopra, S., & Meindl, P. (2010). *Supply chain management: Strategy, planning, and operation*. Pearson Education.

Coase, R. (1937). The nature of the firm. In G. J. Stigler & K. E. Boulding (Eds.), *Readings in price theory* (pp. 331–351). Irwin.

Faria, A. J., Hutchinson, D., Wellington, W. J., & Gold, S. (2009). Developments in business gaming: A review of the past 40 years. *Simulation and Gaming, 40*(4), 464–487. https://doi.org/10.1177/1046878108327585

Greeno, J. G. (1994). Gibson's affordances. *Psychological Review, 101*(2), 336–342.

Harrigan, P., & Hulbert, B. (2011). How can marketing academics serve marketing practice? The new marketing DNA as a model for marketing education. *Journal of Marketing Education, 33*(3). https://doi.org/10.1177/0273475311420234

Ho, T. H., Lim, N., & Camerer, C. F. (2006). Modeling the psychology of consumer and firm behavior with behavioral economics. *Journal of Marketing Research*. https://doi.org/10.1509/jmkr.43.3.307

Holmström, B., & Roberts, J. (1998). The boundaries of the firm revisited. *American Economic Association, 12*(4), 73–94.

Hooley, G., Piercy, N. F., & Nicoulaud, B. (2004). Marketing strategy and competitive positioning. *Education*. Retrieved from http://www.pearsoned.co.in/web/books/9788131727997_Marketing-Strategy-and-Competitive-Positioning_Brigitte-Nicoulaud.aspx

Horn, R. (1977). *The guide to simulations/games for education and training*. Didactic Systems.

Jaye, P., Thomas, L., & Reedy, G. (2015). "The diamond": A structure for simulation debrief. *Clinical Teacher, 12*(3), 171–175. https://doi.org/10.1111/tct.12300

Johnson, L., Adams Becker, S., Cummins, M., Estrada, V., Freeman, A., & Hall, C. (2016). *Horizon report – 2016 Higher Education edition*. *NMC Horizon Report*. ISBN 978-0-9968527-5-3

Levant, Y., Coulmont, M., & Sandu, R. (2016). Business simulation as an active learning activity for developing soft skills. *Accounting Education*. https://doi.org/10.1080/09639284.2016.1191272

Levitt, T. (1965). EXPLOIT the product life cycle. *Harvard Business Review, 43*(6), 81–94. https://doi.org/10.2139/ssrn.383242

Nielsen, J. A., Mathiassen, L., & Hansen, A. M. (2018). Exploration and exploitation in organizational learning: A critical application of the 4I model. *British Journal of Management, 29*(4), 835–850. https://doi.org/10.1111/1467-8551.12324

Oliver, C. (1997). Sustainable competitive advantage: Combining institutional and resource-based views. *Strategic Management Journal, 18*(9), 697–713.

Pitkethly, R. (2006). Analysing the environment. In D. Faulkner & A. Campbell (Eds.), *The Oxford Handbook of Strategy* (1st ed., pp. 232–266). Oxford University Press.

Ravitch, S., & Mittenfelner Carl, N. (2016). *Qualitative research: Bridging the conceptual, theoretical, and methodological* (1st ed.). Sage Publications Inc..

Reiners, T., & Wood, L. C. (2015). Gamification in education and business. In Gamification in Education and Business. https://doi.org/10.1007/978-3-319-10208-5.

Robertson, J. (2011). The educational affordances of blogs for self-directed learning. *Computers & Education, 57*(2), 1628–1644. https://doi.org/10.1016/j.compedu.2011.03.003

Salen, K., & Zimmerman, E. (2004). Rules of play: Game design fundamentals. MIT Press.

Sauser, B., & Boardman, J. (2015). Systemigram modeling for contextualizing complexity in system of systems. In *Modeling and simulation support for system of systems engineering applications*. Wiley. https://doi.org/10.1002/9781118501757.ch11

Schumpeter, J. (1927). The explanation of the business cycle. *Economica, 21*, 286–311.

Schumpeter, J. (1942). Creative destruction. *Capitalism, Socialism and Democracy*, 82–85.

Smith, W. K. (2014). Dynamic decision making: A model of senior leaders managing strategic paradoxes. *Academy of Management Journal, 57*(6), 1592–1623. https://doi.org/10.5465/amj.2011.0932

Stephen, A. T. (2016). The role of digital and social media marketing in consumer behavior. *Current Opinion in Psychology, 10*, 17–21. https://doi.org/10.1016/j.copsyc.2015.10.016

Suddaby, R., & Foster, W. M. (2017). History and organizational change. *Journal of Management, 43*(1), 19–38. https://doi.org/10.1177/0149206316675031

Teece, D. D., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal, 18*(7), 509–533. https://doi.org/10.1002/(SICI)1097-0266(199708)18:7<509::AID-SMJ882>3.0.CO;2-Z

Thavikulwat, P. (2004). The architecture of computerized business gaming simulations. *Simulation and Gaming, 35*(2), 242–269. https://doi.org/10.1177/1046878104263545

Warren, S. J., & Jones, G. (2017). In D. Ifenthaler, S. Warren, & D. Esreyel (Eds.), *Learning games: The science and art of development*. Springer.

Wernerfelt, B. (1984). A resource-based view of the firm. *Strategic Management, 5*(2), 171–180.

Wolfe, J. (1993). A history of business games in English-speaking and post-socialist countries: The origination and diffusion of a management education and development technology. *Simulation and Gaming, 24*, 446–463.

Yang, H., Lin, Z. J., & Lin, Y. L. (2010). A multilevel framework of firm boundaries: Firm characteristics, dyadic differences, and network attributes. *Strategic Management Journal, 31*, 237–261. https://doi.org/10.1002/smj

Zhang, Y., & Wildemuth, B. M. (2009). Qualitative analysis of content. *Applications of Social Research Methods to Questions in Information and Library Science*. https://doi.org/10.1002/hbm.20661

Chapter 6
Serious Games as Assessment Tools: Visualizing Sustainable Creative Competence in the Field of Retail

Susanne Weber, Mona Off, Tobias Hackenberg, Matthias Schumann, and Frank Achtenhagen

6.1 Introduction

Serious games are games designed to be played in settings whose primary intention is to achieve certain learning goals or to purposefully impact the lives of players beyond the game's self-contained aims of engagement, entertainment, or satisfaction (Kapp, 2012; Mitgutsch & Alvarado, 2013; Sailer, 2016; Sailer et al., 2017). The increasing availability of new platforms, mobile technologies, online games, virtual worlds, and augmented reality experiences have increased the accessibility to games and introduced new ways in which they can be played (Connolly et al., 2012). Serious games can be an effective learning tool to engage with young adults, given their affinity with technology (Boctor, 2013; Day-Black et al., 2015; Hummel et al., 2017). The JIM-Studie (Jugend, Information, Medien-Studie; Youth, Information, Media) survey shows that 97% of German teenagers (between 12 and 19 years old) own digital devices, including smartphones (93%), computers/laptops (65%), and tablets (25%) (Medienpädagogischer Forschungsverbund Südwest (mpfs), 2019, p. 5). Fifty-six percent of teenagers watch videos online daily, 84% at least several times a week. This survey also found that 31% of teenagers play digital games daily and 63% do so several times a week (mpfs, 2019, p. 12). Thus, the inclusion of gamified systems in the workplace to address the needs of young employees and modern learners is not unexpected (Larson, 2020; Singh, 2012).

Blohm and Leimeister (2013) estimate that 40% of the largest 1000 organizations in the world implement gamification techniques and principles to refine their

S. Weber (✉) · M. Off · T. Hackenberg
Ludwig-Maximilians-University Munich, Munich, Germany
e-mail: Susanne.Weber@bwl.lmu.de

M. Schumann · F. Achtenhagen
Georg-August-University Göttingen, Göttingen, Germany

C. Aprea, D. Ifenthaler (eds.), *Game-based Learning Across the Disciplines*,
Advances in Game-Based Learning, https://doi.org/10.1007/978-3-030-75142-5_6

business activities (Larson, 2020). For example, the European Central Bank promotes the serious game *Economia* to teach their employees the impact of interest rate changes on financial indicators (European Central Bank, 2019); Cisco uses the gamified program *MindShare* to help its employees develop principles of networking and hardware; and the call center LiveOps Inc. uses a digital gamification platform inspired by *Bunchball* to keep calls brief and close more sales (Larson, 2020).

Serious games are garnering popularity in teaching and learning processes, especially in Vocational Education and Training (VET) and in business and professional development (Larson, 2020; Westera, 2019). The application of serious games in learning and teaching/training seeks to extend the natural play moments of *homo ludens* (Huizinga, 2011) into serious everyday contexts, such as school and work (Larson, 2020; Westera, 2019). The word "serious" does not mean that these games are boring or humorless (Mitgutsch & Alvarado, 2013), but that players find enjoyment in the face of challenging tasks that require seriousness, engagement, and commitment. Players are eager to see how they can expand their own competences (Westera, 2019) which includes knowledge, skills, and attitudes (Blömeke et al., 2015). Hence, using these game properties in learning/training contexts can help learners to fulfill their basic human needs for autonomy, competence, and relatedness (Deci & Ryan, 1993, 2002, 2012) but also successfully encourage learners to engage with hands-on challenges, tasks, and lessons, and stay active past school or working hours (Westera, 2015; Westera, 2019).

Research on serious games shows mixed results. On the one hand, meta-studies claim that serious games have positive effects on cognitive, affective, emotional, motor, and social skills (Connolly et al., 2012; Boyle et al., 2016) and scientific reasoning through Commercial-Off-the-Shelf (COTS) or Massively Multiplayer Online Games (MMOs) (Connolly et al., 2012). On the other hand, some studies report unintended negative effects, such as a decrease in intrinsic motivation and changes to extrinsic motivation as a consequence of purely behavioral external award mechanics. Such "crowding-out-effects" of gamified curricula have been connected to poor performance and lower grades in final examinations (Hanus & Fox, 2015). A critical phase is also observed after the "novelty effect" wears out (Tsay et al., 2019).

Furthermore, studies show that the effectiveness of serious games is largely determined by game properties, the way it is implemented into the learning and training processes (Garris et al., 2002; Plass et al., 2015; Van Rosmalen & Westera, 2014), and to what extent it meets the needs and preferences of players (cf., Larson, 2020). There are games that neglect intended learning effectiveness and outcomes by ignoring postulated domain-specific or domain-general learning goals and content in favor of isolated experiences that emphasize either the fidelity of the environment, the quality of gameplay, or entertainment value for the player. Such games lack the necessary impulses to activate relevant teaching and learning processes to guide players (cf., Canhoto & Murphy, 2016; Westera, 2019). Serious games may improve learning processes when technology, content, and pedagogy successfully align. This alignment, which must be driven both by theory and evidence, occurs through (a) technologies featured in commercial games; (b) content that embraces the intended learning goals and competences through knowledge, skills, and attitudes; and (c) pedagogical teaching and learning processes and assessments that regard the intended outcomes (Loh et al., 2015; Mislevy et al., 2014; Verschueren et al., 2019; Weber et al., 2014).

Several authors (Gee & Shaffer, 2010; Ifenthaler et al., 2012) argue that games that are good learning engines should also be good assessment engines. In practice, applying serious games to learning environments that fit the set learning goals requires an adequate assessment of the whole environment, including the effect serious games have on players' learning progress and behavioral and social changes (Hummel et al., 2017; Mitgutsch & Alvarado, 2013). Before a serious game is widely adopted, we must first ensure its effectiveness as a learning and assessment tool (Hummel et al., 2017; Verschueren et al., 2019) by answering the following questions:

- Does this serious game evoke and foster the intended learning processes?
- Does this serious game measure the intended output/outcome in a valid and reliable manner?

With regard to these considerations, the literature introduces several elements, lists, and frameworks to assess the efficiency and effectiveness of serious games in learning, including but not limited to Kapp (2012), Mitgutsch and Alvarado (2013), Sailer (2016), Verschueren et al. (2019), and Warren et al. (2012). The evidence-centered design (ECD) approach (Mislevy & Rionscente, 2006; Pellegrino et al., 2016) and its evidence-centered game design (ECgD) (Mislevy et al., 2014; Mislevy, Steinberg, & Almond, 2003) variation are prominent frameworks used to set up a sound assessment. Nevertheless, it is often unclear how different assessment layers correspond to serious game design elements with regard to the player's competence (knowledge, skills, or attitudes) or the intended outcomes (Ifenthaler & Kim, 2019; Ke et al., 2019; Kim & Ifenthaler, 2019, p. 7). In other words, the following questions remain unanswered:

- How can competence models be operationalized and translated to learning mechanics?
- Through which serious game mechanics can players be prompted to show the intended competence?
- How can psychometrics as the basis of the assessment be implemented?

Our study shows how statistical models can help match the observed competence of players with an intended competence model formulated a priori and relate the results to the underlying theoretical competence model (Kim & Ifenthaler, 2019, pp. 7–8). Through our contribution, we sought to merge serious game elements with layers of the ECgD framework. To this end, we underline the changed view on the development of serious games for assessment purposes. By focusing on the third layer of the ECgD assessment—the Conceptual Assessment Framework (CAF) and its student model, task model, and evidence model—we demonstrate how an intended domain-specific competence can be operationalized and translated into learning mechanics, how game features should be selected to prompt the intended learning processes and play actions, and how these mechanics can be related to the intended competence (knowledge, skills, attitudes) through psychometrics. In our case, we selected sustainable creative competence (SC competence) in retail and sales as an example.

6.2 Theoretical Background

6.2.1 Serious Games

Although in general, *games* are not given a standard definition (Oranje et al., 2019), the term *serious game* was introduced by Abt (1970) to contrast the purposeful application of games with leisure games (Westera, 2019, p. 60). Broadly, serious games are games whose primary intentions are to achieve certain learning goals or to have a purposeful impact on the lives of players beyond the self-contained aims of engagement, entertainment, or satisfaction (Hogan et al., 2011, p. 4; Kapp, 2012; Larson, 2020, p. 319; Mitgutsch & Alvarado, 2013; Sailer, 2016, p. 12; Verschueren et al., 2019; Warren et al., 2012; Wouters et al., 2013; Wouters & van Oostendorp, 2017). Playfulness and seriousness are not necessarily opposed; while entertainment may not be their primary goal, serious games are not necessarily boring or humorless (Mitgutsch & Alvarado, 2013, p. 2). Likewise, playfulness and entertainment are not synonymous with easy. Papert (1980) coined the term *hard fun* to describe the entertainment value players find in difficult tasks and problems that require seriousness, engagement, and commitment when prompted to challenge their abilities (skills and competences) (Westera, 2019, p. 60).

Based on a literature review, Warren et al. (2012) defined six core principles that constitute learning games, and by extension, serious games: the possibility of *active play*, *conflict* as a motivator for play and cognitive activity, *rules* that represent the play structure, *interactivity* between the player and the game, *feedback* from the system, and *win/loss* ((2012, p. 15). Serious games can support and enrich school curricula by satisfying learners basic human needs for autonomy, competence, and relatedness (Deci & Ryan, 1993, 2002, 2012) through providing learners with entertainment, lack of negative feedback after failing a task, positive feedback upon success, clear rules and constraints, reasonable time limits, and homework and assessments (Westera, 2019, p. 60; Wouters et al., 2013). Furthermore, serious games are linked to affective, social, motor, and cognitive outcomes (Connolly et al., 2012; Westera, 2019). Therefore, these serious game properties can be applied to learning and work environments to actively engage with and challenge players (Westera, 2015, Westera, 2019, p. 60).

Although research on serious games is still underdeveloped, several meta-studies emphasize their positive effects (Westera, 2019, p. 60). One reason behind the mixed results might be the many possible approaches and methodologies. Based on a systematic literature review, Verschueren et al. (2019) drafted a theory-driven and evidence-based framework that introduces five stages for designing serious games through a holistic approach. The first stage is the serious game's *scientific foundation* that considers the target audience, learning objectives and outcomes, relevant pedagogical and game theory, the content domain, and the evaluation of the developed serious game in terms of quality and ethics. In the second stage, the scientific foundation is translated into the *design elements* of game mechanics (e.g., narratives, rewards, feedback, levels, protégé effect, etc.), design requirements (e.g., simple language, complexity level), and trial designs (e.g., data collection processes). The third stage consists of *practical development*, which includes selecting the game genre, formulating the narrative and story, programming game rules and algorithms, and visual design. The fourth stage is related to *validating* the developed serious game and the fifth and final stage concerns its *implementation* with aspects of dissemination, rollout, and follow-up. This broad approach covers a variety of serious game development aspects mentioned other renowned serious game taxonomies (Mitgutsch & Alvarado, 2013) and gamification elements for learning and work environments (Deterding et al., 2011; Kapp, 2012; Sailer, 2016; Sailer et al., 2017). On this basis, Verschueren et al. (2019) claim that an efficient and effective serious game design requires a coherent relationship between learning design and game design principles, which Arnab et al. (2015) introduces as the Learning Mechanics–Game Mechanics (LM-GM) model. The LM-GM model proposes the translation of learning goals into learning game mechanics based on learning theory (Verschueren et al., 2019, p. 11). According to the model, learning mechanics (LM) encompass a priori defined learning goals such as thinking skills like exploration, planning, and repetition, which may be related to problem-based learning theories and behavioral approaches. Those skills can be linked to one or more game mechanics (GM) such as story, strategy, and planning, and cascading information describing why they would be expected to evoke the necessary learning activities leading to the intended learning goal and output/outcome (Verschueren et al., 2019, p. 11; Patino et al., 2016). Here, it becomes overt that serious game design goes beyond the traditional game development framework mainly following the so-called MDA (mechanics, dynamics, aesthetics) procedure of Hunicke et al. (2004). The underlying assumptions here are that *game mechanics* (e.g., leaderboards) prompt a certain play behavior (*game dynamics*) such as collecting or competing and these actions provide the players with experiences and emotions such as satisfaction and fun (*game aesthetics*) (Hunicke et al., 2004; Sailer, 2016). In serious games, the learning goals and related learning theory are the points of departure.

Beyond these more cross-functional skills also domain-specific competences can be defined as learning goals. In the international discussion, competence is defined as learnable behaviors that encompass latent cognitive dispositions (knowledge and skills) and affective-motivational facets (attitudes) that manifest within the directly observable situation-specific performance (Blömeke et al., 2015; Mulder & Winterton, 2017). With regard to the design of serious games the intended domain-specific competence has to be operationalized into situation-specific learning behavior resulting in a particular performance. To realize this performance and, thereby, to show the domain-specific competence the learner must develop interest, motivation, or willingness to act in a particular situation (Blömeke et al., 2015; Deci & Ryan, 1993, 2002, 2012; Weinert 2001). Hence, the game design elements must be chosen in a way that they trigger such processes. Various learning theories sustain such learning and game mechanics (Patino et al., 2016).

6.2.2 Serious Games as Assessment Tools

Connolly et al. (2012) show that serious games are mainly used for learning rather than for summative assessment purposes (Hummel et al., 2017; Oranje et al., 2019, p. 37). To employ serious games as an assessment tool, Mislevy et al. (2014) suggest an evidence-centered assessment design (ECD) framework applied to game-based assessment, which they name evidence-centered game design (ECgD). The main focus of this framework lies on the structure of evidence-based reasoning, in the sense that it draws "reasoning from what students say and do, to understand what they know and can do" (Mislevy et al., 2013, p. 2). To implement the ECgD framework as a way to infer the extent of the intended competence from the observed behavior of students, Mislevy et al. (2014) suggest the application of five layers in a stringent and cohesive way:

1. *Domain Analysis*: In this first layer, we delve into the domains, including content, concepts, terminology, tools, common mistakes, difficulty levels of challenges to draw a bigger picture. It is also important to identify typical situations people face and which competences (knowledge, skills, and attitudes) are necessary to manage them. For learning, domain analysis provides us with information to formulate learning goals and build environments where students can show to which extent they have developed the intended competence. For game design, it provides us information on how to create engaging, interesting narratives and challenging domain-specific tasks. For assessment tools, it helps us craft specific situations and tasks through which we can assess the understanding and competences of students (Mislevy et al., 2014, p. 41, 136).
2. *Domain Modeling*: With regard to this layer, we must design the structure of the assessment argument. In other words, a specific learning goal must be drafted based on the domain analysis (e.g., systemic thinking competence). This will constitute the intended competence in the assessment. Such learning objectives may arise from empirically observed workplace affordances, from curricula set by companies, or from national school curricula (Mislevy et al., 2014, p. 42, 136).
3. *The conceptual assessment framework (CAF)*: The CAF represents the threefold central models of assessment: student model, task model, and evidence model. Through the *student model,* the intended competence is explicated and operationalized toward expected evidence that can be observed within the latter stages of the assessment process (e.g., the systemic thinking competence can be operationalized into "naming two main effects of a particular method and two unintended side effects"). In the specified ECgD, the overarching learning objective

or secondary objectives must be translated into the learning goal of the serious game and incorporated into the learning mechanics. The *task model* describes challenges (tasks, problems, conflicts, etc.) that are to be tackled and solved according to the student model (with regard to systemic thinking, in some situations, players are required to recognize major and side effects, whereas, in other situations, they should name or analyze them). These challenges in the task model represent situations that prompt players to act, and their actions produce evidence. To encourage players to act toward the intended outcome and keep playing, certain game mechanics are necessary to create challenges and tasks within the game. These game mechanics should be linked to learning mechanics and tackle the three basic needs proposed in the self-determination theory of Deci and Ryan (1993, 2002, 2012): autonomy, competence, and relatedness. This can take place through rules that enable autonomous decision-making or through challenges that allow players to perceive their competence via feedback or achievement graphs and figures. According to situated learning theory, such challenges should consider domain, content, and subject to be authentic and relevant for the particular learning or working context, while remaining meaningful and interesting enough to motivate players (CTGV, 1997; Lave, 1991). The challenges should be related to an intermediate achievement level for the target audience. This can be done by using learning taxonomies (Marzano & Kendall, 2007) and cognitive load criteria (van Merriënboer & Kirschner, 2018). The integrated feedback game mechanic informs the player about the progress toward the intended competence. With regard to relatedness, game mechanics should allow players to identify, collaborate, and empathize with the story and characters in serious games (Mislevy et al., 2014, p. 34–39). The *evidence model* bridges the task model—which prompts the players to act and enables them to show their competence in different situations—and the student model—which allows us to infer the progress toward intended competences. Within the evidence model, the observed play behavior (responses) are identified, collected, and evaluated through a scoring guide, which has to be developed a priori in accordance with the learning mechanics and goals. Additionally, players' responses are synthesized across all game situations and matched with the expected evidence formulated a priori by the student model. This can be done through classical test theory, but also through more complex statistical models, such as item response theory or inference in Bayesian networks (Mislevy et al., 2014, p. 51–53, 136).

4. *Assessment Implementation*: The fourth layer focuses on the production and prototyping of the serious game according to the theoretical and conceptual foundation made in the former layers. This layer includes authoring tasks, finalizing the rubrics, and automated scoring rules, piloting the serious game with regard to length, usability, motivation, cognitive load, etc., and evaluating the tool with regard to its quality, including validity, reliability, and fairness (Mislevy et al., 2014, p. 55, 122–133, 136). Salen and Zimmerman (2004) emphasize the necessity to perceive game development as an iterative process with several rounds of improvement and modification.

5. *Assessment Delivery*: This final layer is related to the architecture of the game process. In other words, how tasks are selected by the players, in which manner these tasks are presented to the players (different task formats, e.g., open-ended, classification, multiple- or single-choice, online or offline, via social media, etc.), when and where the players' responses are collected and documented (e.g., outside the game environment; within the game with regard to an expected behavior on a predefined work product, or with regard to a reaction on a class of tasks defined a priori) (Oranje et al., 2019). The responses are scored according to a transparent scoring guide, synthesized across the tasks, levels, and the whole serious game, matched with the student model and interpreted by inferring the results to the constituting target argument for the assessment, i.e., evidence-based reasoning on whether players achieved the intended competence (Mislevy et al., 2014, p. 55–57).

Figure 6.1 below shows how we merged the criteria for developing serious games according to the lists, frameworks, and taxonomies of Deterding et al. (2011), Kapp (2012), Mitgutsch and Alvarado (2013), Sailer (2016), Verschueren et al. (2019), and Warren et al. (2012), with the developed game-based assessments criteria based on the ECgD developed by Mislevy et al. (2014). Within this merging process, we have to disentangle the multitude of terms applied in the different sources and to express our connotation. We use *learning features (LF)* for the set learning goal and intended competence, the necessary engaging and emotionally relevant learning situations (*game aesthetics*) motivating to act in an intended manner (*intended game dynamics*). We use *game features (GF)* for means (*game mechanics*) prompting the players to show the intended competence through the observed performance (*observed game dynamics*). Decisions on both learning features and game features are based on learning and game theory and are stringently linked. The overarching

Serious Game as learning tools		Serious Games as assessment tools
Serious Games design	**Overarching guiding questions**	**ECD / ECgD**
Scientific foundation		
Purpose/Research objective	*What is the purpose and context of the game? What is the primary objective of playing the game?*	**Domain Analysis & Modeling**
Target audience Profile (age, prior knowledge, play literacy) Needs	*Who is the target audience?*	
Curricular (external) objective	*What should be the educational overarching objective?*	**Domain Analysis & Modeling**
Content /information	*Which domain should be treated and assessed?*	(A. Reporting Objectives)
Theoretical basis theories of learning theories of game theories of assessment theories of the particular domains	*How should the game achieve these intended objectives?* *Which theoretical considerations are necessary to achieve these intended objectives?*	
Output and Outcomes knowledge (e.g., insights in sustainability concepts) skills (e.g., efficient use of work tools, services) attitude (e.g., motivation, beliefs, loyalty) transfer (e.g., changed consumption behavior) social change (e.g., developing a new CSR strategy)	*What outcomes should be achieved?*	
Multidisciplinary approach	*Which disciplines are relevant to manage the design process?*	
Quality evaluation validity, reliability, comparability, fairness etc. ethical considerations	*Does the game achieve the intended curricular objective? Does it consider ethical issues?*	

continue

Fig. 6.1 Merging serious game mechanics with ECgD assessment criteria

Design foundation		**Conceptual Assessment Framework (CAF)**
Learning features (LF)		***Student model***
game dynamics (intended) game intended competence (verbs) game content/information rules	*Which secondary objectives of the curriculum should be achieved within the particular serious game? What should be the game goals?* *Which competence (facets) (game behavior/dynamics) should be prompted by the game mechanics?* *Which content raises interest, motivation and volition to play the game and to show the intended competence?* *Through which rules are we able to create a controllable assessment frame?*	(B integrating external objectives into game goals)
game aesthetics experiences (aesthesis: 'perception from the senses') surface design (graphics, language etc.)	*Which play experience must be created to stimulate and enable the players to show the intended competence (game behavior/dynamics)?* *Do and in which way players perceive the created game world and game mechanics?* *Which requirements have to be recognized to design the interface, considering the needs of the target audience?*	(D Engagement + meaning)
Game features (GF)	*By which game mechanics can we prompt the players to show their competence?*	***Task model***
game mechanics abstraction of concepts and reality storytelling/narrative characters protégé effect feedback reward challenge (conflict, competition, cooperation) curve of interest / flow time levels replay/do over win/lose		(C Formative feedback)
Game dynamics (realized and observed)	*Do the player show the intended and expected game behavior/dynamics?*	***Evidence model***
Game output/outcome knowledge (e.g., insights in sustainability concepts) skills (e.g., to counsel clients in sustainability issues) attitude (e.g., belief in sustainability values) transfer (e.g., changed consumption behavior in private life) social change (e.g., developing a new CSR strategy)	*Which play-behavior should be expected, observed and accepted as output/outcome resp. evidence?* *As product or process of playing?*	***Evidence model***

continue

Production of the game (Prototyping)		**Assessment Implementation**
Development of tasks, layout, etc. genre creating a domain-specific meaningful story/narrative producing the challenges, tasks, … building difficulty levels / play levels formulating the feedback programming the rules to define the playground formulating a scoring guide checking copyrights for pictures, graphs, etc.	*How can a theoretical-based game be realized within a CAF?* *Using results from the domain analyses*	authoring tasks finalizing rubrics automated scoring rules (D Engagement + meaning)
Evaluation		task/item analyses
tool evaluation motivation cognitive load think aloud usability	*Does the serious game enable players to show their competences?*	estimating parameters in measurement model piloting
quality validity reliability objectivity fairness	*Does the tool/serious game measure the intended competence in the necessary quality?*	
Administration		**Assessment Delivery**
play per course digital, analog, tasks formats data/evidence collection + scoring calculating scores + evaluating performance	*How do processes of (a) task selection, (b) task presentation, (c) data collection, and (d) scoring and interpretation occur?* *(a) out of the game; (b) product within the game; (c) process within the game* *task level, game level, game goals, coherence with overarching learning objective*	*Four-Process Architecture:* (a) activity selection process (b) presentation process *(c) evidence identification process (Evidence model)* *(d) evidence accumulation process (Evidence model)*
In accordance with Deterding et al. (2011); Kapp (2012); Mitgutsch & Alvarado (2013); Sailer (2016); Verschueren et al. (2019); Warren et al. (2013)		In accordance with Mislevy, Oranje, Bauer, von Davier & Hao (2014)

Fig. 6.1 (continued)

guiding questions demonstrate the connection and compatibility of serious games as learning tools as opposed to serious games as assessment tools.

With regard to our theoretical considerations and the results depicted in Fig. 6.1, (knowing that the rubrics are not necessarily exhaustive), in accordance with Mislevy et al. (2013), we assume that serious game design and assessment are compatible because both are related to the same principles of learning based on the structure of reasoning; in other words, we may draw conclusions from what the players say and do, to get insights into what they know and can do (Mislevy et al., 2013, p. 2). However, there are some constraints that must be considered during serious game design and the aligned assessment design right from the beginning. The primary focus of game-based assessment tools is gathering information to measure the progress toward the competence model formulated a priori, leaving play, engagement, and entertainment in the background. Furthermore, in game-based assessment, the results of player-driven actions and the processes they engaged in to achieve these results may be of interest to the analyses. When serious games are employed as assessment tools, Hummel et al. (2017) stated that the assessment should be as seamless and unobtrusive as possible to the players, while simultaneously maintaining reliability and validity (Hummel et al., 2017).

6.3 The Serious Game MyBUY

6.3.1 Context of the Serious Game MyBUY

Sustainable consumption behavior plays a central role in climate change (Harlow et al., 2016). To strengthen such competence, the German Federal Ministry of Education and Research launched the *Berufsbildung für nachhaltige Entwicklung 2015–2019* VET initiative for sustainable development (BiBB, 2019). From the perspective of VET apprentices in the field of retail, they can assume multiple functions and roles. On one hand, VET apprentices mediate sales through the company's corporate social responsibility (CSR) strategies to meet the needs of customers for sustainable products and services. On the other hand, they should also adopt sustainable consumption behavior in their private lives. Hence, the VET apprenticeship program in retail and sales, which is one of the most popular apprenticeship programs in Germany (BMBF, 2018), seems to be a good starting point to boost SC competence. Furthermore, salespeople often change places, as they must move between the selling floor, storage, accounting department, internal and external suppliers, etc. We decided, therefore, to create a mobile digital learning environment that can be accessed anywhere and anytime. The app-based learning environment has three components (Weber et al., 2019): (1) a training app to promote SC competence, (2) a serious game to visualize and assess the SC competence of players, and (3) a diary featured in the app (Rausch, 2011) to monitor the progress of the SC competence at the workplace. Our focus is on item (2): the serious game as a summative assessment tool.

6.3.2 Scientific Foundation: Domain Analysis and Domain Modeling

The serious game MyBUY was developed as an individual achievement tool (Oranje et al., 2019, p. 39) to assess SC competence. This is not only an affordance raised by workplaces but rather a learning object according to the official VET and school curricula. Thus, MyBUY's *target audience* comprises primarily apprentices in retail graduating their three-year program, but also young adults and responsible consumers.

We ran extensive domain analyses to narrow down the broad content area of sustainable consumption behavior and operationalized the intended learning goals toward SC competence. We included primarily expert focus groups, literature reviews, analyses of curricula, textbooks, Germany-wide examinations, and newsletters of sales organizations to identify real-life affordances and analyze the tasks and competences salespeople face in their workplace. As a result of these analyses, salespeople, apprentices in retail, and responsible consumers must cope, to a greater extent, with the following *typical situations* that comprise the *content* dimension of the game (Table 6.1):

Table 6.1 Typical situations and affordances in retail linked to sustainability: selected results of domain analyses

Sustainable situations	Situational affordances
CSR (Corporate Social Responsibility) report	• Improving the image and profit through transparent reports, e.g., according to the global reporting initiative standards (*economically*) • Reporting the turnover of careful resource programs (*ecologically)* • Sensitization of employees and customers with regard to sustainability (*socially*)
Seals as orientation for customers and symbols of the idea of sustainability	• Increase in turnover for products with seals (*economically*) • Certification on the basis of ecological standards (*ecologically*) • Information to consumers about a sustainable increase in value (*socially*)
Packaging and recycling	• Cost-cutting through fewer resource requirements (*economically*) • Awareness of substances and material (*ecologically*) • Information to consumers (e.g., reduction of plastic bags) (*socially*)
Energy efficiency	• Reducing energy costs (*economically*) • Reducing energy consumption (*ecologically*) • Communicating sustainable guidelines to consumers (*socially*)
Fair dealings with employees and stakeholders	• Increase in turnover through image-making (*economically*) • Increase in sustainable actions by informing employees and stakeholders (*ecologically*) • Further professional education and equal rights (*socially*)

To master these domain-specific situations in retail under a sustainability perspective, we identified the following facets of a domain-specific SC competence (Ritter von Marx et al., 2019) which becomes the *goal of our serious game*. Concerning the cognitive area, the competence facets are: (a) anticipatory thinking (ANTI), (b) systemic thinking (SYST), (c) instrumental understanding (INST), (d) sustainable managing (MANA), (e) obtaining and assessing information (OAI), and (f) communication (COMM). As for the noncognitive area, the facets are: (g) personal attitudes (ATTI), (h) personal standards of values (VALU), and (i) reflection (REFL). We grounded these categories on the *structure of our assessment argument*; players should be able to act in the context of retail and consumption in a sustainable and creative competent manner. Players should be able to anticipate present and future scenarios and identify sustainable challenges; for instance, creating or adapting a product line (ANTI). They should be able to apply systemic thinking by considering the tensions between the three subsystems of the triple bottom line method social (people), ecology (planet), economy (profit), when analyzing, for instance, the CSR report (SYST). They should be able to apply their domain-specific knowledge and tools in a sustainable creative competent manner (INST) when counseling a client, for example.

To develop a serious game that encourages players to improve their SC competence, we worked on the game as a *multidisciplinary project* with information scientists, VET experts, and professional media designers. We sought to use this serious game as an assessment tool, so we adopted a *theoretical learning* approach (including problem-solving) to get deep-level insights and generalized understandings based on conceptual background facts, principles, and theories (Westera, 2019). Simultaneously, we required instruction and guidance (Garris et al., 2002; Johnson et al., 2017; Kerres et al., 2009; Virvou et al., 2005; Westera, 2019) to avoid extended processes of search that could generate a heavy cognitive load on the working memory, which might evoke thoughtless trial and error strategies and lead to task completion at the expense of deep understanding (Westera, 2019). Thus, serious games should combine and integrate challenging gameplay properties and dedicated instruction (Westera, 2019). Hence, we decided to use the four-component instructional design (4C/ID) systematic approach, developed by van Merriënboer and Kirschner (2018), that assists and supports the development of serious games that offer entertainment and guidance while recognizing the cognitive load of learners. With regard to *theoretical game criteria,* we refer to the game mechanics summarized in our holistic framework in Fig. 6.1. As for the domain-specific content, we focus on *theoretical approaches to economy and business* with the triple bottom line concept of sustainability (Elkington, 2018; Pufé, 2014) and Corporate Social Responsibility (CSR) report (Elkington, 2018; Morsing & Schulz, 2006). Through these approaches, we intend to invite players into an interesting and engaging game-based assessment journey (Conejo, 2014; Tsay et al., 2019). The ECgD proposed by Mislevy et al. (2013) is applied to analyze the *quality of the game as an assessment tool* linked to the game criteria, as shown in Fig. 6.1.

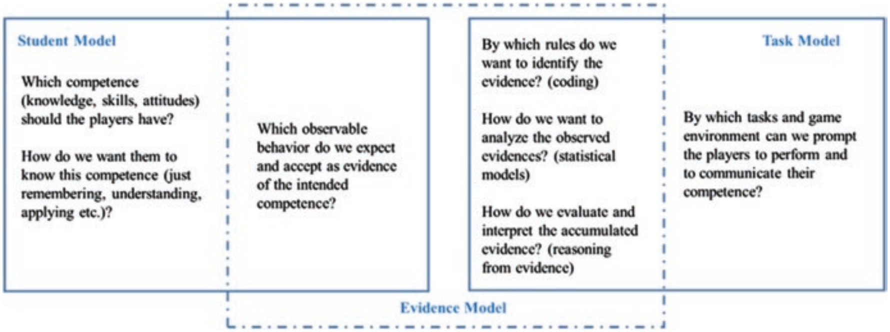


Fig. 6.2 Design Foundation—Conceptual Assessment Framework (CAF)

6.3.3 Design Foundation: Conceptual Assessment Framework (CAF)

The core of the Conceptual Assessment Framework (CAF) are the three models that depict the evidence-based reasoning process: the student model, the task model, and the evidence model (see Fig. 6.2). However, seeing as we sought to assess a domain-specific competence, our approach of using a serious game as a competence-driven assessment tool through the implemented questions had to change the chain of effects of traditional game development processes as introduced by Hunicke et al. (2004). Play and fun were not the primary goals under this perspective. We are also going beyond traditional serious game design suggested for example by Arnab et al. (2015) as this lacks the assessment view. First, we must clarify that the competence under assessment by the serious game (including facets of knowledge, skills, and attitudes) embedded in domain-specific situations (associated with game aesthetics) was operationalized through expected evidence (associated with intended game dynamics). By selecting certain game mechanics, we sought to prompt the aesthetics of players to allow them to willingly and joyfully perform the domain-specific tasks to show their competence respectively their observable performance (observable game dynamics).

6.3.3.1 Student Model

For this serious game, we explicitly formulated *SC competence as an assessment tool* set in the *domain modeling* layer, but only for the six cognitive competence facets, as the primary purpose of the serious game is assessment. However, noncognitive competence facets addressed by the app include videos for sensitization, for instance. Then, we further operationalized the assessment argument in relation to the retail-specific domain with typical everyday challenges (*learning features (LF) incl. Game aesthetics and intended game dynamics*). For example, to assure that players achieved systemic thinking as one cognitive facet of SC competence, players had to show that they understand and can judge the different steps of the supply chains of their products for sale with regard to sustainability issues. Through the game, they should show their ability to analyze the ecological, economical, and social effects with regard to individual consumers as well as the whole production and consumption system. They also should show SC competence in complex problem situations (e.g., creating or adapting a sustainable new product for a product line, judging the quality of fair trade, counseling a client with regard to their sustainable consumption decision-making, explaining seals to a customer). The operationalization toward observable behaviors is essential to make evidence-based inferences of the SC competence in players (Mislevy et al., 2014). In summary, our *goals for the serious game* in this model were that the players understood, analyzed, and applied six domain-specific SC competence facets: (a) anticipatory thinking (ANTI), (b) systemic thinking (SYST), (c) instrumental understanding (INST), (d) sustainable managing (MANA), (e) obtaining and assessing information (OAI), and (f) communication (COMM) (Ritter von Marx et al., 2019) (*intended game dynamics)* when solving authentic interesting challenges (*game aesthetics*).

6.3.3.2 Task Model

For the task model, we asked ourselves: through which tasks and *game features (GF)* can we prompt players to show the extent of their competence? Following Arnab et al. (2015), we mapped the translation of the SC competence model to specific *LF* (ownership, cognitive stimulation, etc.), *observed game dynamics* (systemic thinking to analyze the interrelationship of ecological, economic, and social tensions, etc.) and the *game mechanics* (authentic narrative, story, challenging tasks, etc.) within our serious game MyBUY as an assessment tool (see Fig. 6.3). After launching the serious game, players are led by an authentic narrative into a simulated retail shop. Here, they are welcomed by a fictional team member who is the head of the CSR department (protégé effect). This team member introduces them to the contents of the game, sustainability, CSR reporting, the context behind the annual sustainability contest, and the rules (tutorial). Then, players assume the role of an employee of the MyBUY company (ownership/identity/responsibility) who is responsible for holding the company's title won in the prior sustainability contest (competition; motivation) by solving typical authentic problems and tasks in retail concerning sustainability issues (authenticity; interest).

These typical tasks and problems occur throughout their year working in retail; for example, players can advise clients on sustainability issues along the supply chains or refute a client's concern about a scandalized product (authenticity, actions, motivation, and interest). The tasks were designed according to difficulty-generating factors related to cognitive requirements (Marzano & Kendall, 2007) as well as to cognitive load (van Merriënboer & Kirschner, 2018) which give support and guidance.

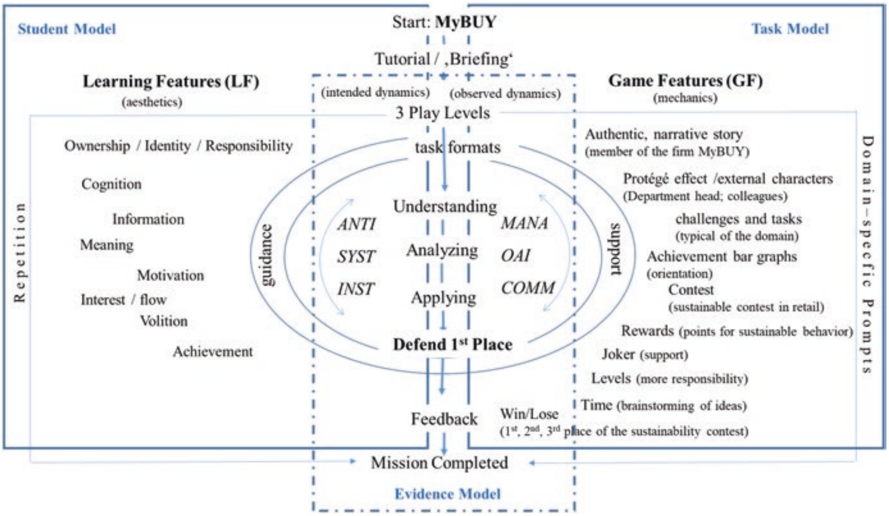


Fig. 6.3 Serious game map of MyBUY

The player gets one point for each correct answer relevant to responsible sustainable performance (formative feedback). A correct answer is defined a priori and fixed within an underlying coding guide (reward). If players need help, they can ask a virtual colleague (protégé, characters, identification, responsibility) using a joker (as all-purpose request assistance) (support, guidance). Feedback on the sustainable performance of players is given by a display bar in the format of a CSR department's satisfaction meter (orientation, achievement). The player runs through linear tasks that present domain-specific challenges along with the overarching storyline (interest curve/motivation). All players get the same tasks in the same order so that the assessment is standardized. The tasks are organized in three time frames (January to April, May to August, September to December) with three blocks each (blocks); each block consists of three tasks that rope players into one to four types of obstacles (decisions, judgments, and counseling and informing clients); for instance, treating a scandal on poisoned Rooibos teas (authenticity, interest, cognitive stimulation). Over the time frames the difficulty level increases (representing the increasing responsibility players earn for the MyBUY company) as players progress, and tasks also become more challenging. Correct answers award players double the points in the second time frame and quadruple in the third time frame) (rewards, levels, achievement, and motivation).

Each block represents different domain-specific areas to be tackled by the players to improve MyBUY's position in the sustainability contest (motivation; interest). By designing the surface with simple texts and pictures, we try to meet the aesthetic perceptions and needs of players (aesthetics, simple language). Since the serious game is a summative assessment, players are not allowed to replay failed tasks (replay/do-over), albeit early mistakes in the first time frame can be compensated for.

When players finish the game, they are given their individual scores and mastery percentage via the satisfaction meter (bar graph, feedback, orientation). Unused jokers add extra points at the end of the game (rewards). A player that gets a score lower than 60% gets feedback that they do not reach the winners' podium. If players reach a score from 60% to 75%, they get a bronze medal; scores from 76% to 85% award players a silver medal; and players who score over 85% get a gold medal (win/loss). The player can interrupt the serious game at any point and resume later without losing progress. A progress bar shows players how much game content is left (orientation, feedback).

6.3.3.3 Evidence Model

Since we developed the serious game as an assessment tool in accordance with the ECgD framework, we sought to assess the players' acquired SC competence (focusing on the cognitive facets) through goals and achievements. In further studies, we intend to analyze logfiles or transfer the implemented learning and working diary to monitor the effect the game had on players.

6.3.4 Production of the Serious Game: Assessment Implementation

6.3.4.1 Development of the Tasks

After mapping out the serious game on a conceptual level, we *authored* the concrete narrative and the single tasks and incorporated the tasks into a sequence of *sense-making game blocks along with a storyline*. The information of the broad and deep domain analyses provides fruitful guides to construct correct and *authentic tasks* and problems in the field of retail and sales (e.g., counseling clients on seals, selecting sustainable products for the production line, clearing up customer complaints) (curve of interest/flow; meaningful actions, interest, motivation). *Levels* were implemented by structuring the tasks into three time frames (January to April, May to August, September to December); as players progress, they are given more and more responsibility. Task difficulty also varies according to four difficulty-generating factors following the instructional design approach for complex learning developed by van Merriënboer and Kirschner (2018): (a) cognitive requirements, (b) complexity, (c) problem structure, and (d) support within the task format. This procedure allows us to control *intrinsic cognitive load* by (a) using different levels of the cognitive taxonomy (Marzano & Kendall, 2007); (b) varying the number of elements to be simultaneously worked on (Paas et al., 2003; Sweller et al., 1998); (c) offering well- and ill-structured problems—the latter often has multiple solutions or are redundant, in the sense that players must first identify and then select relevant information (Bley et al., 2015; van Merriënboer & Kirschner, 2018); and

(d) altering the amount of support given within the task format and guidance offered to the players (Van Merriënboer et al., 2002). To this end, we posed classification tasks, multiple-choice tasks, fill-in tasks, open-ended tasks, whereas completion tasks and conventional tasks were given to players who had built their cognitive schemata through the course of the game (van Merriënboer & Kirschner, 2018). Additionally, we developed score guidelines in the code. For open-ended tasks, the rubrics were fixed. For other tasks, the scores were linked to the possible responses by an automated procedure. The algorithm for weighing the scores from the second and third time frames, as well as the algorithm for use/nonuse of jokers, was implemented to affect the final score. Simultaneously, the output file was designed and created to record the players' actions and responses in the backend for future analyses.

6.3.4.2 Design and Layout

The layout of the app was designed to avoid *extraneous cognitive load* that results from poorly designed instructions and tasks. Therefore, we reduced the nondesirable kind of cognitive load by (a) highlighting headlines or using symbols to point out important information (Mayer & Moreno, 2010); (b) respecting the different audio, verbal, and visual channels to consider different types of modality (van Merriënboer & Sweller, 2005); (c) avoiding redundancies by giving relevant information on the tasks via a single channel (Mayer & Moreno, 2010); (d) considering the contiguity principle when presenting information and elements along with pictures and graphs to be processed simultaneously; and by (e) using a simple verbal language to prevent misunderstandings that may evoke biases (Kettler et al., 2011; Schnell, 2017). By balancing the intrinsic and extrinsic cognitive loads, the remaining cognitive load is reserved for the *germane cognitive load*, which is the load necessary to work on problems.

Thus, 27 tasks with different difficulty structured in nine blocks on three different levels (time frames) serve as a tool for summative assessment (Oranje et al., 2019, p. 40). To check our theoretically designed tasks we ran an expert rating. Thereby each task was rated by VET experts with regard to the difficulty aspects: *cognitive requirements* (understanding: 0; analysis: 1; application: 2), *complexity* (element interactivity: < 2 elements: 0; otherwise: 1), *problem structure* (clear solution and no redundant information: 0; otherwise: 1), and *support within the task format* (completion task: 0; conventional task: 1). Thus, there was a maximum of 5 difficulty points per task, 15 per block (5 × 3) and 135 total difficulty points (27 × 5) (Bley, 2017; Bley et al., 2015; Weber et al., 2016). To the end of this ranking got a difficulty index for the tasks.

Let us take a *simple task* (time frame 1, block 1, task 2; Fig. 6.4) as an example. This task contains three stimuli for players to act upon a customer dialogue according to the triple bottom line concept (profit, planet, people). A customer asks players "Is the MyBUY really engaged in social belongings? I, as a consumer, did not hear anything about such endeavors." The player is requested to choose the most

Fig. 6.4 Examples for *simple task* in time frame 1, block 1, task 2

adequate answer that will convince the customer that MyBUY is involved in social belongings.

To solve this task, players must apply their declarative knowledge on the triple bottom line approach, analyze the presented arguments, and select the most adequate or correct answer (cognitive requirement: 1). The players focus only on one element, the social belongings of MyBUY (complexity: 0).

There are no conflicts to be solved (clear solution: 0). There is just one right available answer to be marked (completion task: 0). The task is quite supportive because it is preprocessed. The player has no need to create or formulate their own arguments since the arguments can be selected in the task (SC-format: 0). In total, the difficulty index amounts to 1 difficulty point from a maximum of 5 (=20%). Hence, this task is classified as simple according to our standards. This is supported by the empirical model, which has a high solution rate.

Now, let us take a *difficult task* (time frame 1, block 2, task 2; Fig. 6.5). This task contains three stimuli for the players to act upon according to the triple bottom line approach and different seals. With regard to a tea scandal, MyBUY took a certain Rooibos tea out of the shelf. Now the CSR manager asks players to decide on a new tea product to fill up the assortment. Hence, they must consider the following MyBUY conditions: (a) it should be an organic product, (b) the producer of the tea should take social responsibility, and (c) 10 g of tea should cost at most 1 €.

Here, players must analyze the given characteristics of three tea types considering the three MyBUY requirements and to mark for the presented criteria and whether they fit the requirements or not. The players select the tea type that they consider the most suitable and formulate an argument for their decision (cognitive requirement: 2). For this analysis, players must tackle many elements (the MyBUY requirements, the three dimensions of the triple bottom line approach, and the different seals) (complexity: 1). Although there is one single solution to this problem, there is redundant information (a) kept within the drop-down field for defining the fulfilling criteria and (b) the seal for tea C overfulfills the MyBUY requirements (no

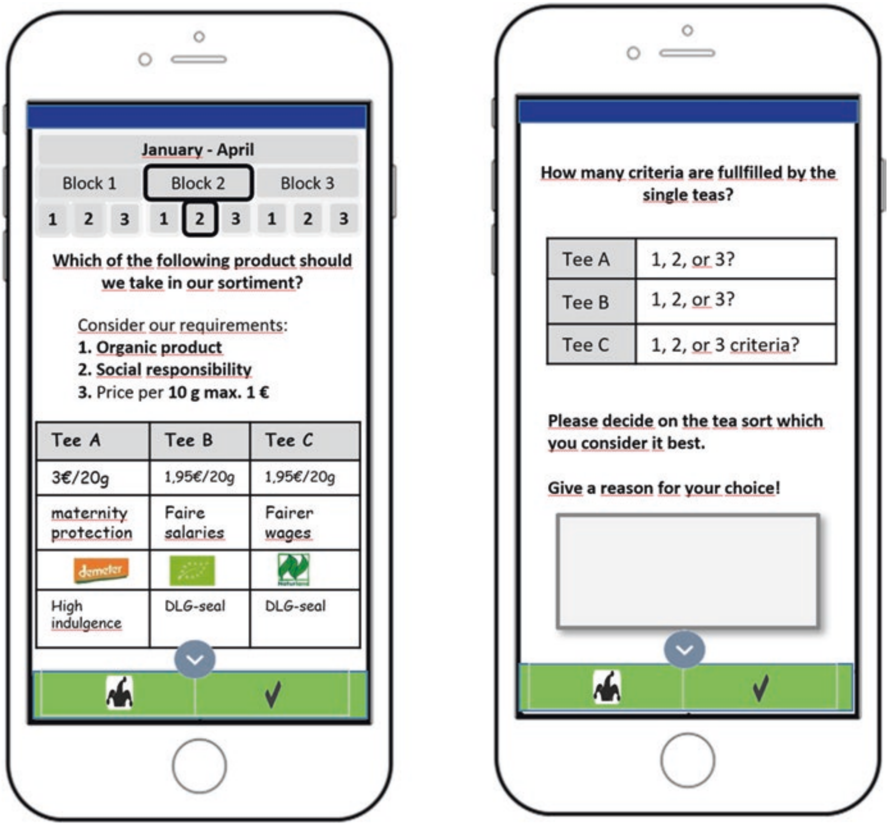


Fig. 6.5 Examples for a *difficult task* time frame 1, block 2, task 2

clear solution, redundant information: 1). The task format provides no support. The player has to analyze the information, mark the right criteria, and formulate an argument in an open input field (no support, conventional task: 1). In total, the difficulty index amounts to 5 difficulty points from a maximum of 5 (=100%). Hence, this task is classified as difficult according to our standards. This is supported by the empirical model, which has a low solution rate.

6.3.5 Evaluation: Assessment Implementation

Before commencing the assessment, the serious game MyBUY has to be piloted for quality assurance. Mislevy, Wilson, et al. (2003) consider validity, reliability, comparability, and fairness important qualities of assessment arguments. Depending on the evidence and the intended inference (lower or higher stakes), these quality criteria are more or less critical and operationalized at different levels. In our first pilot of MyBUY, we focused on validity. We sought to answer the question: does the serious game measure the intended construct of SC competence (with a focus on the cognitive part) in retail and sales contexts? Since there is no gold standard to test validity, we selected three types of validity studies in accordance with Messick (1989): (a) to assess *content validity*, we ran extended domain analyses (cf., analyzing newsletters, textbooks, final examinations in the retail of the Chambers of Industry and Commerce) and focus groups with VET teachers, trainers, and students; (b) to assess *cognitive validity*, we conducted think-aloud studies with VET apprentices and analyzing their mental processes as they solved the serious game tasks (Brünken et al., 2003); (c) finally, our current study addresses the *structural validity.* To secure quality assurance, we evaluated the usability of the serious game (Brooke, 1996) and the evoked cognitive load (van Merriënboer & Kirschner, 2018) and motivation (Deci & Ryan, 1993, 2002, 2012).

6.3.6 Assessment Delivery

To provide players with a seamless and as unobtrusive as possible assessment via the serious game (Hummel et al., 2017), Mislevy et al. (2013, p. 56) suggest a four-step process to standardize and monitor the assessment procedure: (a) task selection, (b) task presentation, (c) data collection, and scoring, and (d) accumulating the evidence for evidence-based reasoning and interpretation.

6.3.7 Research Questions

Through our pilot studies, we provide a first-hand look at our approach to answering open questions as asked by Kim and Ifenthaler (2019, p. 7). Our approach merged serious game development criteria and learning theory with the ECgD layers. To this end, we integrated the learning and assessment aspects of serious games into a holistic framework (Fig. 6.1). Simultaneously, we suggested—with regard to SC competence—how competence models can be transformed into learning mechanics and interesting, engaging game mechanics in a serious game. We showed how formalized assessment models as the ECgD can be linked to serious game design elements and how psychometrics can be implemented. Through this procedure, we were also able to demonstrate how players' responses can be inferred to the intended competence and the underlying theoretical competence model. Our pilot led us to four research questions:

- RQ1: How can we assess SC competence in the serious game MyBUY?
- RQ2: Is usability for the serious game MyBUY given?
- RQ3: To what extent do cognitive load dimensions (extraneous, intrinsic, germane) affect players of the serious game MyBUY?
- RQ4: Through which aspects does the serious game MyBUY motivate players?

6.4 Methodology

6.4.1 Sample and Data Collection

Within our pilot study, N = 30 bachelor's students in the first year of Business Studies played the serious game MyBUY. Their experiences are comparable with those of third-year VET apprentices in retail. Since the tasks were related to sales, they also mirrored the perspective of private consumers. Data collection occurred within the serious game as responses on a class of domain-specific tasks and problems defined a priori (Oranje et al., 2019, p. 40). Additionally, we collected data on usability, cognitive load, and motivation via a questionnaire. We allowed students to play the serious game with no time constraints. On average, students took 63 min to play the serious game and 10 min to answer the questionnaires.

6.4.2 Measures and Analyses

Within this pilot, we ran a holistic evaluation of the serious game MyBUY through different approaches. First, we wanted to observe the players' empirical *sustainable creative performance* when solving sustainable challenges and tasks in the domain of retail to validate our theoretical model and carefully infer the underlying SC competence (RQ1). Second, we wanted to control for *usability* (Bangor et al., 2008; Brooke, 1996, 2013) to assure that there are little to no negative influences from handling the app (RQ2). Third, we sought to monitor the *cognitive load* (Leppink et al., 2014) to further increase validity and ensure that the players were not distracted by poorly designed elements and to regulate the task difficulty (RQ3). Finally, we were interested in whether we offered the players interesting tasks through which they experience autonomy, competence, and (social) relatedness, and are thus *motivated* (Deci & Ryan, 2012; Sailer, 2016; Sailer et al., 2017) (RQ4).

6.5 Results

6.5.1 Validating the Sustainable Creative Competence Model

When playing the serious game MyBUY, players employed their competence to solve typical domain-specific problems through their responses and their progress became evident through their performance. According to the evidence-based reasoning underlying the ECgD used, we can infer the latent SC competence from this observed performance (Mislevy et al., 2014). Simultaneously, the theoretical SC competence model (see Fig. 6.6, left) matches the empirically observed SC performance (see Fig. 6.6, right). The identified SC competence facets are displayed in the columns in Fig. 6.6. These facets were assigned to nine different game blocks (displayed in the lines) by typical domain-specific tasks. While working on these tasks, players tackled sustainable challenges and problems in typical retail situations (see Table 6.1) identified by domain analyses. For instance, they analyzed seals (block 8) using their anticipatory thinking (ANTI) competence or applied a CSR report statement as they advised a customer using their communication (COMM) competence (block 6).

To match the theoretical and the empirical model, all designed game tasks were ranked by a difficulty index. Tasks were classified as (a) simple (S) when they reached 0–33% of the maximum of points within the expert ratings on the difficulty index, (b) medium (M) when they reached 34–66% of the maximum points within the difficulty index, and (c) difficult (D) when they reached 67–100% of the maximum points within the difficulty index.

The 27 tasks were classified as follows: 9 simple, 10 medium, 8 difficult distributed over the nine game blocks. This distribution according to the expert ratings reflects a balanced picture of the challenges to be mastered across the serious game MyBUY. The tasks also demonstrated an overall medium level of difficulty, which fits the profile of the target audience. For the empirical model, we classified the observed performance scores of the students playing MyBUY as simple (S) when

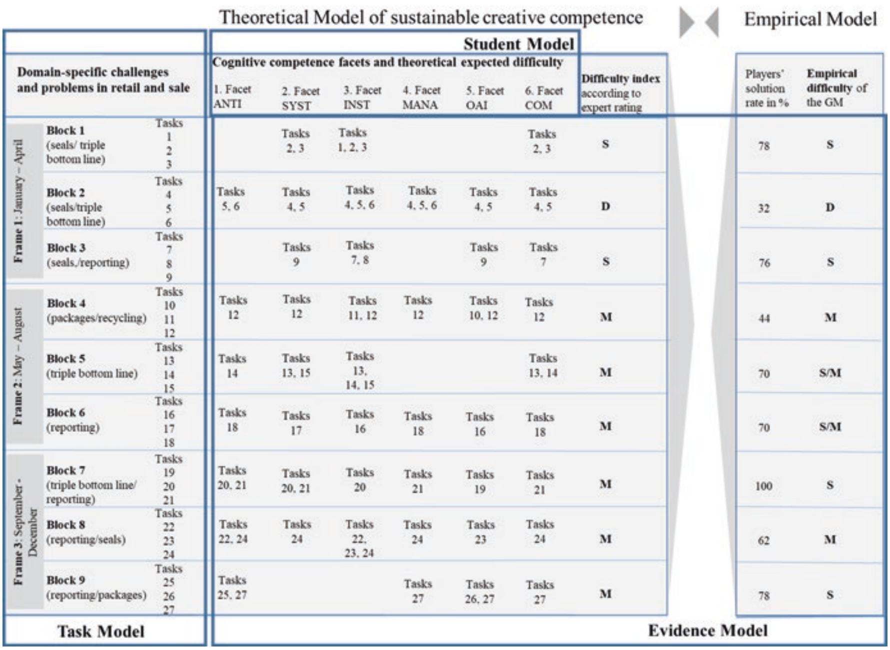


Fig. 6.6 Examples of the domain-specific SC competence modeled a priori matched with the performance observed when solving domain-specific problems and tasks

they reached 67–100% of the possible solutions; medium (M) when they reached 34–66% of the possible solutions and difficult (D) when they reached only 0–33% of the possible solutions. The empirical results showed an overall Cronbach's Alpha value of $r = 0.69$.

The results of the matching procedure show that the theoretically-founded design of the serious game MyBUY fits the empirical achievement of the players. In five of nine game blocks, our theoretical model fits the solution rates of the empirical model, and they were closest in blocks 5 and 6. Hence, we may assume that our merged framework (Fig. 6.1) of linking theory-based learning mechanics and game mechanics with the ECgD framework is a reliable way to design a game-based learning environment using a serious game as an assessment tool.

6.5.2 Usability

According to international standards, products with a practical value are those that allow users to reach an intended goal and that can be efficiently and effectively used in a given context that leads to everyone's overall user satisfaction (DIN EN ISO 9241-110, 2020; Niegemann et al., 2008; Preece et al., 1994). Brooke (1996) outlines three major concepts within that framework: (a) *effectivity* refers to the ability of users to fulfill tasks within the system and the quality of output of those tasks, (b) *efficiency* is related to the number of resources consumed when completing these tasks, and (c) *satisfaction* describes the subjective reactions of users as they perform these tasks (Bangor et al., 2008; Brooke, 1996, 2013; Sangmeister et al., 2018). Although there are additional ways to assess practical value (e.g., functionality, transparency, complexity) (Herczeg, 2009; Issing & Klimsa, 2002; Sangmeister et al., 2018), these are the three basic criteria outlined by the ISO. These criteria are operationalized by the 10-item System Usability Scale (SUS) questionnaire (Brooke, 1996) to ensure a high response rate and quality responses (Brooke, 1996). The SUS is a practical and relevant tool (Bangor et al., 2008; Brooke, 2013) that shows reliable results with small samples ($N = 8$ to 12) (Brooke, 2013, p. 33). The comparison with Cronbach's Alpha shows a value of $r = 0.85$ (Bangor et al., 2008, p. 575).

Figure 6.7 shows the answer distribution for the 10 items of the SUS (adapted from Brooke, 1996) when applied to players of the MyBUY serious game in the pilot stage. Since four of the items are formulated negatively (−) with respect to our game, the difference to 100 was taken as a value. The average usability was 69.3. This value corresponds to the averages for 206 studies in a meta-analysis by Bangor et al. (2008, p. 577) for individual surveys (70.1) and multiple surveys (69.7). According to Bangor et al. (2008, p. 588), a 69.3 usability is within the "marginal ok" rating scale, almost at the "acceptable good" range. Comparable values in the context of serious games are found in the literature (cf. Arnab et al., 2015, p. 15).

Fig. 6.7 Usability of the serious game MyBUY

6.5.3 Cognitive Load

Through the 4C/ID approach in the serious game, we tried to balance the cognitive load and, simultaneously, task difficulty for the players. We measured three types of the cognitive load caused by the serious game MyBUY, using the Cognitive Load Questionnaire (Leppink et al., 2014) with its ten items on a Likert scale from 1 to 6 (Table 6.2):

These first results demonstrate that the cognitive load of the learners could be influenced as expected by the theoretical assumptions of the 4C/ID approach. For the MyBUY serious game, the germane cognitive load has the highest value and the extraneous cognitive load has the lowest. The tasks, therefore, could be considered goal-oriented. The highest effort from the part of players was related to the main mental processes when solving the tasks and problems of the game. The intrinsic cognitive load, which is related to the number of elements to be handled simultaneously ("elements interactivity"), showed an average value that indicates that the tasks in the serious game MyBUY corresponded to a medium level of cognitive affordances with respect to task difficulty (related to cognitive level, complexity, problem structure, and support within the task format).

6.5.4 Motivation

Serious games can motivate young people and motivation is necessary to assess performance. Thus, we assessed the motivational effects of our serious game by using the questionnaire designed by Sailer (2016). This questionnaire drew from the

Table 6.2 Cognitive load within the serious game MyBUY

Types of cognitive load	*Serious Game*	
	Mean	*SD*
Germane cognitive load (GCL)	4.06	0.95
Intrinsic cognitive load (ICL)	3.42	1.13
Extraneous cognitive load (ECL)	2.42	1.17
Total cognitive load (TCL)	3.38	1.27

Remarks. $N = 30$; reliability: $r = 0.68$ ($r_{GCL} = 0.95$; $r_{ICL} = 0.61$; $r_{ECL} = 0.56$)

self-determination theory of Deci and Ryan (1993, 2002, 2012) with the dimensions *autonomy*, *competence*, and *(social) relatedness*. This 13-item questionnaire took the form of a Likert scale from 1 to 6 with Cronbach's Alpha values of $r = 0.76$ ($r_{aut} = 0.76$, $r_{com} = 0.79$, $r_{rel} = 0.92$).

The results for *autonomy* (x = 4.07; SD = 1.32) and *competence* (x = 4.31; SD = 1.00) were satisfactory and good. *(Social) relatedness* showed lower values (x = 2.39; SD = 1.17). Items such as "I feel as part of a team" were scored "not satisfactory". This score can be justified by the fact that the serious game MyBUY is played offline because some players may not have a permanent internet connection. Therefore, networking within the serious game is not possible. Additionally, the assessment was directed to the individual and not the collective performance of the players.

6.6 Discussion and Impact

The popularity, appeal, and potential of serious games are definitely behind the novel interest in applying them as learning and summative assessment tools. However, our literature review on serious games shows the majority of these games seem to be applied primarily in a learning context; only a few are used as assessment tools. Furthermore, most (serious) games prioritize authentic experiences without offering support or guidance and focus primarily on general knowledge and skills instead of fostering domain-specific competences. Thus, most serious games do not fit the requirements for a sophisticated assessment tool, regardless of their purpose. Additionally, existing serious games show weaknesses with regard to objectivity, reliability, validity, and design (Hummel et al., 2017; Westera, 2019; Wouters et al., 2013).

In our contribution, we sought to merge serious game criteria with the assessment layers of the ECgD. To this end, we also left behind the traditional perspective of common game design procedures. When applying serious games as assessment tools it is not sufficient to just impose game mechanics which evolves certain game dynamics and further more positive responses from the players in the sense of game aesthetics. With regard to serious games—with a specific educational purpose—we must consider learning theory to stimulate corresponding cognitive and noncognitive learning processes. Additionally, by using a serious game as an assessment tool, we shift the view toward a game-based assessment perspective.

The Conceptual Assessment Framework (CAF) of the ECgD approach allowed us to develop a student model, task model, and evidence model in a stringent and cohesive way to demonstrate how an intended domain-specific competence can be operationalized and translated to learning features, and how game features should be applied to prompt intended learning processes and evoke play actions. We also show how game features can be related via psychometrics to a specific competence (knowledge, skills, or attitudes) of interest; in our case, the SC competence in retail and sales. Through the MyBUY serious game, we show that it is possible and worthwhile to take the hard path and formulate domain-specific competences to identify typical real-life situations and translate them into challenging authentic tasks and serious game features. The evidence-based construction of tasks—especially integrated game features built on instructional design components and cognitive load aspects—seems to yield fruitful results. We achieved the expected performance and difficulty levels by using these construction criteria. Furthermore, the serious game MyBUY shows usability and is perceived as motivating. The players can act in an autonomous space and experience competence. Although we could not answer all questions within the presented study, our results, especially those with regard to the fit between the theoretical competence model and the solution rate of the empirical model, encourages us to investigate further.

6.7 Limitations and Outlook

This study does have some limitations. First, further validation studies by more complex theory-oriented statistical models are needed, such as IRT (item response theory) and other analytic techniques for pattern detection in game-based research (Embretson, 2010; Schrader et al., 2019, p. 22). In addition, there is a lack of comparative studies with known groups or groups with other expected effects and longitudinal studies to analyze development processes. Such approaches may provide more insights into the realized cognitive processes and allow for generalizability of the results (Achtenhagen & Winther, 2014; Bley, 2017; Kreuzer et al., 2017; Weber & Achtenhagen, 2014; Weber et al., 2016).

Furthermore, it is also necessary to include more noncognitive elements into assessments to cover the entire SC competence. Further studies should include more extensive data collections within and out of the game—also with regard to big data. From a more critical point of view, the goals, intentions, added value, and consequences of observing people (students, apprentices, applicants, employees, etc.) while playing must be analyzed and reflected upon under an ethical perspective to avoid exploitation and manipulation (Kim & Werbach, 2016; Larson, 2020).

Acknowledgements This study was part of the overarching government-funded project "Development of training and qualification concepts for sustainability in commercial occupations" endorsed by the German Federal Ministry of Education and Research (BMBF; https://www.bibb.de/de/33716.php). Within the funded overarching project, we developed an app-based tool that integrated a learning app, an app-based serious game, and a learning diary for young adults in retail and sales (see Weber et al., 2018; funding no.: 21BBNE12). Several people have contributed to the project as a whole at different times and in different ways. We would like to extend our thanks to Sandra Bley, Janne Kleinhans, Christine Kreuzer, Raphael Meyer von Wolff, Sophia Reh, Susanne Ritter von Marx, and Henrik Wesseloh.

References

Abt, C. (1970). *Serious games*. Viking Press.

Achtenhagen, F., & Winther, E. (2014). Workplace-based competence measurement: Developing innovative assessment systems for tomorrow's VET programmes. *Journal of Vocational Education & Training, 66*, 281–295.

Arnab, S., Lim, T., Carvalho, M. B., Bellotti, F., de Freitas, S., Louchart, S., Suttie, N., Berta, R., & De Gloria, A. (2015). Mapping learning and game mechanics for serious games analysis. *British Journal of Educational Technology, 46*(2), 391–411.

Bangor, A., Kortum, P. T., & Miller, J. T. (2008). An empirical evaluation of the system usability scale. *International Journal of Human-Computer Interaction, 24*(6), 574–594.

BiBB. (2019). *Berufsbildung für nachhaltige Entwicklung 2015–2019*. BiBB.

Bley, S. (2017). Developing and validating a technology-based diagnostic assessment using the evidence-centered game design approach – An example of intrapreneurship competence. *Empirical Research in Vocational Education and Training, 9*(6), 1–32. https://doi.org/10.1186/s40461-017-0049-0

Bley, S., Wiethe-Körprich, M., & Weber, S. (2015). Formen kognitiver Belastung bei der Bewältigung technologiebasierter authentischer Testaufgaben – eine Validierungsstudie zur Abbildung von beruflicher Kompetenz. *Zeitschrift für Berufs- und Wirtschaftspädagogik, 111*(2), 268–294.

Blohm, I., & Leimeister, J. M. (2013). Gamification: Design of IT-based enhancing services for motivational support and behavioral change. *Business & Information Systems Engineering (BISE), 5*(4), 275–278. https://doi.org/10.1007/s12599-013-0273-5

Blömeke, S., Gustafsson, J.-E., & Shavelson, R. (2015). Beyond dichotomies. Competence viewed as a continuum. *Zeitschrift für Psychologie, 223*(1), 3–13.

BMBF (Bundesministerium für Bildung und Forschung). (2018). *Berufsbildungsbericht 2018*. BMBF.

Boctor, L. (2013). Active-learning strategies: The use of a game to reinforce learning in nursing education. A case study. *Nurse Education in Practice, 13*(2), 96–100.

Boyle, E. A., Hainey, T., Connolly, T. M., Gray, G., Earp, J., Ott, M., Lim, T., Ninaus, M., Ribeiro, C., & Pereira, J. (2016). An update to the systematic literature review on empirical evidence of the impacts and outcomes of computer games and serious games. *Computer & Education, 94*, 178–192. https://doi.org/10.1016/j.compedu.2015.11.003

Brooke, J. (1996). SUS: A 'quick and dirty' usability scale. In P. W. Jordan, B. Thomas, B. A. Weerdmeester, & A. L. McClelland (Eds.), *Usability evaluation in industry* (pp. 189–194). Taylor and Francis.

Brooke, J. (2013). SUS: A retrospective. *Journal of Usability Studies, 2*, 29–40.

Brünken, R., Plass, J. L., & Leutner, D. (2003). Direct measurement of cognitive load in multimedia learning. *Educational Psychologist, 38*(1), 53–61.

Canhoto, A. I., & Murphy, J. (2016). Learning from simulation design to develop better experiential learning initiatives: An integrative approach. *Journal of Marketing Education, 38*(2), 98–106.

Conejo, F. (2014). Loyalty 3.0: How to revolutionize customer and employee engagement with big data and gamification. *Journal of Consumer Marketing, 31*(5), 403–404.

Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education, 59*(2), 661–686.

CTGV (Cognition and Technology Group at Vanderbilt). (1997). *The Jasper project: Lessons in curriculum, instruction, assessment, and professional development*. Erlbaum.

Day-Black, C., Merrill, E. B., Konzelman, L., Williams, T. T., & Hart, N. (2015). Gamification: An innovative teaching-learning strategy for the digital nursing students in a community health nursing course. *Journal of the Association of Black Nursing Faculty in Higher Education (The ABNF Journal), 26*(4), 90–94.

Deci, E. L., & Ryan, R. M. (1993). Die Selbstbestimmungstheorie der Motivation und ihre Bedeutung für die Pädagogik. *Zeitschrift für Pädagogik, 39*(2), 223–238.

Deci, E. L., & Ryan, R. M. (2002). *Handbook of self-determination research*. The University Rochester Press.

Deci, E. L., & Ryan, R. M. (2012). Motivation, personality, and development within embedded social contexts: An overview of self-determination theory. In R. M. Ryan (Ed.), *The Oxford handbook of human motivation* (pp. 1–59). Oxford University Press.

Deterding, S., Sicart, M., Nacke, L., O'Hara, K., & Dixon, D. (2011). Gamification. Using game-design elements in non-gaming contexts. In *CHI 2011 extended abstracts on human factors in computing systems* (pp. 2425–2428). ACM. https://doi.org/10.1145/1979742.1979575

DIN EN ISO (Deutsches Institut für Normung e.V., International Organization for Standardization). 2020). *Ergonomie der Mensch-System-Interaktion – Teil 110: Interaktionsprinzipien (ISO 9241-110:2020)* [Ergonomics of human-system interaction - Part 110: Interaction principles]. Deutsche Fassung EN ISO 9241-110:2020.

Elkington, J. (2018). 25 years ago I coined the phrase "triple bottom line" Here's Why It's Time to Rethink It. *Harvard Business Review Digital Article* (6),

Embretson, S. E. (2010). Measuring psychological constructs with model-based approaches: An instruction. In S. E. Embretson (Ed.), *Measuring psychological constructs: Advances in model-based approaches* (pp. 1–7). American Psychological Association.

European Central Bank. (2019). *Economia game*. Retrieved August 7, 2020, from https://www.ecb.europa.eu/ecb/educational/educational-games/economia/html/index.en.html

Garris, R., Ahlers, R., & Driskell, J. E. (2002). Games, motivation, and learning: A research and practice model. *Simulation & Gaming, 33*(4), 441–467. https://doi.org/10.1177/1046878102238607

Gee, J. P., & Shaffer, D. W. (2010). Looking where the light is bad: Video games and the future of assessment. *Phi Delta Kappa International EDge, 6*(1), 3–19.

Hanus, M. D., & Fox, J. (2015). Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance. *Computers & Education, 80*, 152–161. https://doi.org/10.1016/j.compedu.2014.08.019

Harlow, J., Bernstein, M. J., Girod, B., & Wiek, A. (2016). Consumption and sustainability. In H. Heinrichs, P. Martens, G. Michelsen, & A. Wiek (Eds.), *Sustainability science* (pp. 293–301). Springer.

Herczeg, M. (2009). *Software-Ergonomie: Theorien, Modelle und Kriterien für gebrauchstaugliche interaktive Computersysteme*. 3. Aufl. de Gruyter/Oldenbourg.

Hogan, M., Kapralos, B., Cristancho, S., Finney, K., & Dubrowski, A. (2011). Bringing community health nursing education to life with serious games. *International Journal of Nursing Education Scholarship, 8*(1), 1–13. https://doi.org/10.2202/1548-923X.2072

Huizinga, J. (2011). *Homo Ludens: Vom Ursprung der Kultur im Spiel (22. Aufl., herausgegeben von Burghard König)*. Rowohlt.

Hummel, H. G. K., Joosten-ten Brinke, D., Nadolski, R. J., & Baartman, L. K. J. (2017). Content validity of game-based assessment: Case study of a serious game for ICT managers in training. *Technology, Pedagogy and Education, 26*(2), 225–240. https://doi.org/10.1080/1475939X.2016.1192060

Hunicke, R., LeBlanc, M., & Zubek, R. (2004). MDA: A formal approach to game design and game research. Retrieved August 7, 2020, from https://www.researchgate.net/publication/228884866

Ifenthaler, D., Eseryel, D., & Ge, X. (2012). *Assessment in game-based learning. Foundations, innovations, and perspectives*. Springer.

Ifenthaler, D., & Kim, Y. J. (2019). *Game-based assessment revisited*. Springer.

Issing, L., & Klimsa, P. (2002). *Information und Lernen mit multimedia und internet*. 3. Aufl. Beltz.

Johnson, C. I., Bailey, S. K. T., & van Buskirk, W. L. (2017). Designing effective feedback messages in serious games and simulations: A research review. In P. Wouters & H. van Oostendorp (Eds.), *Instructional techniques to facilitate learning and motivation of serious games* (pp. 119–140). Springer. https://doi.org/10.1007/978-3-319-39298-1_7

Kapp, K. (2012). *The gamification of learning and instruction: Game-based methods and strategies for training and education*. ASTD.

Ke, F., Shute, V. J., Clark, K. M., & Erlebacher, G. (2019). *Interdisciplinary design of game-based learning platforms*. Springer.

Kerres, M., Bormann, M., & Vervenne, M. (2009). Didaktische Konzeption von Serious Games: Zur Verknüpfung von Spiel- und Lernangeboten. *Zeitschrift für Theorie und Praxis der Medienbildung*, (Occasional Papers), 1-16. DOI: https://doi.org/10.21240/mpaed/00/2009.08.25.X.

Kettler, R. J., Rodriguez, M. C., Bolt, D. M., Elliott, S. N., Beddow, P. A., & Kurz, A. (2011). Modified multiple-choice items for alternative assessments: Reliability, difficulty, and differential boost. *Applied Measurement in Education, 24*(3), 210–234.

Kim, T. W., & Werbach, K. (2016). More than just a game: Ethical issues in gamification. *Ethics and Information Technology, 18*(2), 157–173. https://doi.org/10.1007/s10676-016-9401-5

Kim, Y. J., & Ifenthaler, D. (2019). Game-based assessment: The past ten years and moving forward. In D. Ifenthaler & Y. J. Kim (Eds.), *Game-based assessment revisited* (pp. 3–11). Springer.

Kreuzer, C., Weber, S., Bley, S., & Wiethe-Körprich, M. (2017). Measuring intrapreneurship competence as a manifestation of work agency in different educational settings. In M. Goller & S. Paloniemi (Eds.), *Agency at Work. An agentic perspective on professional learning and development* (pp. 373–399). Springer. https://doi.org/10.1007/978-3-319-60943-0_19

Larson, K. (2020). Serious games and gamification in the corporate training environment: A literature review. *RechTrends, 64*, 319–328.

Lave, J. (1991). Situating learning in communities of practice. In L. B. Resnick, J. M. Levine, & S. D. Teasley (Eds.), *Perspectives of socially shared cognition* (pp. 63–82). American Psychological Association. https://doi.org/10.1037/10096-003

Leppink, J., Paas, F., van Gog, T., van der Vleuten, C. P. M., & van Merriënboer, J. J. G. (2014). Effects of pairs of problems and examples on task performance and different types of cognitive load. *Learning and Instruction, 30*, 32–42.

Loh, C. S., Sheng, Y., & Ifenthaler, D. (2015). *Serious games analytics. Methodologies for performance measurement, assessment, and improvement*. Springer.

Marzano, R. J., & Kendall, J. S. (2007). *The new taxonomy of educational objectives* (second ed.). Corwin Press.

Mayer, R. E., & Moreno, R. (2010). Techniques that reduce extraneous cognitive load and manage intrinsic cognitive load during multimedia learning. In J. J. Plass, R. Moreno, & R. Brünken (Eds.), *Cognitive load theory* (pp. 131–152). Cambridge University Press.

Medienpädagogischer Forschungsverbund Südwest (mpfs). (2019). *Jugend, Information, Medien (JIM)*. Igepa, SoporSet Premium.

Messick, S. (1989). Validity. In R. L. Linn (Ed.), *Educational measurement* (pp. 13–103). American Council on Education.

Mislevy, R., Oranje, A., Bauer, M. I., von Davier, A., Hao, J., Corrigan, S., Hoffman, E., DiCerbo, K., & John, M. (2014). *Psychometric considerations in game-based assessment*. GlassLab.

Mislevy, R., Steinberg, L. S., & Almond, R. G. (2003). On the structure of educational assessments. *Measurement: Interdisciplinary Research and Perspectives, 1*, 3–67.

Mislevy, R. J., Behrends, J. T., Dicerbo, K. E., Frezzo, D. C., & West, P. (2013). Three things game designers need to know about assessment. *ETS Research Spotlight, 8*, 2–6.

Mislevy, R. J., & Rionscente, M. M. (2006). Evidence-centered assessment design: Layers, concepts, and terminology. In S. Downing & T. Haladyna (Eds.), *Handbook of test development* (pp. 61–90). Erlbaum.

Mislevy, R. J., Wilson, M. R., Ercikan, K., & Chudowsky, N. (2003). Psychometric principles in student assessment. In T. Kellaghan & D. Stufflebeam (Eds.), *International handbook of educational education* (pp. 489–531). Kluwer.

Mitgutsch, K., & Alvarado, N. (2013). *Purposeful by design? A serious game design assessment framework*. Retrieved December 30, 2020, from https://studio.edx.org/asset-v1:MITx+11.127x+1T2015+type@asset+block@Purposeful_by_Design.pdf

Morsing, M., & Schulz, M. (2006). Corporate social responsibility communication: Stakeholder information response and involvement strategies. *Business Ethics: A European Review, 15*(4), 323–338.

Mulder, M., & Winterton, J. (2017). Introduction. In M. Mulder (Ed.), *Competence-based vocational and professional education. Bridging the worlds of work and education* (pp. 1–43). Springer International Publishing.

Niegemann, H. M., Domagk, S., Hessel, S., Hein, A., Hupfer, M., & Zobel, A. (2008). *Kompendium multimediales Lernen*. Springer.

Oranje, A., Mislevy, B., Bauer, M. I., & Jackson, T. (2019). Summative game-based assessment. In D. Ifenthaler & Y. J. Kim (Eds.), *Game-based assessment revisited* (pp. 37–65). Springer.

Paas, F. G. W. C., Renkl, A., & Sweller, J. (2003). Cognitive load theory and instructional design: Recent developments. *Educational Psychologist, 38*(1), 1–4.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic Books.

Patino, A., Romero, M., & Proulx, J.-N. (2016). Analysis of game and learning mechanics according to the learning theories. Conference: VS-games 2016 At: Barcelona, Spain. DOI: https://doi.org/10.1109/VS-GAMES.2016.7590337; Retrieved December 30, 2020, from https://www.researchgate.net/publication/308140290_Analysis_of_Game_and_Learning_Mechanics_According_to_the_Learning_Theories

Pellegrino, J., DiBello, L., & Goldman, S. (2016). A framework for conceptualizing and evaluating the validity of instructionally relevant assessments. *Educational Psychologist, 51*(1), 59–81.

Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of game-based learning. *Educational Psychologist, 50*(4), 258–283.

Preece, J., Rogers, Y., Sharp, H., Benyon, D., Holland, S., & Carey, T. (1994). *Human-computer interaction*. Pearson.

Pufé, I. (2014). *Nachhaltigkeit*. 2. Aufl. UVK.

Rausch, A. (2011). *Erleben und Lernen am Arbeitsplatz in der betrieblichen Ausbildung*. VS Research.

Ritter von Marx, S., Kreuzer, C., Weber, S., & Bley, S. (2019). Nachhaltige Gestaltungskompetenz im Einzelhandel. Ein konnektivitäts-orientierter Ansatz zur Spezifikation eines Kompetenzmodells. In C. Aprea, V. Sappa, & R. Tenberg (Eds.), *Konnektivität und lernortintegrierte Kompetenzentwicklung in der beruflichen Bildung* (pp. 83–112). ZBW-Beiheft 29). Steiner.

Sailer, M. (2016). *Die Wirkung von Gamification auf Motivation und Leistung*. Springer.

Sailer, M., Hense, J. U., Mayr, S. K., & Mandl, H. (2017). How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction. *Computers in Human Behavior, 69*, 371–380.

Salen, K., & Zimmerman, E. (2004). *Rules of play: Game design fundamentals*. MIT Press.

Sangmeister, J., Winther, E., Deutscher, V., Bley, S., Kreuzer, C., & Weber, S. (2018). Designing competence assessment in VET for a digital future. In D. Ifenthaler (Ed.), *Digital workplace learning* (pp. 65–92). Springer.

Schnell, C. (2017). Lautes Denken' als qualitative Methode zur Untersuchung der Validität von Testitems: Erkenntnisse einer Studie zur Diagnose des ökonomischen Fachwissens von Schülerinnen und Schüler der Sekundarstufe I. *Zeitschrift für ökonomische Bildung, 5*, 26–49.

Schrader, P. G., McCreery, M. P., Carroll, M. C., Head, D. L., & Laferriere, J. R. (2019). Assessing learning from, with, and in games revisited: A heuristic from emerging methods and commercial Off-the-shelf games. In D. Ifenthaler & Y. J. Kim (Eds.), *Game-based assessment revisited* (pp. 13–35). Springer.

Singh, S. P. (2012). Gamification: A strategic tool for organizational effectiveness. *International Journal of Management, 1*(1), 108–113. Retrieved August 7, 2020, from http://www.zahiruddinarif.yolasite.com/resources/AIJM%20June%202012.pdf#page=109

Sweller, J., van Merriënboer, J. J. G., & Paas, F. G. W. C. (1998). Cognitive architecture and instructional design. *Educational Psychology Review, 10*(3), 251–296.

Tsay, C. H.-H., Kofinas, A. K., Trivedi, S. K., & Yang, Y. (2019). Overcoming the novelty effect in online gamified learning systems: An empirical evaluation of student engagement and performance. *Journal of Computer Assisted Learning, 36*, 128–146.

Van Merriënboer, J. J. G., Clark, R. E., & de Croock, M. B. M. (2002). Blueprints for complex learning: The 4C/ID-model. *Research and Development, 50*(2), 39–64.

Van Merriënboer, J. J. G., & Kirschner, P. A. (2018). *Ten steps to complex learning* (third ed.). Routledge.

Van Merriënboer, J. J. G., & Sweller, J. (2005). Cognitive load theory and complex learning: Recent developments and future directions. *Educational Psychology Review, 17*(2), 147–177.

Van Rosmalen, P., & Westera, W. (2014). Introducing serious games with wikis: Empowering the teacher with simple technologies. *Interactive Learning Environments, 22*(5), 564–577.

Verschueren, S., Buffel, C., & Vander Stichele, G. (2019). Developing theory-driven, evidence-based serious games for health: Framework based on research community insights. *JMIR Serious Games, 7*(2), e11565. https://doi.org/10.2196/11565

Virvou, M., Katsionis, G., & Manos, K. (2005). Combining software games with education: Evaluation of its educational effectiveness. *Educational Technology and Society, 8*(2), 54–65.

Warren, S. J., Jones, G., Dolliver, B., & Stein, R. A. (2012). Investigating games and simulations in educational research and theory: Enhancing academic communication and scholarship with a common language. *International Journal of Gaming and Computer-Mediated Simulations, 4*(4), 1–18.

Weber, S., & Achtenhagen, F. (2014). Fachdidaktisch gesteuerte Modellierung und Messung von Kompetenzen im Bereich der beruflichen Bildung. *Zeitschrift für Erziehungswissenschaft, 17*(2), 33–58.

Weber, S., Bley, S., Hackenberg, T., Kreuzer, C., Off, M., Ritter von Marx, S., Schumann, M., Meyer von Wolff, R., Wesseloh, H., & Achtenhagen, F. (2019). *Didaktische Anregungen für Ausbilderinnen und Ausbilder*. Bertelsmann.

Weber, S., Draxler, C., Bley, S., Wiethe-Körprich, M., Weiß, C., & Gürer, C. (2016). Large scale assessments in der kaufmännischen Berufsbildung – Intrapreneurship (CoBALIT). In K. Beck, M. Landenberger, & F. Oser (Eds.), *Technologiebasierte Kompetenzmessung in der beruflichen Bildung* (pp. 75–92). Bertelsmann.

Weber, S., Schumann, M., Bley, S., & Achtenhagen, F. (2018). "*Inno-BBNE im Einzelhandel"*—Gefördert durch das Bundesministerium für Bildung und Forschung (BMBF). Retrieved May 1, 2018, from www.wipaed.bwl.uni-muenchen.de/forschung/bbne/index.html#top.

Weber, S., Trost, S., Wiethe-Körprich, M., Weiß, C., & Achtenhagen, F. (2014). Intrapreneur: An entrepreneur within a company. In S. Weber, F. K. Oser, F. Achtenhagen, M. Fretschner, & S. Trost (Eds.), *Becoming an entrepreneur* (pp. 279–302). Sense.

Weinert, F. E. (2001). Concept of competence: A conceptual clarification. In D. S. Rychen & L. H. Salganik (Eds.), *Defining and selecting key competencies* (pp. 45–65). Hogrefe & Huber.

Westera, W. (2015). Games are motivating, aren't they? Disputing the arguments for digital game-based learning. *International Journal of Serious Games, 2*(2), 3–17. Retrieved August 7, 2020, from http://journal.seriousgamessociety.org/index.php/IJSG

Westera, W. (2019). Why and how serious games can become far more effective: Accommodating productive learning experiences, learner motivation and the monitoring of learning gains. *Educational Technology & Society, 22*(1), 59–69.

Wouters, P., van Nimwegen, C., van Oostendorp, H., & van der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games. *Journal of Educational Psychology, 105*, 249–265.

Wouters, P., & van Oostendorp, H. (2017). *Instructional techniques to facilitate learning and motivation of serious games*. Springer. https://doi.org/10.1007/978-3-319-39298-1_7

Chapter 7
Gameful Learning and the Syrian Conflict: Developing Global Learning Competencies in a Complex Conflict

Jason Rosenblum, Selin Guner, Christie Wilson, and Mity Myhr

7.1 Conceptual and Theoretical Foundations

7.1.1 Overview

From 2012 to 2016, a team of five educators from St. Edward's University, a medium-sized liberal arts university in the Southwestern United States, engaged in sustained collaboration to design and deliver a game-based simulation to challenge student perspective-taking and decision making related to the civil war in Syria. Known as the *Syria Simulation*, this experiential activity took place both within and outside of the traditional classroom, in settings that included gameplay set over two to three class sessions, cocurricular activities, and workshops delivered over a continuous 3-h timespan. During this period, the *Syria Simulation* was delivered to approximately 850 students in classroom and workshop formats. The simulation was delivered to seven traditional classes, averaging approximately 20 students each, three cocurricular activities (each 3-h long) with 10–18 students each, and seven global understanding workshops (each 3-h long) with approximately 90 students each. Each format was broadly designed to meet university outcomes for global understanding, while simultaneously meeting course-level outcomes focused on helping students to understand the geopolitical, cultural, and international contexts of actors involved in the conflict. The simulation required students to work in teams role-playing an actor in the conflict. The actors represented a wide variety of

J. Rosenblum (✉)
Department of Curriculum and Instruction, The University of Texas at Austin, Austin, TX, USA
e-mail: jason.rosenblum@austin.utexas.edu

S. Guner · C. Wilson · M. Myhr
St. Edward's University, Austin, TX, USA

C. Aprea, D. Ifenthaler (eds.), *Game-based Learning Across the Disciplines*, Advances in Game-Based Learning, https://doi.org/10.1007/978-3-030-75142-5_7

groups involved in the conflict. The design of the *Syria Simulation* was rooted in three core theoretical frameworks, namely, culturally responsive and significant high impact learning, game-based learning through enactive role-play, and low-fidelity simulation design. In this chapter, we will describe how this simulation was designed from these perspectives and embedded within a liberal arts curriculum. We also elaborate on successes and challenges and present a framework to design similar experiences.

7.1.2 Significant, High Impact Curriculum for Liberal Education

The *Syria Simulation* was conceptually designed from what Fink (2003) describes as a significant learning perspective. In Fink's taxonomy, significant learning is that which includes an equal emphasis on cognitive, metacognitive, and affective learning outcomes. The simulation was broadly designed to elicit student participation that demonstrated both perspective-taking and empathy building, in addition to moral reasoning and cooperative decision-making. The *Syria Simulation* required that students learn about themselves and others, integrate ideas about far-away populations with current events, and develop and demonstrate caring through non-Western perspective-taking. Taken holistically, this simulation functioned as a comprehensive learning activity within a liberal arts curriculum. Critically, the adoption of a significant, high-impact learning theoretical frame was embedded throughout the application of the AAC&U Global Learning VALUE rubric through its deep integration as a curricular tool to meet core university outcomes (AAC&U, 2014). This deep integration thus represents what Kuh (2008) describes as a high-impact learning practice since it demands that students have a deep, extended engagement with both subject matter and faculty over a prolonged period. In this experiential strategy, students were encouraged to draw connections between what they were learning in their general educational and disciplinary courses and apply their knowledge to the complex global issues discussed in the workshop. This extended immersion defines what Ferren and Anderson (2016) describe as an integrative learning approach. In the spring semester of 2016, the simulation was applied to the "Workshops for Global Understanding" (GU), a required cocurricular activity for students taking two junior-level, globally focused general education courses. The workshops met two shared Student Learning Outcomes for the courses: *Students will apply the knowledge and analytical skills gained in the classroom and through experiential activities to selected issues of global significance* and *Students will analyze the social justice implications of increasing globalization in a historical and/or contemporary context.* These learning outcomes fulfill specific elements of the University's Mission that address global learning, moral reasoning, and critical and creative thinking. As the University engaged in the work of integrating global learning into our curriculum, the strategic plan and quality enhancement program (QEP) was focused upon providing students, both on and off campus, curricular and cocurricular experiences focused on global learning.

Each semester for 10 years, the course directors (Wilson and Myhr) organized a "Workshop for Global Understanding" that addressed a different significant global issue such as the global water crisis, food justice, and global health. The planning of each workshop was influenced by the *AAC&U's Shared Futures: Global Learning and Liberal Education* program and *LEAP Goals*, which are rooted in *High Impact Practices* (AAC&U, 2020; Hovland, 2005, 2006; Kuh, 2008; Nair & Henning, 2017; Schneider, 2015). These initiatives focus on active and collaborative learning to address intellectual and practical skills needed in the increasingly interconnected world of the twenty-first century. Furthermore, design and assessment of the simulation relied on the AAC&U Global Learning VALUE rubric. A 6-year report on the application of this Global Learning rubric by Calahan (2018) maintains that this rubric continues to be vital for institutions whose educators wish to "consider the ways learning goals align with cultural diversity, understanding global systems, or social responsibility." The AAC&U rubric draws from Bennett's (1986) perspective that maintains that developing higher degrees of cultural competence and intercultural sensitivity requires students to move through stages of personal growth along a path that leads from ethnocentrist to ethnorelativist ways of thinking about the world (Bennett, 1993). Crucially, as Nadan (2014) notes, attaining such perspectives meant more than providing students with knowledge about the "other" in the cultures represented in this simulation. It meant encouraging students to gain cultural fluency by playing actors from international cultures through a global, socio-culturally relevant, contextual lens and adopting perspectives by highlighting power dynamics between conflict actors and affected populations like the Syrian refugees and non-politicized Syrian population (Chun & Evans, 2016; Deardorff, 2009). Gaining a contextual understanding of the Syrian conflict through these dynamics is a critical component of social justice work (Nadan, 2014). The culturally responsive and game-based design elements in this simulation required students to analyze problems, propose solutions and make responsible decisions that lead to sustainable, just outcomes through experiential learning of a Middle East conflict.

7.1.3 Game-Based Learning, Conflict, and Social Justice

We have thus far discussed the curricular frameworks and multicultural and social justice perspectives that guided the conceptual thinking about this project. We now turn our attention to the game-based learning and role-playing perspectives that further guided this project's design. That contemporary students spend a great deal of time playing video games is a truism (Lenhart, 2008). However, this assumption is insufficient to justify designing a game, instead of another learning tool, to help students build empathy for people in a conflict far distant from the lives of typical liberal arts university students. It was critical to prioritize the design of a game as a learning environment, while simultaneously adopting a Deweyian lens to help students understand the “moving force of [their] experience” while playing the game to learn about the Syrian conflict (Squire, 2007; Dewey, 1938, p. 14). The moving force of the game experience rested upon what Salen and Zimmerman (2003) describe as an intersection of the systems of rules, play, and cultural representation (intended or otherwise) within a game’s design. Games are also often defined by a complex system of interactions and reactions between players and the ludic environment that situates their play (Walz, 2010). These environments are wide-ranging and include everything from intricate three-dimensional spaces to the world of the imagination that serves as the arena for role-playing games (Männamaa & Leijen, 2015; Simkins, 2011; Zagal & Deterding, 2018). Game environments are defined by the interactions and the transactions that players take between themselves, the environment of the game, and between each other if play is cooperative (Bogost, 2010; Gee, 2005; Squire, 2003, 2006). According to Gee (2005), one reason educators should consider games as tools for learning is that players experience more than entertainment when they play a game. They interact with components like the environment, characters, and rule systems while tackling challenges using, at times, real-world processes. And, depending upon the game, they are presented with cultural representations embedded within the game (Gee, 2005; Salen & Zimmerman, 2003). In our example, these components can be taken to represent what Gee (2005) describes as an *internal design grammar* that reflects a game’s interlocking complex, embedded meanings. Game environments, rule systems, and associated mechanics are outlets for what Squire (2006) describes as *designed experiences*. According to Squire (2003), as players play and otherwise interact with the game, they transact within purposefully designed *possibility spaces* that offer them a chance to understand the ideologies that permeate the worlds in which they visit.

The *Syria Simulation* represented such a designed space, open to multiple interpretations, complex moral dilemmas, and a large range of possible actions on the part of the students who played the game. The experiences within the game required that we adopt a design grammar that defined the actors, events, game mechanics, and rules according to real-life conflict outcomes. Despite having the identical set of resources, game actions, and embedded geopolitical content, no two endings to the simulation were exactly alike, and no sets of student choices were identical. Similar to opportunities to explore racial stereotypes in commercial digital games like *Grand Theft Auto San Andreas* or the historic and geographic factors that drive the rise and fall of empires in *Civilization* or *Europa Universalis*, our project presented students with an opportunity to trial decisions and to learn from their experiences (Egenfeldt-Nielsen, 2005; Squire, 2006). These play experiences that challenged student worldviews are consistent with what we see from other role-playing projects. Simkins and Steinkuehler (2008) otherwise describe such moments of critical perspective-taking as “significant moments in games [where] players be given legitimate choices about what action to take that are experienced as important in some way” (p. 18).

Simulations allow students to model complex real-world processes using varying levels of technology integration while allowing for experiential, real-life decision-making. We use the term simulation to denote real-life experiential play, instead of virtual play using a digital game. Experiential simulations have a significant history of supporting a range of disciplines particularly in business and healthcare education (Faria, 2001; Gold, 2016; Wolfe & Keys, 1997; Zhang, Grandits, Härenstam, Hauge, & Meijer, 2018). Highly structured business simulations frequently ask students to interact with software-based platforms to perform computations and forecasts, while integrating their use as experiential teaching tools (de Smale, Overmans, Jeuring, & Grint, 2016; Gold, 2016; Tanner, Stewart, Totaro, & Hargrave, 2012; Vlachopoulos & Makri, 2017; Zhang et al., 2018). Notably, as found in Tanner et al. (2012), students can improve their decision-making through an iterative decision-making process. Some simulation games, like the *Prosperity Game* described by Kevin Boyack and Marshall Berman in Wolfe and Keys (1997), organize play using paper assets and competitively challenge MBA students to game within unfamiliar real-life systems to improve decision-making and to learn global perspectives while role-playing. The *Syria Simulation* bears a striking resemblance to this simulation, despite differences in audiences and the fields. In *Prosperity* and the *Syria Simulation* students were asked to adopt global perspectives and asked to solve complex real-life problems. Similar to the *Syria Simulation*, *Prosperity* students were subsequently organized into working teams comprising various business roles and provided a policy toolkit to prime gameplay. In both simulations students tackled political and social issues within a game structure and with rule-based play. Further insights came from healthcare simulations, where student participation within non-technical healthcare simulations faced an arguably broader set of challenges, since real-life and real-time operational and strategic processes in addition to negotiation and reasoning skills (Zhang et al., 2018). Notably, the simulations described provide a highly structured environment to support gameplay. Research into nonstructured simulation environments (e.g., *Minecraft*) reveals the tendency for some players to engage in "nonsensical" play as players explore the boundaries and structure of their environment (Tornqvist, 2014).

Although our project was a highly structured face-to-face activity, we incorporated similar design elements from the serious digital game, *Peacemaker*, into our simulation's design. *Peacemaker* was designed by Asi Burak, a former Israeli intelligence officer (now with Games for Change) to help people to understand the complexities of the Israeli–Palestinian conflict by playing the role of either the prime minister of Israel or the president of Palestine (Burak, 2014). *Peacemaker* connected player choices to real-life news reports of similar actions and used a system to indicate approval ratings by stakeholder groups ranging from local populations to the United States. This global perspective on conflict outcomes was compelling, and we incorporated a voting phase and approval outcomes into the mechanics for the *Syria Simulation*. Researchers at The Ohio State University who studied the application *Peacemaker* found that using this simulation to teach dispute resolution helped students to learn about this complex conflict (Goodrich & Schneider, 2010). Referencing this simulation, Goodrich and Schneider (2010) discuss ways that simulations focused on international conflicts can also help to shape attitudes toward the conflict and can be used to support learning-related topics such as dispute resolution. Similarly, in their research on using simulations to change player attitudes about a

Mideast conflict, Williams and Williams (2011) examined multiple identification theory (MIT) as a possible strategy to change attitudes about an international conflict within their game, *Culture and Creed*. *Culture and Creed* require that people role-play a country involved in the conflict (e.g., Israel, Iraq, Iran, Syria, Turkey, the EU, and Syria), while also situating play within a facilitated face-to-face game. According to these researchers, participants demonstrably changed their attitudes about the conflict after playing over an extended 10-day period. According to this study, players were able to accomplish this because they, "care[d] at an emotional level about the game's outcome," "associate[d] the structure, processes, and results of the simulation with reality" and were playing in ways in which they were able to "formulate different approaches to play, test them out, and witness the results" (p. 735).

We have thus far used both of the terms *game* and *simulation* to describe this project, sometimes in tandem. We describe this project as a *game-based simulation*, as a way to reflect our attempt to model a real-life, extraordinarily complex phenomenon involving multiple state and non-state actors. There is no single accepted academic language to distinguish between these two terms, and in fact, these terms are often grouped when talking about educational technology innovations (Edutech Wiki, n.d.; Vlachopoulos & Makri, 2017). Another attempt to distinguish between these two very similar educational tools describes the different terms of enjoyment by participants (Prensky, 2007). These definitions are inadequate to properly situate our application of game and simulation elements to create this simulation. However, perspectives by Sauvé, Renaud, Kaufman, and Marquis (2007) and Lean, Moizer, Towler, and Abbey (2006) are useful. Both agree that simulations reflect a degree of modeling of real-life systems, and both agree that game-based systems include elements that engage players through competition, cooperation, and conflict. Lean et al. (2006) also include collusion as a type of interaction available in games. If one assumes that competition, cooperation, and conflict are required to "win", then one arguable distinction between games and simulations is that people participate in these behaviors in games, but not in simulations, to win.

Games have the potential to help people see the world differently (McGonigal, 2011). According to McGonigal's research, one of the reasons that we play games is to strive for what she describes as an *epic win*. To achieve such a win inherently implies overcoming difficult, or nearly insurmountable, obstacles, and the historical examples of using game play to support human survival are compelling. Furthermore, it is possible, according to McGonigal (2016), for individuals to apply gameful approaches in ways that improve their quality of life by taking steps that include "go[ing] for an epic win" (Kindle location 284). By way of example, Rosenblum (2012) designed an undergraduate global social problems course based on McGonigal's (2011) design to encourage students to take direct actions to solve those problems and encourage epic engagement in the course. Research into student immersion within social science simulations similarly reveals that such deep immersion is correlated with the enjoyment of learning, and that personality traits such as player interest were critical to this immersion (Preuß, 2020).

In this project, we asked students to work toward an *epic win* by gaming for peace in a real-life, tragic conflict. The game-based simulation framework for this design engaged students experientially, in ways that supported learning through authentic decision-making and action-taking (Kolb, 1984). Driving toward social justice outcomes prompted students to think critically about "cultural models regarding the world" as they worked toward achieving an epic win, that of peace in Syria (Gee, 2005, p. 211).

7.1.4 Role-Play and Culturally Responsive Design

We have described the use of role-play in the *Syria Simulation*. We use enactive role-play to define the process used by students to play game characters, and to take actions based on the role of that character (Simkins & Steinkuehler, 2008). This usage differs somewhat from Coutou's (1951) sociological framing of role-playing as being connected to the obligations and behaviors that are defined by a particular role in society. It could, however, be argued that what we discuss as role-playing in the context of games is what Coutou might otherwise describe as "role-taking," or "thinking and feeling like someone else," without actually needing to perform the real-life behaviors of that person (Coutou, 1951, p. 182; Muhamad & Yang, 2019). A central assumption of this simulation was to craft student perception of the war in Syria as a conflict between state and non-state actors, involving proxy wars, conflicts between different religious groups represented across widely varied strands of a single religion, and impacting members of the non-politicized Syrian population. Thus, this conflict was (and still is) driven by equal parts of complex geopolitical interests, decision-making, and culturally derived sociocultural contexts. Culturally responsive design within the *Syria Simulation* uses a decolonizing pedagogy to build cultural competencies and knowledge about the Syrian conflict through role-play. Liberal arts university students were thus given a sociocultural lens that prioritized knowledge about the conflict from the perspective of what would be seen as "the other" by many of these students. We adopted what Tejeda, Espinoza, and Gutierrez (2003) describe as a decolonizing pedagogy to frame non-Western ways of thinking about the conflict. Through this strategy, students participating in the *Syria Simulation* would be able to develop what Ladson-Billings describe as *cultural competencies* about the conflict (Ladson-Billings, 1995).

Role-play has been previously used to design opportunities to develop cultural competencies in other simulation games. Männamaa (2013) details the application of role-play within a game intended to develop cultural fluency around the Bronze Night conflict in Estonia. Männamaa and Leijen (2015) discuss the application of a similar tabletop simulation game (*FOUNTAINS*) to examine cultural integration processes by students as a result of playing the game. Muhamad and Yang (2019) similarly describe how they applied role-taking to immerse students in a novel culture within their game, *BAFÁ*. Unlike these examples, the *Syria Simulation* was not designed specifically to study the acquisition of cultural competency; rather, a primary goal of the simulation was to foster global perspective-taking and social justice orientations among students. With the integration of active learning and self-reflection, along with asking students to consider actions that would increase social justice, the simulation incorporated elements designed for transformative social justice education (Vaccaro et al., 2017). However, the successful application of role-playing or role-taking in these games as a strategy to address cultural awareness within an international conflict is compelling and aligns with our application of role-play within the *Syria Simulation*.

We designed opportunities for students to develop cultural awareness as they role-played, made decisions as actors in the conflict, and interpreted the actions of other groups as the simulation progressed. Interestingly, a 2006 review of role-playing in international and comparative politics courses found that "in terms of focusing learning in the desired direction, role-playing can foster identification with 'the other.'" (Wheeler, 2006, p. 334). Beyond politics or general education goals, role-play is equally vital to help people develop cultural competence in other fields of study, including in communications, engineering, and medical education. Beyond using role-play to design engaged, active learning, student self-efficacy, and subject-matter competency role-play works to improve fluency in other culturally diverse settings (Ampatuan & San Jose, 2016; McLaughlan & Kirkpatrick, 2004; Shearer & Davidhizar, 2003).

Engaging in role-play necessitates a voluntary suspension of disbelief and entering into what Huizinga describes as the "magic circle" of play (Huizinga, 1971; Salen & Zimmerman, 2003). While the notions of this circle typically refer to temporal or physical boundaries that demarcate the space for play, we designed this circle to demarcate new boundaries based on adopting novel cultural frames of reference, what Stenros (2014) describes as a culturally defined border for the play space. Similarly, the magic circle also represents the boundaries of a complex social system, specifically, the geopolitics of the Syrian conflict (Klabbers, 2006).

7.2 Syria Simulation Game Play

7.2.1 Workshop Simulation Overview

The GU workshop in spring 2016 was the *Syria Simulation*, which represented its final iteration. Each workshop was organized and led by a team of faculty and staff, working with a group of 12 to 15 student interns who served as peer instructors. Over a 3-h block of time, 80 to 100 students learned about the issue at hand, with time to consider its political, economic, social, and cultural complexities and finally, develop socially just solutions. To encourage integrative learning, the workshop theme was reinforced in other cocurricular events and activities. In spring 2016, the programming included a film series and panel discussion of the challenges facing refugees, both from Syria as well as other conflict zones around the world. Students also had opportunities to engage with organizations in the metropolitan area that serve refugees, encouraging them to appreciate the impact of global issues on local communities and organizations.

Play within the *Syria Simulation* was organized using (a) a three-phase timeline of the conflict, (b) 12 distinct conflict actors, (c) real-world limits as defined by each actor, (d) rule systems as defined by simulation mechanics, (e) unique player actions defined by actor, and (f) cultural representations based upon an actor's geopolitical and moral ideology. Each round was further divided into three phases: research, action, and voting. Student teams were grouped by the table, corresponding to each actor in the conflict. By running the simulation in a team-based setting, we also created a space for cooperative play. As is recommended in other applications of cooperative learning in live, experiential simulation games, we chose this strategy so that groups could process the problems presented during each round of play, gain opportunities to collectively apply theoretical knowledge of the conflict within the "action phase" of the game and, ultimately, reflect upon their decisions before the next round of play (Malave & Figueiredo, 2002).

The three rounds of play corresponded to critical historical markers in the conflict, beginning with the Day of Rage when 50 protesters were killed by security forces while thousands protested against repressive policies of the Syrian government (Al Jazeera, 2011). Each round ended with a major event during the year that the simulation was delivered. The actors and events included shifted slightly over the design of the simulation to account for changes in the conflict. A listing of conflict actors to reflect the geopolitics of 2016 is presented in Table 7.1, while a snapshot of students grouped by an actor is presented in Fig. 7.1.

For the spring 2016 simulation, students had access to the actor information sheets, through web-based resources (provided using iPads), presentations by simulation faculty, and participation of student interns at each table. A sample Actor Information Sheet is provided in Fig. 7.2. Student players were asked to (a) research the problem of peace in Syria, (b) decide on an action to address the problem, (c)

Table 7.1 Syria simulation actors

State actors	Non-state actors
European Union	Hezbollah
Iran	Free Syrian Army rebels
Jordan/Lebanon	Islamist rebels
Russia	Salafi rebels/ISIS
Saudia Arabia	Syrian Kurdish Militia
Bashar al-Assad (President of Syria)	Syrian population
Turkey	United Nations[b]
Western powers (the United States and Great Britain)	
China[a]	

[a]China was not an actor in the 2016 workshop

[b]The U.N. was present in courses and cocurricular presentations and integrated as an external actor in the 2016 workshop

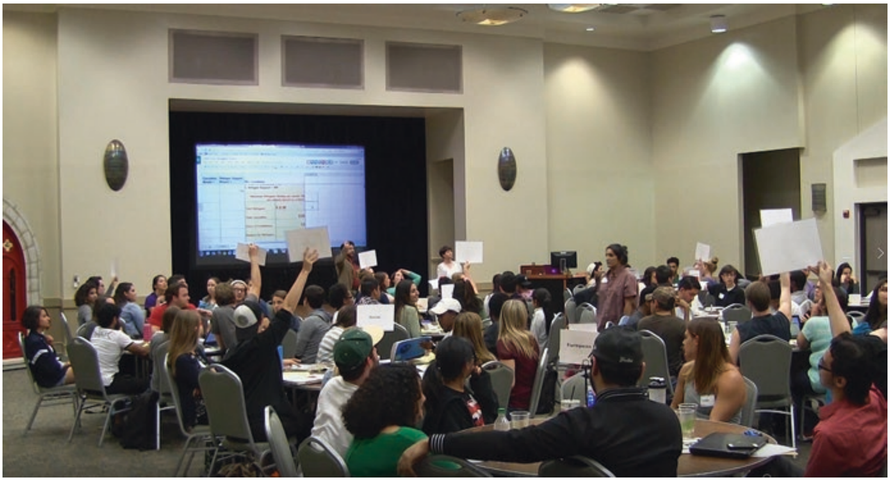


Fig. 7.1 Syria simulation workshop setting

defend their group's choice of action, (d) vote on the outcomes of the actions taken by all of the actors, (e) reflect upon the social justice implications of choices, and (f) repeat the steps for the subsequent rounds of play. The overall objective of the simulation was to achieve a measure of peace or at least a cessation of conflict (Win Condition explained in Sect 7.4.2).

Gameplay began with an overview of the simulation by workshop leaders, which included videos to ground gameplay in the actual events of the conflict in Syria, and a brief lecture by history and global studies faculty members (Table 7.2) (Klein, 2015; Setrakian, 2012). Players were then given 20 min. during the first round of the three-round simulation to research possible decisions based on the beginning of the simulation. The simulated events began in 2012 with the conflict's rise as an internal proxy war, continuing in 2013 as a great powers dispute, and finally beginning round three as a global crisis involving Turkey and Jordan (UNHCR, 2018; Wilson, Myhr, Guner, & Micklethwait, 2016). During the research phase in the first round of play, students worked with trained student interns from a variety of disciplinary backgrounds at each table. Students were subsequently given another 20 min. to decide on what action to take, based on the cards available to their conflict actor (Appendix 1). Actions ranged from military options actions like ground assaults to social media actions and appeals to state actors for aid. A sample of the fronts and backs of social media and military action cards is provided in Fig. 7.3. A full list of action cards available for each actor is available in Appendix 1. Available actions varied, depending on the actor being played.

Students were asked to (a) play their action "in character" consistent with their actor, (b) stand up and state their action and their justification for their action, and (c) react and respond to actions by other tables. Rosenblum played the role of a "game master" (GM) and facilitated these interactions while also tallying game scores and refereeing dialogue between teams. Teams were given time limits for

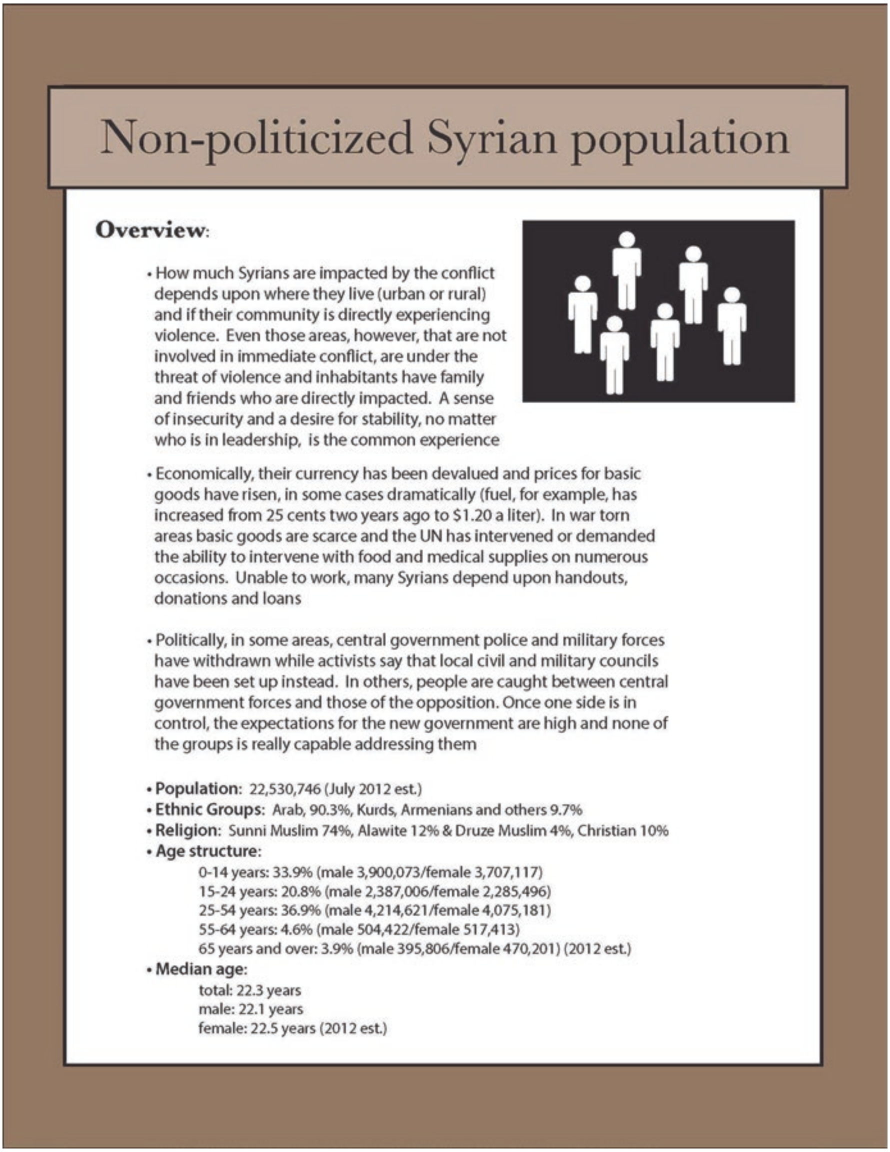


Fig. 7.2 Actor information sheet

each round of play, and response time during each action phase was limited (Fig. 7.4).

Students were asked to present and defend their choice of action at the end of each round. Teams took turns announcing their actions to the group, while the facilitator (a) checked the action to determine eligibility based on potential real-life behavior, (b) determined the consequences for the action based on game mechanics,

Table 7.2 Sequence of events

Introduction	Orientation by faculty	Introductory lecture on the Syrian conflict Introductory videos (Klein, 2015; Setrakian, 2012)
	Orientation by game master	Gameplay Basic Win Condition
Round 1	Research phase	Students consult resources. Students consult interns.
	Action phase	Dice rolls for play order Students are prompted to enter actions in Google docs Tables take turns to state and defend actions Casualty and refugee counts are updated
	Voting phase	Actors vote on approval or disapproval of actions taken
Social justice reflection	Students are prompted to enter reflection to social justice reflections in Google docs	
Round 2	Action summary	Actions from prior round are reviewed Win condition is reviewed
	Research phase	Round 2 introductory video is shown Students consult resources and interns
	Action phase	Dice rolls for play order Student tables are coached on follow-up actions (e.g., social media, alliance making, or breaking) Students are prompted to enter actions in Google docs Tables take turns to state and defend actions Casualty and refugee counts updated
	Voting phase	Actors vote on approval/disapproval of actions taken
Social justice reflection	Students are prompted to enter reflection to social justice reflections in Google docs	
Round 3	Action summary	Actions from prior round are reviewed Win condition is reviewed Final round coaching provided
	Research phase	Round 3 introductory video is shown Students consult resources and interns.
	Action phase	Dice rolls for play order Student tables are coached on follow-up actions (e.g., social media, alliance making, or breaking) Students are prompted to enter actions in Google docs Tables take turns to state and defend actions Casualty and refugee counts are updated
	Voting phase	Actors vote on approval or disapproval of actions taken
Social justice reflection	Students are prompted to enter reflection to social justice reflections in Google docs	

and (c) offered affected actors the chance to respond verbally to actions that immediately impacted their play. Like Simkins and Steinkuehler (2008), we found the application of role-play to be essential to student reasoning and immersion. In this simulation, role-play was essential for students to immerse themselves and to make decisions from the perspective of culturally distant individuals and groups. This immersion was evident as students stood to deliver their choices of action at the end

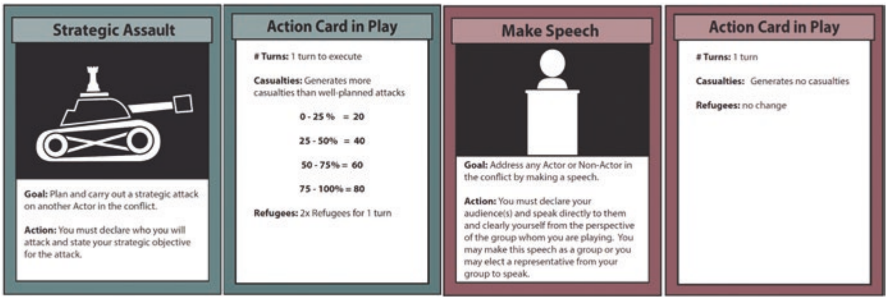


Fig. 7.3 Sample action cards

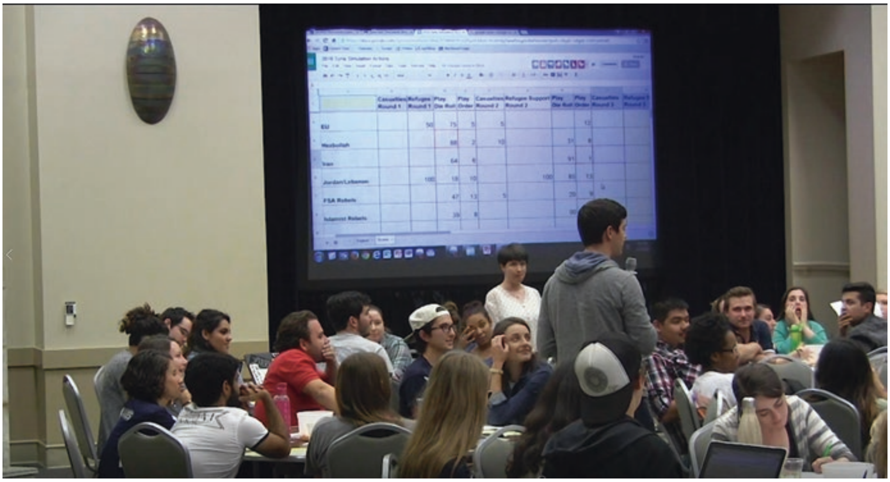


Fig. 7.4 Student speeches, action round

of each turn (Fig. 7.4). Prior to standing to make their choices, student groups were asked to record their thoughts by writing down their decisions in a spreadsheet (Table 7.3).

An example of the simulations dynamics comes from the second workshop (Table 7.2) when students playing Bashar al-Assad made a decision to:

"Bomb the leader of the FSA (Military Assault). Objective: Send a message to the FSA that if you choose to attack my government directly, I'll react accordingly. I have always wanted what is best for the Syrian people, and when the FSA kills one of my own, I cannot properly represent the Syrian people." (Assad table, anonymous workshop communication, 2016).

For this assault to succeed, players had to roll two 20-sided dice to determine a random percentage. The assault then generated as many casualties as the corresponding percentage on the casualty table listed on the action card, with a minimum of 50 casualties and a maximum of 200 (Table 7.4). However, given the specific target called by the Assad team, the GM imposed a further penalty on the attack, to

Table 7.3 Sample simulation actions, workshop 2

Round 1	Round 2	Round 3
Actor: Assad Bomb the leader of the FSA (military assault). Objective: Send a message to the FSA that if you choose to attack my government directly, I'll react accordingly. I have always wanted what is best for the Syrian people, and when the FSA kills one of my own, I cannot properly represent the Syrian people.	Make a speech: In the recent chemical weapon attacks, many of our beloved Syrian people were killed and harmed. I want the world to know first and foremost, it was not me. I would never harm our people. If the FSA was already capable of killing a representative of the people, why wouldn't they use these chemical weapons to harm the Syrian people further and blame it on me. The rebels have always been the obstacle toward modernizing Syria. I only want what is best for Syria and the Syrian people	Launch a solidarity social media campaign through a speech. I will use Facebook and Twitter, as well as the speech to make sure the message reaches everybody. The entire world is against ISIS. We are all agreeing on one thing: The defeat of ISIS. I am prepared to provide the necessary support for anyone who wants to join our cause against ISIS. I am offering air bases as well as land and resources for strategic planning to meet the goal of defeating ISIS. No matter if you oppose my politics, we can all agree that ISIS is a threat to the world and most importantly my beloved Syrian people
Actor: Islamist rebels Made an alliance with Saudi Arabia and with the Salafi rebels	We decided we are going to use social media to speak out to other rebel groups and get support from them because we all have similar goals and want to take down Assad	
Actor: Salafi rebels Made military alliance with the Islamists	Random assault on the Kurds. Made a speech to all devout Sunni Muslims asking them to come live in our caliphate and fight with us against the Western infidels. Join us for a purpose; we will guide you to paradise and a new era	We launched a social media campaign to gain support and grow our ranks. Additionally, we made a speech calling upon vulnerable youths and devout Sunni Muslims to convert to our way of life. We encourage them to go to the west and strike them on their soil—for this, they will be awarded in eternity

Table 7.4 Heavy military assault

Action	Heavy military assaults involve heavy artillery such as tanks as well as airstrikes. State who you will assault, by what means, and state your objective for launching a military action
Turns	1 turn to plan and 1 turn to execute
Casualties	Generates extreme numbers of Casualties 0–25% = 50 25–50% = 100 50–75% = 150 75–100% = 200
Refugees	3× refugees for 2 turns

account for the difficulty in finding and assassinating the leader of the Free Syrian Army (FSA, one of three rebel groups). This attempt to crush the rebellion by the FSA, with an ill-planned first strike, failed. This example illustrates the need for a facilitator to account for potentially unplanned actions on the part of the players, and to adapt to decisions in the simulations, based on real-life actions. This facilitator is referred to in the context of live action role-playing (LARP) and role-playing game literature as a game master (GM) (Torner & Jones, 2014; Zagal & Deterding, 2018). Any attempt in real life to eliminate the rebellion by Assad had failed. However, the GM allowed for the possibility of this action succeeding in the simulation, only giving it a 1/1000 chance of success. Had the attack actually succeeded, the number of casualties would have been counted, and the number of refugees fleeing Syria would have tripled in size from the default of one million refugees fleeing per round. These outcomes were recorded in the *Google Doc* and counted against the win condition (Table 7.4). In addition, the FSA would have continued, with a corresponding disadvantage, which the GM would have needed to adapt in real-time. Following this failed attack by the Assad group, the FSA chose not to respond immediately and instead forged an alliance with the Kurds to seek military support. Their response in round two was to "make a speech denouncing Islamic extremism. Currently, we are halting military activity on Assad so we can focus on ending ISIS's power (we are still angry about Assad's use of chemical weapons). We are asking the EU and Saudi Arabia for backing and small arms/surface to air missiles" (FSA table, anonymous workshop communication, 2016). Indeed, students playing the FSA were also asked to take a "Plea for Support" action and requested military aid from the European Union and Saudi Arabia (Appendix 1, Make a Speech, Plea for Support).

When making a speech, students were asked to provide specific details of their actions. When students attempted to simply summarize their response, the GM intervened to ask for further detail, and when necessary, simulation faculty also provided the coaching needed to help the student effectively role-play the speech. The action card that defined the speech action (a) required that students speak in the voice of their actor and (b) allowed subsequent actions to be taken simultaneously.

Once all tables shared their actions, and in the last phase of each of the three rounds of play, we began the voting phase of the simulation. Participants held up cards to acknowledge whether they approved or disapproved of actions taken during the round using "Confidence" and "Contempt" cards (Fig. 7.5). We asked students to vote from the perspective of the actor. Approvals by the represented actors typically fell within the bounds of what student groups interpreted as in the best

Fig. 7.5 Voting cards

interests of the actor, or in the case of groups like the Syrian population, what was in the best interest of the Syrian refugees. At the end of each round of play, students were also asked to answer questions such as, "What are social justice challenges?" and "What actions were most likely to lead to peace?" Although these questions did not direct students to play toward these goals, the process of asking students to reflect on their experiences was essential in developing critical awareness of their decision-making during play. We did not attempt to define what constituted social justice decision-making by providing a single decision-making framework. In fact, by describing preset moral frameworks for actors, such as for the Salafi Rebels (a group that later played as ISIS), we gave students normative and dogmatic lenses from which to play their assigned actor (Fig. 7.3). The Syrian population and United Nations (U.N.) body, with members composed of student representatives and faculty, voted, with votes tallied separately.

A full accounting of any delivery of this simulation is beyond the scope of this book chapter. However, the examples presented reflect the basics of the role-play, mechanics, and experiential engagement of students during gameplay.

7.2.2 Critical Decision-Making

The decisions and statements made by Assad and the FSA during the first round of this workshop reflect similar descriptive and critical social justice choices that emerged from gameplay as the simulation continued over three rounds of play. These statements in particular were made within the context of the moral framework available to the students playing Assad and the Free Syrian Army. The example from the Assad character (as defined by the actor's information sheet) interestingly allowed for a range of decision-making. In real life, Assad is known for having received a Western education and for neoliberal and capitalist-oriented decision-making (Al Jazeera, 2018). He is also criticized for political repression and human rights abuses (U.N. Human Rights Council, 2016; Wilson et al., 2016). With this social justice framing, students could choose to play Assad as a leader who grossly violates human rights, or as someone who has chosen to act from neoliberal political positions in ways that otherwise benefit his regime. These students chose to play Assad as a bully who had few qualms about assassinating a leader in an attempt to end the conflict, instead of exercising diplomatic actions to achieve similar ends. Although this decision may not have been strategically realistic, it nevertheless was allowable based on the character defined for these students.

However, other actors had moral frameworks that allowed for little latitude for player choices. One example of this was the group who at the time of this simulation was known as the Salafi Rebels, known as a group that rejected state control by countries like Saudia Arabia, and that was condemned as terrorists by state actors (Moniquet, 2016). Although their numbers were relatively small (fewer than 20,000 Syrians), their doctrines gave rise to the movement commonly represented by the extremist group, ISIS (Liepman, Nichiporuk, & Killmeyer, 2014). Given their militant, jihadist framing, the students playing this group were informed that they would collaborate with moderate groups, including the Islamist Rebels and the FSA; however, this group did not share a democratic vision for Syria. Their goal was to create an Islamic State based on Sharia, Islamic Law (Moniquet, 2016; Wilson et al., 2016). Consequently, the moral framing available to students for the Salafi Rebels was extraordinarily narrow and ran in opposition to their personal moral perspectives. The act of both observing and taking actions inconsistent with their own perspectives thus reflected at least attainment of basic cultural knowledge about these rebels (Calahan, 2018). As Bennett (1993) describes, as students make progress in deepening their sophistication with their cultural competency, they necessarily "mov[e] from ethnocentrism through stages of greater recognition and acceptance of difference, here termed 'ethnorelativism'" (p. 22). Thus, the dichotomy experienced by these students likely reflects their cognitive dissonance as they compared the actions they may have been either normatively or dogmatically driven to take, with actions that either their liberal arts university or personal positions may have inclined them to take.

Students articulated this dissonance in their writing both during the workshop and in postworkshop essays. In the workshop, two students who were role-playing the Salafi Rebels made an alliance with the team playing the Islamists. These groups justified their alliance through a shared goal of overthrowing Assad. The Salafi table further called upon, "all devout Sunni Muslims asking them to come live in our caliphate and fight with us against the Western infidels. Join us for a purpose, we will guide you to paradise and a new era" (Table 7.2). In workshop 6, students in the role of Assad specifically spoke to this as they reflected on the social justice implications after round three saying "every time we took an action, we had to consider it. We didn't act socially just, but we still discussed it at the table." (Syria Simulation, Workshop 6). Similar dissonance was evident in student reflective essays as they described their discomfort with deciding to take actions that increased the number of refugees and suffering of the population. These dissonances are compelling since students demonstrated a willingness and facility to play this simulation from these perspectives and included this learning in their reflections (Table 7.2).

7.2.3 Course Simulation Overview: A Middle East Survey and Politics and Government Course

In the preceding, we describe the design of the *Syria Simulation* in a 3-h workshop format. This workshop's general education student population was composed of various majors, and most students did not have in-depth course work in either Middle East history or Middle East politics. However, this simulation can be applied in smaller classes and more advanced settings, including courses with an emphasis on the history and politics of the Middle East.

In a role-playing application of the Syrian conflict within a class setting, Frank and Genauer (2019) highlight a semester-long classroom simulation of the Syrian conflict, within an introductory international relations (IR) course. Students are randomly assigned to play one of 15 roles involving three actor types: states, non-state actors, and international organizations. The simulation culminates with 2 weeks of multi-stakeholder negotiations addressing four issues: humanitarian aid, economic sanctions, ceasefire, and political transition. This simulation design highlights crucial theories in IR and is mainly conference- and negotiation-based. It does not have the components of a game-based system. The model presented in this paper includes both negotiation and game elements that are potentially more engaging for students. The *Syria Simulation* was implemented in Guner's Middle East Survey (GLST 1327) and Middle East Government and Politics (POLS 3316) courses in the spring semesters of 2014–2016. Below is a short description of these courses, their student learning objectives (SLOs), and student population, which can provide a background for the impact of the *Syria Simulation* game. We have found that the *Syria Simulation* is more engaging than other similar Syria simulations published in the literature.

7.2.3.1 Middle East Survey Course Description and Student Learning Objectives

The Middle East Survey course provides Global Studies students who chose a regional focus of the Middle East a basic introduction to the history and politics of the region with the goals of assisting students in understanding history and politics of the Middle East, developing a comparative perspective (i.e., the ability to discern similarities and differences between Middle Eastern countries, their politics and government), and developing an understanding and awareness of current important issues in the Middle East. The course discusses issues such as the geographical and political definition of the Middle East, the Israel-Palestine conflict, and Islam's role in the political structure of the Middle East. This course emphasizes the historical background of the Middle East with an understanding that any solid knowledge of a given region should include the region's political history. The course explores the political history, government, and political structure, and society and culture of Turkey, Egypt, Syria, Iraq, Iran, Israel, Palestine, Libya, Jordan, Lebanon, Saudi Arabia, Kuwait, Bahrain, Qatar, UAE, and Oman. As the prerequisite course before students specialize further in their region, these are students who are interested in the region but do not have in-depth knowledge of the history and politics of the region.

Middle East Government and Politics is a higher level course in Middle East Politics that involves further discussions on the above-mentioned countries and their political regimes. This course builds on the learning objectives of the survey with added emphasis on the political and governmental structure of the Middle Eastern countries.

The *Syria Simulation* was implemented in the fifth or sixth week of the semester in both classes after students were introduced to some basic history of the region. The average class size during the exercise was 17. The simulation was implemented in two separate 75-min sessions. During the simulation, the Syrian crisis was very current on the world agenda and the game could be employed at any time because the conflict is ongoing.

7.3 Simulation Assessment

7.3.1 Workshop Format

According to the Partnership for twenty-first-Century Skills, synthesizing, interpreting, and reflecting behaviors are essential to critical thought during the process of making and evaluating decisions (National Education Agency, 2004). Developing critical inquiry skills is an essential aspect of designing playful and gameful learning, and is a common goal shared by face-to-face role-play and digital game-based learning interventions alike (Qian & Clark, 2016; Salen & Zimmerman, 2003; Simkins & Steinkuehler, 2008). In a review of 29 digital games, Qian and Clark (2016) discovered that critical thinking skills were targeted in nearly 70% of the studies involving various digital games, together with creativity, collaboration, and to a lesser extent, communication. Moreover, these researchers recommend that learning game designers incorporate, "collaboration, competition, complexity, exploration and discovery, role play, self-expression and interactivity" in building twenty-first-century skills through gameplay (p. 53). The design of the *Syria Simulation* used role-play, combined with moral dilemmas, strategic use of game decisions, mechanics, and competitive participation as a design strategy to structure collaboration, competition, build complexity, encourage discovery and apply self-expression as students made and defended their respective decisions.

Assessment researchers such as Christian Loh in Ifenthaler, Eseryel, and Ge (2012) describe structured, quantitative assessment models to answer questions about retention or progress toward outcomes. Researchers in Ifenthaler et al. (2012) critically noted the importance of perspectives from learners, trainers, and administrators in assessing a game's effectiveness. While we collected formative feedback from learners and used a summative assessment instrument to gauge perspective-taking, quantitative measures on the retention of knowledge were not a goal in our application. Additionally, although students certainly demonstrated behavior like cooperation, mediation, and conflict resolution in this project, this measure was not a defined learning outcome and was not vital to the project's success. Thus, we did not collect empirical data to describe what comprised the so-called "black box" of our game-based simulation project (Ifenthaler et al., 2012). Nor was it a primary goal to study the cognitive, affective, and behavioral identification markers critical to an application of MIT that might have led to attitude change. Nevertheless, we hoped to challenge student social justice attitudes about Mideast conflict. Our experience supports Goodrich and Schneider's (2010) and Williams and Williams's (2011) findings that students who interact within complex, gameful, and playful role-playing simulations have an opportunity to challenge their world view and change attitudes about complex, difficult to understand international conflicts. Evidence from both the *Syria Simulation* workshop format and the traditional classroom setting indicates that students were challenged by the experience, understood the conflict in more complex ways, and had an increasingly nuanced understanding of the interconnectedness of the parties involved and the increased difficulty that these connections brought to any proposed solutions.

Students completed multiple assessments, derived from the AAC&U Global Learning Rubric (AAC&U, 2014). As the VALUE rubric was integrated into the workshop and its assessment as part of an interdisciplinary curriculum assessed at the institutional level, its use was aligned with best practices for obtaining the most reliable results. As is a hallmark of the VALUE approach, the rubric was modified to meet the needs of the local campus, while staying true to the designated dimensions and definitions contained within the rubric (Filer & Steehler, 2018; Finley, 2011; Pike & McConnell, 2018). In the workshop format, multiple layers of assessment with increasing levels of reflection provided insight into student achievement, particularly with regard to their ability to engage in the complex perspective-taking embedded in the simulation. It allowed students to consider complicated and consequential social justice implications of decisions at each stage of the conflict. The workshop was a cocurricular element of one of two upper-division General Education courses at this liberal arts university, and thus multiple layers of assessment were needed. The first layer consisted of questions about social justice posed to students following each round of play. The final two layers allowed for measurement of its effectiveness in expanding students' understanding of the various perspectives involved in the civil war and how they critically considered the implications for justice that resulted from the decisions of various actors in the conflict. Students completed comments during the workshop, evaluations at the end of the workshop, and graded reflective essays for their course. The reflective essays were then subsequently used for data collection as part of the assessment of the Global Learning program at the university, which involved tallying the scores given by instructors on the essay rubric and holistic scoring of some student artifacts by program coordinators.

The learning outcomes for the workshop and associated assessments were derived from the "Perspective Taking," "Personal and Social Responsibility," "Cultural Diversity" and "Knowledge Application" dimensions of the Global Learning Rubric developed by the American Association of Colleges and Universities (AAC&U, 2014). The definitions from these dimensions and descriptions of "Benchmark" to "Capstone" levels of mastery were the basis for defining the outcomes and measuring student performance.

The first pieces of evidence of student responses were online in *Google Docs* responses to social justice questions during the course of the workshop (Table 7.5). These comments tended to be brief and incomplete. While expected of all groups,

Table 7.5 Social justice questions, round 1 and 2

Round 1	**Workshop 2 Student Responses**
Who most benefited from decisions?	The refugees from Syria
Who was left out?	<No response given>
What were some consequences of the choices that stakeholders made?	Increased military presence in Syria
Round 2	
What would a socially just world look like? What is needed to achieve peace?	Do we do what's best for people as Russia versus society as a whole? We'd have leadership in Syria that represents all people—re: Assad doesn't do this Being able to educate the masses. Not being able to overcome Assad—he sees differences as being a bad thing. A socially just state—differences are accepted and thus people can live together
What are social justice challenges?	[A]mount of refugees going into Jordan & Turkey that affect their economy. Not all countries share responsibility for refugees equally. To assess the extent Turkey/Jordan have the responsibility to make refugees comfortable. Balance needs of refugees w/own country [sic]

as the simulation was quite involved and students were interested in participating in the simulation and interacting with their peers, reducing the frequency of recording their thoughts digitally. However incomplete, the comments indicate some critical thinking about the complexities of addressing the injustices created by the actions of the simulation. For example, one group commented that "[c]asualties, aid, and military spending [created] a circle of violence" (*Syria Simulation*, workshop 5). Some students grappled with the effects of powerful actors on the people, stating, "Syrian civilians (those least responsible) suffer the hardest consequences." (*Syria Simulation*, workshop 3) Also, groups demonstrated perspective-taking in noting that a barrier to peace was "[c]lashing ideals between our own cultures" (*Syria Simulation*, workshop 3), the "fear of losing influence" and that "Western ideas of justice and Eastern ideas are different" (*Syria Simulation*, workshop 7). They felt that it was hard to overcome entrenched interests to support an agenda that might advance justice, as "[c]ountries wanted to do what was right for their country" (*Syria Simulation*, workshop 3) and that "actors all have their own self-interest" (*Syria Simulation*, workshop 6). In all, these comments suggest that students who responded were thinking about the complexity of the situation, but were frustrated by the difficulty of finding solutions due to the various perspectives and interests involved. These comments indicate that students made cursory progress on demonstrating perspective-taking and were starting to address the social justice questions.

The evaluations at the conclusion of the simulation invited students to rate their workshop experience and answer questions related to their understanding of the perspectives of actors in the conflict, and the social justice issues at stake in the simulation. These questions connected to each of the AAC&U Global Learning

Table 7.6 Workshop evaluation responses

Evaluation responses	Average score (out of 5)
Gained a clear understanding of the perspectives of different actors in the Syrian crisis	4.22
Had a greater ability to consider the moral questions posed by the crisis and how these are understood differently by different stakeholders in the conflict	4.24
Were challenged to consider the kinds of actions/interventions that could lead to more socially just outcomes for the Syrian people	4.33

dimensions that undergirded the learning outcomes. These evaluations were distributed and collected at the conclusion of the workshop and were completed within 5 min or less. In addition to responding to questions using a 5-point Likert-type scale (1—Strongly Disagree, 2—Disagree, 3—Neutral, 4—Agree, 5—Strongly Agree), students could leave freeform comments. Table 7.6 provides an average of responses for each question. Five hundred and eleven evaluations were collected over the course of the term. These results indicate that students increased their understanding of the different perspectives represented in the simulation, their ability to consider the complex moral questions posed by the conflict, and were challenged to consider what kinds of changes could lead to more just outcomes.

Overall, these responses indicate that students were challenged by the questions posed by the workshop, particularly that of what intervention could be found that would result in a more socially just outcome. In the face of that challenge, they were engaged with the work of examining different perspectives and the moral questions that the civil war raises. When invited to comment on these evaluations, students indicated both that they had found the experience instructive and frustrating. Comments included observations such as, “the situation is complex, intricate, and hard to understand, further it should not be trivialized.” Another common reflection was that, “sitting in a ballroom at [their] university was very far away,” so meaningful intervention was difficult to imagine (Appendix 2, Workshop Evaluation).

Finally, students were required to write reflective essays as a graded assignment in the general education class associated with the workshop. The essay prompt and grading rubric were common to all sections of the courses and essays were scored by individual professors during the semester. As part of the program assessment after the conclusion of the semester, all rubrics from a subset of classes (approximately 120 rubrics) were collected and the scores on each item (Knowledge, Analysis, Social Justice Knowledge, and Social Justice Application) were tallied and averaged (Table 7.7).

The tally of the rubrics gives a view of how students performed as a group. However, as faculty in individual classes completed these rubrics, there was necessarily variation in how each faculty member scored their students as part of their overall grading schema in their class. Therefore, the rubrics did not have a sufficient level of consistency for the final program assessment. As an additional step, a sample of approximately 25 essays was holistically scored by the General Education program coordinators to evaluate the impact of the workshop related to its goals of global and ethical learning (Table 7.8). The holistic rubric is used to evaluate each

Table 7.7 Tally of rubrics assessed by professors in class

Skill evaluated:	Description of skill evaluated	Average score (out of 10)
Knowledge	Essay demonstrates an understanding of the perspective of the stakeholder in the Syrian conflict: Paper clearly explains the perspective of the stakeholder and decisions and implications of those decisions	8.9
Analysis	Essay critically analyzes the consequences of decisions and related actions for the whole group—Did they result in more peaceful and just circumstances or not, and why: Essay identifies a key decision and understands the nature of the decision and the implications of the consequences for the Syrian people and other actors in the conflict	8.6
Social justice: Knowledge	Essay demonstrates an understanding of social justice: Paper demonstrates an understanding of what is meant by social justice as it relates to the implications of decisions for the lives of people impacted by the Syrian conflict	8.4
Social justice: Application	Essay analyzes the social justice implications of working toward the win conditions: Paper demonstrates an understanding of the social justice implications of the degree to which the simulation was able to achieve the "win" conditions and why these were or were not achievable	8.3

Table 7.8 Holistic scoring of sample essays by program coordinators

Skill evaluated	Description of skill evaluated	Average score (out of 10)
Knowledge	Essay demonstrates an understanding of the perspective of the stakeholder in the Syrian conflict: Paper clearly explains the perspective of the stakeholder and decisions and implications of those decisions	8.1
Analysis	Essay critically analyzes the consequences of decisions and related actions for the whole group—Did they result in more peaceful and just circumstances or not, and why: Essay identifies a key decision and understands the nature of the decision and the implications of the consequences for the Syrian people and other actors in the conflict	8.0
Social justice knowledge	Essay demonstrates an understanding of social justice: Paper demonstrates an understanding of what is meant by social justice as it relates to the implications of decisions for the lives of people impacted by the Syrian conflict	7.0
Social justice application	Essay analyzes the social justice implications of working toward the win conditions: Paper demonstrates an understanding of the social justice implications of the degree to which the simulation was able to achieve the "win" conditions and why these were or were not achievable	6.9

semester's workshop in four areas (Knowledge, Analysis, Social Justice Knowledge, and Social Justice Application). How these areas of program assessment are interpreted for each workshop is defined by the student learning outcomes specific to the workshop experience and is specified in the scoring rubric used by instructors (which is rooted in the AAC&U Global Learning rubric). The program coordinators did a blind reading of several essays to establish inter-rater reliability, and scoring was as follows. The essay prompt and holistic rubric are attached in Appendix 1: Essay and Rubrics.

These rubric scores indicate that students did demonstrate achievement related to the learning outcomes stated for the workshops. As evidence of their Knowledge and Analysis of the Syrian civil war (as defined in the student learning outcomes and rubric), students noted that the choices faced by actors often posed moral and social justice dilemmas for them as students sitting safely in a workshop at their university. To act in the assigned role and take actions such as making a decision that would force people to become refugees, meant to contradict their values. Furthermore, some student papers underscored a shift in student understanding of the conflict, explicitly indicating that participating in the workshop moved their understanding of the civil war from the abstract, to a more concrete realization of the nature and consequences of the war, for example, with regard to the issue of refugees. Several students reported gaining more clear opinions about how they and their society should respond to the crisis in Syria, saying that it was not acceptable for individuals or society not to act, especially in light of the refugee crisis. Together this category of statement demonstrates that students made gains in Perspective Taking and Personal and Social Responsibility (the underlying dimensions of the AAC&U Global Learning Rubric) (AAC&U, 2014). Students demonstrated a greater appreciation of the complexities of the decisions made by different actors in the conflict and the myriad consequences of decisions as seen from the perspective of different stakeholders. This increased understanding is reflected in their relatively higher scores in the Knowledge and Analysis dimensions, where they were more consistently able to articulate the perspectives and power relations involved in the decision making, as well as consider the implications and consequences of these different positions (thus relating to the Cultural Diversity dimension of the AAC&U rubric). Less consistent in the student artifacts, resulting in the somewhat lower average scores in Social Justice Application, was a reflection on the depth of the tragedy for the Syrian population and the degree to which ending the conflict would require actors to stop acting in their self-interest. Some students considered the ideological and cultural components of the conflict that were barriers to finding a peaceful solution, though this was generally less specific than a reflection on political and military decisions, resulting in lower scores. Social Justice Knowledge was demonstrated by the ability to clearly articulate the interplay of actions of one or more actors on the rights and opportunities of other actors. One example was the tensions involved in choosing an action designed to ameliorate the suffering of the Syrian population (e.g., Turkey choosing to build refugee camps) that was motivated by social justice concerns and the real potential consequences of such a move (retaliatory violence or economic or political instability) that could create new social justice concerns for other populations. The immense difficulty of meeting the win conditions underscored the complexity of the conflict and the costs for the people and the region for many students.

7.3.2 Syria Simulation *Course Assessments and Outcome*

In both GLST 1327 (Middle East Survey) and POLS3316 (Middle East Government) classes, the *Syria Simulation* helped students understand the conflict better by making them think critically from various viewpoints. All students were engaged and participated in the game and they have commented that the class was successful in integrating current events. One student commented that the class provided "great methods in teaching on an un-biased platform" (GLST 1327-Middle East Survey/SP 15 Course Evaluations). Another commented that the class did a "great job integrating history and current events" (GLST 1327/SP 15 Course Evaluations). Another comment stated that the simulation was very important in integrating current events (GLST 1327-SP 16 Course Evaluations). Overall students found the game interesting and fun (GLST 1327- SP 16 Course Evaluations). Guner found that there was an increase in course evaluation ratings after incorporating the *Syria Simulation* game in her syllabus. The success of the simulation in both small classes (as small as 12 students) and bigger workshops (as big as 100) shows that *Syria Simulation* can be applied in various class settings. The simulation can be divided into two 75-min sessions as well as one 3-h session.

One important adjustment that was made in a smaller class setting provided the best outcomes from the simulation. Students were required to prepare a short presentation before they came to class to play the game. The presentation was graded and this gave students motivation to better prepare for the game. More specifically, the presentation assignment included an overview of the main stance of the assigned actor including their priorities and their political associations. The assignment also asked students to define some turning points in the Syria conflict (presentation instructions available). Although formal assessments for the simulation itself were not conducted, the positive course evaluations indicate that students found the simulation an interesting and fun learning experience.

7.3.3 Implications

Students of the *Syria Simulation*, whether in the full workshop or the course format demonstrated key twenty-first-century global learning skills. Assessment outcomes reveal that the simulation prompted students to consider additional and complex perspectives and engage in critical moral thinking in evaluating actions and decisions. Student evaluations and reflections indicate that their sense of understanding and certainty as to what might be a "right" outcome often becomes less clear. Many students demonstrated achievement of the desired outcomes of increased perspective-taking and empathy. These results are consistent with the changes in attitude seen from the application of strategies such as MIT, to affect attitudes about international conflict. Participation through role-play also supported a culturally responsive design, in which students gained increased fluency with a novel culture and conflict.

Moreover, these results remain consistent with the ability of role-play to foster identification with “the other” within disciplines like comparative politics. Rubric-based assessments of student writing strongly indicate that a game-based simulation, based on a high impact, significant learning format that incorporates role-play and game-based learning in a low-fidelity simulation, can positively impact knowledge and social justice outcomes common to general global learning goals and Middle East politics courses.

7.4 Design and Development

We have described strategies to design experiential engagement, role-play, game-based participation, and curriculum design. We have also given an overview of the *Syria Simulation* implemented as both a workshop and a stand-alone class, and have described how we subsequently assessed student engagement. We now provide the instructional design and game design strategies used to create the simulation. We have also chosen to expose details of the iterative design model used to continuously improve this project. We conclude by presenting a general model by which educators can design their own game-based simulation experiences. We used rapid prototyping and design-thinking model to guide the overall design process. Rapid prototyping approaches are known for prioritizing completing short cycles of design and prototyping that successively develop stronger prototypes through iteration (Daugherty, Teng, & Cornachione, 2007; Desrosier, 2011; Rathbun, Saito, & Goodrum, 1997). This team began by designing what Daughterty (2007) describes as *shallow prototypes* that illustrated the overall flow of the simulation and that improved over time (p. 2). At the beginning of the project, we also adopted an informal design thinking process, outlined by the Hasso Plattner Institute of Design at Stanford University, also known as the d.school (d.school, n.d.). Unlike more procedurally oriented instructional design processes, such as ADDIE frameworks, rapid prototyping approaches prioritize working from a basic prototype of the design, while design-thinking processes initially prioritize building empathy around the group affected by the design. Figure 7.6 shows an early, back-of-the-napkin design to incorporate both casualties and refugees in the simulation, an original, hand-drawn illustration of our early rapid prototyping steps.

Our team first began with a *straw man, a* shallow prototype of a possible simulation with potential actors, actions, and consequences (Fig. 7.7). These hand-drawn illustrations of the planning process provide an example of how the initial ideas for the simulation were conceived and tentatively sketched. No specialized software was used in this stage of development. Later stages of the design process were realized through *Google Sheets*. The decision to keep design tools lightweight enabled us to readily alter designs through successive prototypes. We revised design prototypes based on sometimes-tentative answers to questions related to Salen and Zimmerman’s (2003) notion of rules, play, and cultural considerations in game design, rather than to questions about the knowledge students would gain from the

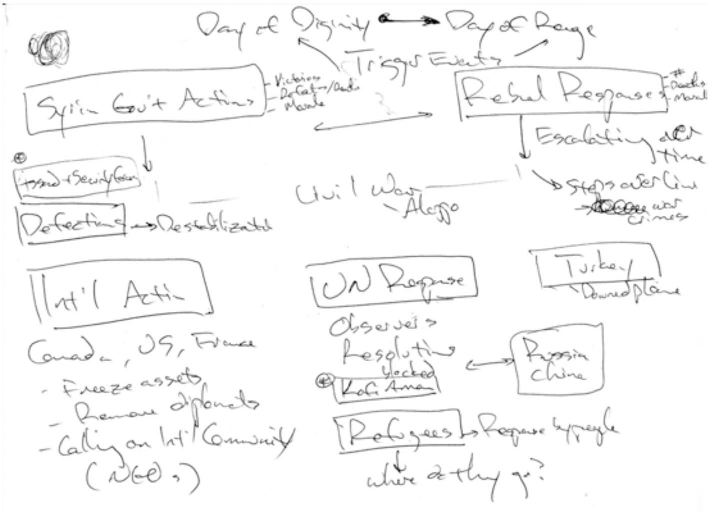


Fig. 7.6 Conflict actors mindmap

simulation or to how performance outcomes could be established that were measured for cognitive gains. Our design process, although well considered, did not follow an otherwise predictable instructional design path. We eschewed systematic approaches to define instructional design outcomes, evaluations, and quantitative assessments (Czerkawski & Lyman, 2016; Dick & Carey, 2000; Roblyer, 2015). Although useful for many projects, systematic instructional design approaches can lack flexibility, prioritizing processes instead of learner-centered approaches to designing instruction (Daugherty et al., 2007; Morrison, Ross, Morrison, & Kalman, 2019; Rathbun et al., 1997).

While we certainly addressed questions related to assessment and outcomes, these factors were used to evaluate and tweak successive prototypes, rather than as a way to plan either the choice of instructional strategy or components of the game itself. We were instead able to drive design and development through rapid, successively deeper design prototypes. As we iterated, we reflected upon the actions taken by students during the simulation and evaluated the extent to which the simulation encouraged culturally aware decision-making and empathy for an oppressed Syrian population. Following each iteration of the game (either in the cocurricular activity or between class sessions), we evaluated student decisions for each round of play and noted the extent to which student engagement reflected contextually and culturally aware perspectives and awareness of social justice outcomes. Lessons learned from this analysis of gameplay enabled us to tweak the game's timeline, actors, and potential actions made available to students. We began sustained design in spring 2012 and iterated the design through spring 2016. Applications of the game in early cocurricular workshops and class settings led to revision of design decisions that eventually allowed this team to polish the simulation's workshop format and deliver the experience to approximately 700 students in the spring of 2016.

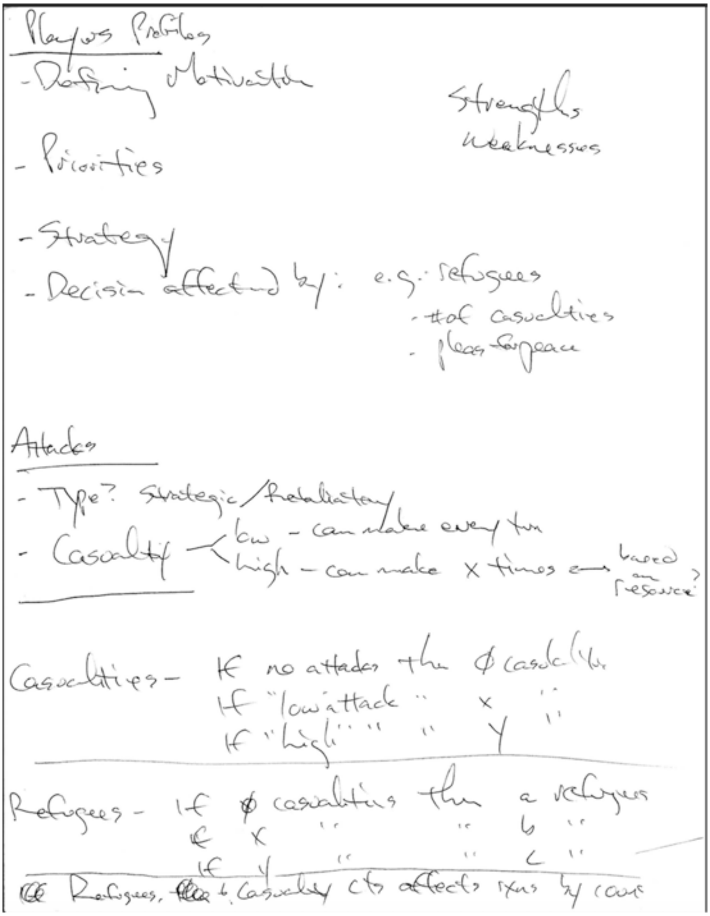


Fig. 7.7 Syrian refugees planning

7.4.1 Game Mechanics

Rosenblum began the process to design the simulation by first researching the factors that propelled the conflict in Syria, which required learning the details of geopolitics, state and non-state actors, and actions by actors like those taken by Bashar al-Assad to attack his people through chemical warfare, or through the use of barrel bombs (Perry & Laila, 2017; United Nations Secretary-General, 2015). Outputs from these actions, which included the increase of Syrian refugees and the curtailing of human rights, such as limiting access to Internet services, were analyzed for their potential inclusion in the simulation (UNHCR, n.d.; UNHCR, 2018). As is suggested by Adams and Dormans (2012), we used the outputs from these occurrences to map variables to quantifiable outcomes (Fig. 7.8). Variables such as casualty counts from a range of different types of military actions were kept as a stable

Fig. 7.8 Variables and outcomes

feature, while tentative variables such as political influence were tried and discarded. Variables related to differing availability of resources across actors were not in the initial design but were added in spring 2016. Variables related to support by other conflict actors, noted in Fig. 7.8 as external support and eventually called *Votes of Confidence,* were used from the start of the simulation's first pilot workshop, although the way this variable was balanced with the win condition shifted over time. One critical variable related to the refugees who were fleeing conflict regions is shown in Fig. 7.6 as *Refugee Count* but is not included within the back-of-the-napkin design shown in Fig. 7.8. This variable was incorporated in the early design stages of the simulation and continued to be a critical variable throughout the simulation. The frequency and type of armed conflicts seen in the region (terrorist assaults, random assaults, and strategic assaults) were connected to the variable of *Casualty Count*. The Refugee Count variable was then connected to casualty counts. These variables were used to define the mathematical levers that we used to structure gameplay. These levers, which included casualties inflicted by military assaults (of all sizes), refugees fleeing Syria, and overall support for the simulation were then drafted in the game's design within *Google Sheets*. The team used this spreadsheet to experiment with mechanics from one iteration of the game to the next.

As Adams and Dormans (2012) suggest for when to plan game mechanics, the designer defined these mechanics early in the design process, so that the rest of the authors could apply their expertise in history and global studies to evaluate, critique, and tweak starting assumptions. The sequence for the game was initially drafted at the start of the simulation's design and remained largely unchanged over the time the simulation was applied as a workshop or an in-class exercise (Fig. 7.9). In practice, successive play tests were required to balance the mechanics so that the casualty and refugee counts were realistic, and the win condition based on these counts was technically achievable within three rounds of player actions. According to Adams and Dormans (2012), the act of balancing mechanics is a "balance between order and chaos," and is one that is "easily upset" (Kindle location 1128). Our

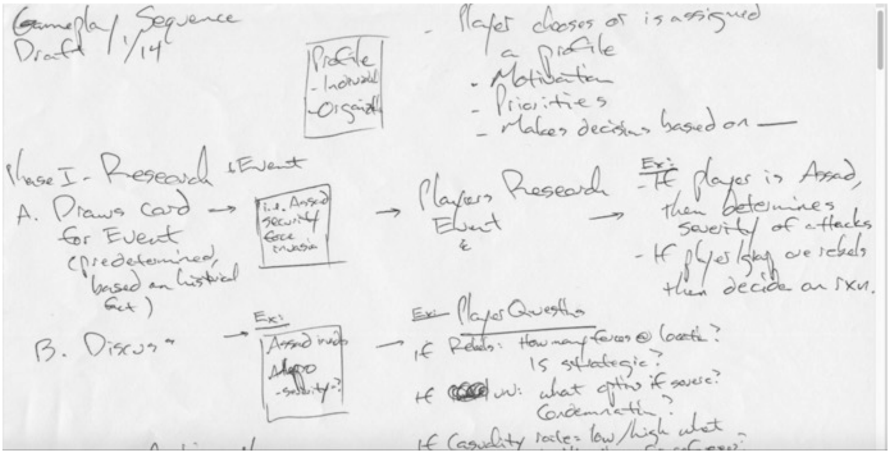


Fig. 7.9 Game sequence

challenge was to balance between offering students enough latitude to inflict casualties without giving them unrealistic or unwelcome capacity to inflict catastrophic casualties that would break the simulation. We originally included the capacity for Bashar al-Assad to obtain a nuclear weapon, and then to use that weapon on the Syrian people, or a state power. Naturally, one student group in 2013 attempted and succeeded in using this power, which inflicted enough devastation that it prematurely ended the conflict by eliminating multiple rebel actors, this led to a chain reaction that ended in Assad himself being attacked with nuclear weapons by state power. To avoid such a "simulation Armageddon" in the future, we eliminated any realistic chance for Assad to obtain and to use such catastrophic force, and thus better balanced chaos with order in the simulation.

The mechanics summarized for the *Syria Simulation* are designed to reflect key aspects of the conflict, including the actors involved in the conflict, casualties inflicted by actors, a steady stream of Syrian refugees, culturally derived social justice contexts, and the approval of conflict actors on local and global conflict outcomes. Defining these mechanics relied upon identifying the variables critical to both the real-life conflict and the curricular goals identified for the simulation. Given the complexity of the variables in the real-life conflict, we based the decisions on which variables to implement in the game by identifying threshold learning concepts that were necessary for student learning and perspective taking for the conflict. At one level, threshold concepts are those ideas that are critical to attaining knowledge, performance outcomes, or understanding of crucial learning goals (Donovan, 2017). On another level, threshold concepts transform learning by helping learners to build relationships between ideas, and by surmounting barriers to learning (Meyer, 2012; Webb, 2016). In the *Syria Simulation*, our threshold concepts required that students (a) form an understanding about complex geopolitical

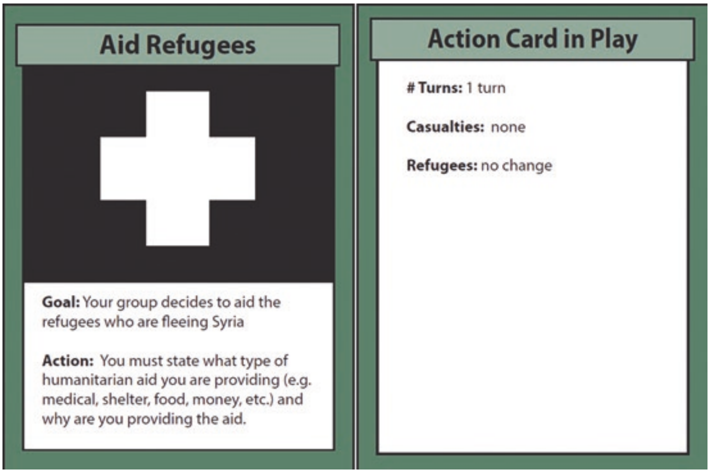


Fig. 7.10 Refugee action

interactions by state and non-state actors, (b) adopt a non-Western centric perspective to gain empathy about these actors, and (c) realize that a cessation of conflict required adopting a global perspective on the conflict (United Nations, 2019). These perspectives were critical assumptions in the decisions to include both game actions and the mechanics to manage the game actions within the game. As is referenced in Fig. 7.9, we identified these threshold concepts early in the simulation's design process and used them to turn refugees and casualties into mathematical levers that powered the game and fueled gameplay until students either did or did not reach the established win condition (Fig. 7.10). Although we revised the mechanics repeatedly, neither the threshold concepts nor the game levers changed substantially during the four-year lifespan of the simulation.

The Syrian conflict is inherently complex, and even with careful planning by this interdisciplinary faculty team, it was extraordinarily difficult to model the nuances of a conflict with real-life behavior by students who are (mostly) novices at geopolitics. Given our explicit goals of non-Western perspective building, we decided to design what Munshi, Lababidi, and Alyousef (2015) refer to as a low-fidelity simulation, which differs from a high-fidelity counterpart in the level of detail used to approximate the real-life environment being simulated. These researchers conducted an in-depth review of the literature on medical simulations to highlight differences between low- and high-fidelity simulations in terms of outcomes. For this review, high-fidelity simulations were not reliably better than low-fidelity simulations at modeling medical concepts, and Massoth et al. (2019) caution that for this topic, high-fidelity simulations can at times be detrimental in terms of overconfidence by participants.

7.4.2 Win Condition

To achieve a win, students had to work collectively to achieve peace, even as certain factions (e.g., ISIS) played actions that would work to sabotage that peace. This design decision reflected a collectivist learning design since the group as a whole would either succeed or fail to achieve peace. This design was intended to mirror the globalized nature of the conflict and represents what Bogost (2010) describes as use of implied procedural rhetoric to design game experiences. Procedural rhetoric is codified in the rule systems used by games, and also reflects real-world processes. The procedural rhetoric embedded in the *Syria Simulation* was based on the assumption that the real-life conflict being role-played was both intractable and without an easy, or even realistic, path toward peace. Moreover, this situation would continue as long as the actors in the conflict continued to make decisions that were consistent with fixed ideological, isolationist, and at times dogmatic frameworks. The win condition is reflected in Table 7.4. The numbers in this example are based on statistics from the UN's Regional Refugee and Resilience Plan in 2015, published by the UNHCR and the UN Development program (United Nations Development Programme, 2015), and reflect the scope of the conflict in 2016, as the numbers of refugees fleeing Syria had increased precipitously since the time the simulation was designed in 2012. As a result, the win condition required that Syrian refugees exiting the country be kept to one million during each turn of the conflict. In a mechanic introduced during the 2016 workshops, the support available to refugees was dictated by the amount of investment made by an actor. To achieve a win, actors needed to collectively provide 300 points worth of support by the end of three turns of play (Table 7.9). We further stipulated that refugees needed to receive minimum support during each round of play. This mechanic connected to the intention for a win in this simulation to reflect a cessation of conflict, a circumstance that could be evaluated by the impact of decisions on the refugee population. Real-life conflict actors have vastly different capacities to provide either humanitarian or military assistance, to either refugees or other conflict actors. We, therefore, defined the level of humanitarian and military resources available to spend during the simulation. The values for military and humanitarian (refugee) support are identical for every actor, except for the Syrian population, since that group could not realistically be expected to be able to provide military support to any group. Notably, actors could use their military or humanitarian resources to back any group represented in the simulation. Figure 7.10 shows an example of an action card to provide refugees with direct

Table 7.9 Win condition

Cessation of armed conflict	500 casualties or less
Votes of confidence	30 "Yes" votes by member countries
Refugee support	300 (100 points per round)
Minimum refugees fleeing per round	1 million

Table 7.10 Humanitarian and military support resources

Actors	Support
Assad	5000
EU	5000
Hezbollah	200
Iran	500
Jordan/Lebanon	700
FSA rebels	200
Islamist rebels	200
Salafi rebels	200
Russia	5000
Saudi Arabia	500
Syrian Kurdish militia	200
Syrian population[a]	900[a]
Turkey	500
Western powers	5000

[a]Unable to provide military support

support. Actors had differing levels of ability to provide either refugee or military support, with state actors possessing exponentially greater resources overall (Table 7.10). Actors could support refugees at a cost of 100 units per action or support military interventions at a cost of 200 units per action. The resources allocated to each actor were based on an assessment of the actor's real-life economic and military power at the start of 2016. This mechanic is still arguably in its infancy, and more iteration is needed to ensure that an appropriate balance between resources and support can be realistically achieved.

In the actions taken from the second 2016 workshop and shared in Table 7.3, the number of casualties present at the end of the three rounds were 90 and came as a result of military actions taken by ISIS, the Kurdish militia, the FSA, and Russia, with ISIS and the Kurds responsible for the majority of the 90 people killed during this iteration of the simulation. The numbers were well below the level of casualties specified in the win condition. However, even though these numbers were low, the accumulation of any casualties prompted a doubling (or tripling for some actions) of refugees fleeing Syria. The total number of refugees who fled the country therefore increased in rounds two and three to a total of seven million refugees by the end of round three. This was more than enough to avert a win. Moreover, there were 22 votes of approval during the voting phases of the workshop, 8 votes shy of the 30 needed for the win. To put this in perspective, to achieve a win, 10 of the 12 actors in each round needed to approve of the actions taken by the group (Table 7.9). To arrive at this number, we assumed that (a) ISIS would never approve of action and (b) the team would have enough votes if Assad (and by extension other supporting actors like Russia) also approved of actions taken. Students were prompted at the end of each round of play to revisit the win condition before choosing actions in the coming round. Although the GM did not explicitly tell students about the procedural rhetoric embedded in the simulation, as a facilitator he reminded players about the likelihood of being able to achieve a win and prompted thinking by posing questions for further thought, including consequences of weak versus strong military actions, or the corresponding retaliation or possible alliance building that could result from actions taken. These in-game markers provided guidance to prompt students to think about the goals they wanted to achieve and to pair those choices against what was needed to “win” in this game.

We supported this guidance at the beginning of the simulation by providing pre-written simulation background resources, and critically, actor information sheets, which were vetted by history and global studies faculty (Wilson et al., 2016). In our discussion of the simulation with students, we made the collectivist orientation embedded in the design rhetoric as transparent as possible, without enforcing value statements on what choices actors should or should not take. A win was designed to be technically possible, but unlikely unless actors decided to work together to achieve a cessation of conflict (see Table 7.9). Moreover, if military action was taken (e.g., by ISIS or Assad), thereby increasing refugees, a corresponding aid action needed to be taken to bring the number of refugees back down to levels compatible with a win condition (Appendix 1, Lend Aid). Student teams playing Jordan and Turkey offered aid, but their ability to provide aid was limited because of their available resources. By the corresponding point in the actual conflict in 2013 and 2014, Turkey had already become overwhelmed with the number of refugees it could support, having created overcrowded encampments along its border with Syria (UNHCR, 2018). Regardless, the number of refugees, although reduced, still accumulated past the win condition. Conversely, actors could also choose to lend military aid to rebel groups, which would (assuming the military action was successful) significantly increase casualties during that actor’s next attack.

Creating what Adams and Dormans (2012) describe as *volatile systems* within a game is an important tool to balancing a game since it leads to the design of a positive feedback loop that can help to drive play toward the game’s conclusion. We adopted such a feedback loop by adding the mechanic to increase the number of refugees that fled Syria based on (a) an initial attack or (b) an aided attack by another actor. Conversely, designers can also use negative feedback loops to slow game progress by introducing a mechanic that assists players in winning the game. In our game, we used cards such as the Lend Aid, Make Alliances, and Social Media action cards to provide students with diplomatic alternatives that could easily be used to reverse enough of the effects of other actors’ decisions. This constrained what would otherwise be chaotic decisions that would make a win unachievable by the end of the simulation. A snapshot of the game mechanics, including the variables of Casualties Inflicted and Refugee Counts as they relate to the specific actions and their corresponding consequences as defined for spring 2016 is provided in Table 7.11.

Table 7.11 Syria simulation mechanics

Response	Group	Casualties inflicted	Turns needed	Refugee count
Strategic assault	Assad/rebel groups/pro-Bashar Palestinians/anti-Bashar Palestinians	0–25% = 5 25–50% = 10 50–75% = 15 75–100% = 20	2	No change
Random assault	Assad/rebel groups/pro-Bashar Palestinians/anti-Bashar Palestinians	0–25% = 20 25–50% = 40 50–75% = 60 75–100% = 80	1	Increase: ×2
Build government	Rebel groups *requires support > = 50 from Syrian population	0	3	Decrease to 0
Negotiate peace	All groups	0	1	Decrease: 1/2
Terrorize population	Assad/rebel groups/pro-Bashar Palestinians/anti-Bashar Palestinians	0–25% = 10 25–50% = 20 50–75%. = 30 75–100% = 40	1	Increase: ×2
Military assault	Assad/pro-Bashar Palestinians/Turkey	0–25% = 20 25–50% = 40 50–75% = 60 75–100% = 80	2	Increase: ×2
Heavy military assault	Assad/Turkey	0–25% = 50 25–50% = 100 50–75% = 150 75–100% = 200	2	Increase: ×3
Make speech	All groups	0	1	No change
Make alliances	All groups	0	1	No change
Break alliances	All groups	0	1	No change
Plea for support	Assad/rebel groups	0	1	No change
Lend military aid	All non-actors, except UN and NGO	On next attack, attack takes −1 turns Casualties increase by 25%	−1	No change
Build shelters for refugees	Turkey	0	1	No change
Lend humanitarian aid	All non-actors	0	1	Decrease: 1/2

7.5 Game Design Recommendations

Four years of iterative design on this simulation began with a thoughtful design embedded within an established institutional context, developed and launched as a limited release pilot, and culminated in scaled delivery to enrolled juniors at St. Edward’s University during the spring of 2016. The model depicted in Fig. 7.11

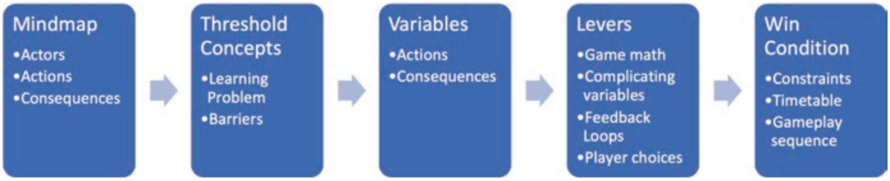


Fig. 7.11 Simulation design model

reflects critical components in the design of the game as was distilled from this process. For other educators to find this model useful, we recommend that they document this process in ways that enable future revision. Management of this complex design required that we adopt a design-thinking approach to sketch ideas and track the design process (d.school, n.d.). The figures presented in Sect. 7.5 are an example of design documentation work products from this process that were used to manage design changes during successive iterations as we revised the simulation to meet course-specific and university learning outcomes. Design documentation can include but is not limited to mind maps of core components and play sequence, back-of-the-napkin calculations of mechanics, spreadsheets to codify and test mechanics and storyboards of game assets to help them to plan the process (Adams & Dormans, 2012; Fullerton, Hoffman, & Swain, 2004).

In addition to the considered use of design assets, we also recommend that educators apply considerable thought to project scope. Educators may find it useful to limit the scope of their designs to a single, solvable learning problem to simulate. Often, by extension, this means identifying a single threshold concept that is critical to solving the problem. Once a threshold concept has been identified for a real-life scenario, educators can then create a map of the most critical elements in the process. Once an outline has been created and relationships between potential variables established, we recommend identifying the stumbling blocks that students often encounter in learning the concept. These blocks can include factors such as faulty assumptions or gaps in prior knowledge. These stumbling blocks can then be turned into complicating variables that can also be gamed. For our simulation, an important stumbling block was understanding that certain actions, such as gaining access to airbases of other state actors or even maintaining alliances with seemingly ideologically compatible actors, could not be assumed. We used these complicating variables in the design of available action cards by making them prerequisites to playing the corresponding action card during a round of play.

Once the variables in the simulation design are identified, designers can turn these into levers that can drive the game. They can subsequently plan a range of choices, and consequences for those choices, that will result as the game levers are flipped. These outcomes can then be used to further constrain gameplay as the simulation moves forward. For instance, if players in the *Syria Simulation* chose to make an alliance with an actor during one round of play, the benefits and consequences of that action then constrained the actions of both parties involved (e.g., to limit military actions or provide social media support) until the actors dissolved the alliance.

The Islamist Rebels in workshop 2 (Table 7.2) made such an alliance with Saudi Arabia and the Salafi Rebels, and thus their actions were constrained during the subsequent round of play, even as their alliance members benefited from their action.

Player choices in this example led to consequences that, in turn, led to more choices that further constrained gameplay while also moving the simulation forward. This design strategy does more than just impact game mechanics. Assuming the variables and levers are based on real-life outcomes, this approach empowers players to think strategically, while making in-character role-playing decisions and playing through realistic constraints. As is reflected in Fig. 7.11, we used this process to define the sequence of play that determined when game levers would be flipped by participants and to balance the game mechanics in ways that would allow us to drive the simulation to a satisfying conclusion. Should other educators wish to adopt this model to design game mechanics, we recommend that designers test the game's win condition mathematically in a spreadsheet, and plan successive iterations of play-testing in low-stakes academic settings to properly balance gameplay.

7.5.1 Future Research Recommendations

This manuscript describes a retrospective view of a large, complex simulation. Our retrospective case details our efforts to design, build and assess this simulation. Any future applications of this project (either in its original context or for another course) would however benefit from research that examined student engagement and decision-making in greater detail. Mixed-methods research involving a combination of pre-test and post-test measures of knowledge-building and perspective-taking, and analyzed with qualitative feedback from students and instructors would be beneficial. Moreover, the Simulation Design Model (Fig. 7.11) should be researched within other simulation contexts. An analysis of quantitative data related to student decision-making would help to shed light on the extent to which learning outcomes, game variables, and mathematical levers within a simulation can impact or predict student decision-making over time. Such an analysis would help to validate the preliminary game mechanics model proposed in this project and allow this design to be transferable to other simulations. Design-based research strategies would also be helpful to examine cognitive and attitudinal outcomes from game participation and role-play within this design. Such strategies would also allow for an extended investigation into outcomes related to player immersion and flow over the course of successive iterations of the simulation.

7.5.2 Concluding Thoughts

The *Syria Simulation* was designed to remain current with the events of the conflict, through its final delivery in the spring of 2016. Student statements during the simulation, and student writing on the topic once the simulations had concluded, demonstrated nuanced perspective-taking, and attention to the complex, and immediate global nature of the conflict. This complex project helped to shape social justice perspectives for students throughout its implementation. However, it is possible for educators to adopt limited components from this simulation design for their own courses. Guner, Wilson, and Myhr applied a role-playing perspective in other history and political science courses. Guner adopted a Model U.N. format including negotiation, diplomacy, and problem-solving skills to address international crises including the ongoing Syria conflict and the Israel-Palestine conflict. In addition, Wilson designed a novel role-playing game to immerse students in the Yugoslavian conflict of the 1990s and the Ukrainian Crisis of 2014. Myhr adopted the role-play format from the *Syria Simulation* to model a debate over asylum policy reform in the European Commission. These applications demonstrate that even without game mechanics, the considered use of role-play can be beneficial to university students across courses in history and political science.

Student participation in the role-play elements within this simulation reflected what Daniau (2016) describes as "transformative role-play." For the students in the *Syria Simulation*, and arguably for the students in the political science and history courses described, this transformative role-play included heightened attention to cultural complexities of simulation actors and assumptions of western-centric geopolitics and social justice, and an appreciation of the complexities of attaining an elusive peace in a volatile region of the world. Indeed, although this simulation was designed as a low-fidelity experience, the decision-making on the part of the students was at times, prescient. Decisions made on the part of conflict actors within the simulation mirrored actions and consequences in real life. We maintain that simulations that incorporate enactive role-play and adopt game mechanics to target threshold concepts on difficult topics can be designed to challenge student thinking about difficult moral dilemmas, particularly as they pertain to complex conflicts like Syria. These simulations-as-learning interventions can in turn also be adopted in the university curriculum, with the potential to impact students across a domain of study (particularly for liberal arts institutions), while also addressing key twenty-first-century global learning competencies. It is the hope of these authors that "pulling back the curtain" on the curricular implementation, instructional design, game design, assessment design, planning and implementation processes used in this project will enable faculty across other disciplines to adopt similar simulations for a wide variety of applications.

Acknowledgements We would like to acknowledge the tireless efforts of university staff, including instructional technology staff, in supporting the process to build the assets needed to deliver this simulation. We would also like to recognize the efforts of the student interns during the spring 2016 workshops. These global studies students were instrumental in facilitating conversations and deliberations at each workshop table, and they were key to our success. Finally, we would like to recognize the support provided by members of the program staff who managed all logistical efforts related to the workshops. Efforts by these participants and the authors of this manuscript represented a longitudinal team effort to help students learn about the complexities of the Syrian crisis through this novel game.

Appendix 1: Syria Simulation Actors and Action Cards 2015–2016

Bashar al-Assad
Make a Speech, Military Assault, Heavy Military Assault, Terrorize Population, Social Media Activity, Make Your Own Card, Broker Cease-Fire with Rebel Groups, Tactical Use of Chemical Weapons

Rebel Groups—Salafi/(ISIS)
Strategic Assault, Random Assault, Make a Speech, Plea for Support, Make/Break Alliances, Negotiate Peace, Build Government, Procure WMD's, Organize Demonstrations, Social Media Activity, General Strike, Tactical Use of Chemical Weapons, Make Your Own Card

Rebel Groups—Islamist
Strategic Assault, Random Assault, Make a Speech, Plea for Support, Make/Break Alliances, Negotiate Peace, Build Government, Procure WMD's, Organize Demonstrations, Social Media Activity, General Strike, Tactical Use of Chemical Weapons, Make Your Own Card

Rebel Groups—Free Syrian Army
Strategic Assault, Random Assault, Make a Speech, Plea for Support, Make/Break Alliances, Negotiate Peace, Build Government, Procure WMD's, Organize Demonstrations, Social Media Activity, General Strike, Tactical Use of Chemical Weapons, Make Your Own Card

Turkey
Make a Speech, Build Shelters for Refugees, Voting Cards, Military Assault, Heavy Military Assault, Aid Refugees, Social Media Activity, Make Your Own Card, Allow US forces to use airbases for strikes on ISIS in Iraq

Iran
Make a Speech, Voting Cards, Lend Military Aid, Aid Refugees, Social Media Activity, Make Your Own Card

Russia
Make a Speech, Voting Cards, Lend Military Aid, Lend Humanitarian Aid, Social Media Activity, Make Your Own Card, Broker an International Deal to Intervene, Support Training for Rebels, Materially Support Rebels, Take Military Action, Launch Airstrikes in Syria, Provide Training for Rebels to Overthrow Assad

Syrian Population
Voting Cards, Organize Demonstrations, General Strike, Join Rebellion, Lend Support to Rebels, Social Media Activity, Make your own card, Syrian Population Members Card, Build Government

Western powers (United States, United Kingdom, Canada)
Make a Speech, Voting Cards, Lend Military Aid, Lend Humanitarian Aid, Social Media Activity, Make Your Own Card, Take Military Action, Seek Parliamentary/

Congressional Approval, Support Training for Rebels, Aid Refugees, Lend Support to Rebels, Launch Airstrikes in Syria

European Union
Make a Speech, Voting Cards, Lend Military Aid, Lend Humanitarian Aid, Social Media Activity, Make Your Own Card, Take Military Action, Seek Governmental Approval, Aid Refugees

Saudi Arabia
Make a Speech, Build Shelters, Voting Cards, Military Assault, Heavy Military Assault, Aid Refugees, Social Media Activity, Lend Military Aid, Lend Humanitarian Aid, Make Your Own Card, Take Military Action, Allow US forces to use airbases, Make/Break Alliances

Syrian Kurdish Militia (YPG and YPJ)
Strategic Assault, Random Assault, Make a Speech, Plea for Support, Make/Break Alliances, Negotiate Peace, Build Government, Procure WMD's, Organize Demonstrations, Social Media Activity, General Strike, Tactical Use of Chemical Weapons, Make Your Own Card, Build Government

Hezbollah
Strategic Assault, Random Assault, Make a Speech, Plea for Support, Make/Break Alliances, Negotiate Peace, Build Government, Procure WMD's, Organize Demonstrations, General Strike, Tactical Use of Chemical Weapons, Make Your Own Card, Social Media Activity

Neighboring States Lebanon/Jordan
Make a Speech, Build Shelters, Voting Cards, Military Assault, Heavy Military Assault, Aid Refugees, Social Media Activity, Make Your Own Card, Allow US forces to use airbases for strikes on ISIS in Iraq, Support training for Rebels; Lend Support to Rebels

Appendix 2: Workshop Evaluation Form

Stakeholder: ________________________________ Group Leader: ___
____

Please indicate your responses to the questions below. The scale is:
1—Strongly Disagree 2—Disagree 3—Neutral 4—Agree
5—Strongly Agree

1. As a result of this workshop I have gained a clear understanding of the perspectives of different actors in the Syrian crisis

   1 ________________ **2** ________________ **3** ______________
   4 ________________ **5** ________________

2. As a result of this workshop I have gained a greater understanding of the power relations that are affecting the Syrian crisis

   1 __________________ **2** __________________ **3** ______________
   4 __________________ **5** __________________

3. As a result of this workshop I have a greater ability to consider the moral questions posed by the crisis and how these are understood differently by different stakeholders in the conflict

   1 __________________ **2** __________________ **3** ______________
   4 __________________ **5** __________________

4. This workshop has challenged me to consider the consequences of various actions/interventions in the conflict by different stakeholders

   1 __________________ **2** __________________ **3** ______________
   4 __________________ **5** __________________

5. I was challenged to consider the kinds of actions/interventions that could lead to more socially just outcomes for the Syrian people

   1 __________________ **2** __________________ **3** ______________
   4 __________________ **5** __________________

6. The material explaining the overall nature of the conflict and the interests of the stakeholders was clear and helpful.

   1 __________________ **2** __________________ **3** ______________
   4 __________________ **5** __________________

7. The discussion about social justice and consideration of socially just outcomes was clear and helpful.

   1 __________________ **2** __________________ **3** ______________
   4 __________________ **5** __________________

8. The material explaining the situation in my assigned state at each stage of the conflict was clear and helpful.

   1 __________________ **2** __________________ **3** ______________
   4 __________________ **5** __________________

9. My group leader effectively helped our group with discussions and group interactions.

   1 __________________ **2** __________________ **3** ______________
   4 __________________ **5** __________________

10. Did you read the information your group leader sent before the start of the workshop? Was it useful?
11. How could this workshop be improved?

Comments:

References

Adams, E., & Dormans, J. (2012). *Game mechanics: Advanced game design*. New Riders.

Ampatuan, R. A., & San Jose, A. E. (2016). Role play as an approach in developing students communicative competence. *International Journal for Innovation Education and Research, 4*(1), 18–24. https://doi.org/10.31686/ijier.vol4.iss1.503

Association of American Colleges and Universities (AAC&U). (2014). Global Learning VALUE rubric. Retrieved from https://www.aacu.org/value/rubrics/global

Association of American Colleges and Universities (AAC&U) (2020). Liberal education and America's promise. Retrieved July 17, 2020, from https://www.aacu.org/leap

Bennett, M. J. (1986). A developmental approach to training intercultural sensitivity. In J. Martin (Guest Ed.), Special Issue on Intercultural Training. *International Journal of Intercultural Relations, 10*(2), 179–186.

Bennett, M. J. (1993). Towards ethnorelativism: A developmental model of intercultural sensitivity. In M. Paige (Ed.), *Education for the intercultural experience*. Intercultural Press.

Bogost, I. (2010). *Persuasive games: The expressive power of videogames*. The MIT Press. https://doi.org/10.7551/mitpress/5334.001.0001

Burak, A. (2014, July). What I learned turning the Israel-Palestine conflict into a video game [editorial]. *:* Gaming Reviews, News, Tips and More. Retrieved June 10, 2020, from https://kotaku.com/what-i-learned-turning-the-israel-palestine-conflict-in-1612148555

Calahan, C. (2018). A six-year journey of global learning faculty and student development. *Peer Review, 20*(1), 8–12.

Chun, E., & Evans, A. (2016). Rethinking cultural competence in higher education: An ecological framework for student development. *ASHE Higher Education Report, 42*(4), 7–162. https://doi.org/10.1002/aehe.20102

Coutou, W. (1951). Role playing vs. role taking: An appeal for clarification. *American Sociological Review, 16*(2), 180–187.

Czerkawski, B., & Lyman, E. (2016). An instructional design framework for fostering student engagement in online learning environments. *TechTrends: Linking Research & Practice to Improve Learning, 60*(6), 532–539. https://doi.org/10.1007/s11528-016-0110-z

d.school. (n.d.). A virtual crash course in design thinking. Retrieved from https://dschool.stanford.edu/resources/a-virtual-crash-course-in-design-thinking

Daniau, S. (2016). The transformative potential of role-playing games—: From play skills to human skills. *Simulation & Gaming, 47*(4), 423–444. https://doi.org/10.1177/1046878116650765

Daugherty, J., Teng, Y.-T., & Cornachione, E. (2007, February–March). Rapid prototyping instructional design: Revisiting the ISD model. Paper presented at the International Research Conference in the Americas of the Academy of Human Resource Development, Indianapolis IN. Retrieved from https://files.eric.ed.gov/fulltext/ED504673.pdf

de Smale, S., Overmans, T., Jeuring, J., & Grint, L. (2016). The effect of simulations and games on learning objectives in tertiary education: A systematic review. In A. De Gloria & R. Veltkamp (Eds.), *Games and Learning Alliance. GALA 2015. Lecture Notes in Computer Science* (Vol. 9599, pp. 506–516). Springer. https://doi.org/10.1007/978-3-319-40216-1_55

Deardorff, D. K. (2009). Synthesizing conceptualizations of intercultural competence: A summary and emerging themes. In D. K. Deardorff (Ed.), *The SAGE handbook of intercultural competence* (pp. 264–270). SAGE Publications.

Desrosier, J. (2011). Rapid prototyping reconsidered. *The Journal of Continuing Higher Education, 59*(3), 135–145. https://doi.org/10.1080/07377363.2011.614881

Dewey, J. (1938). *Experience and education (reprint edition, 1997)*. Free Press.

Dick, W., & Carey, L. (2000). *The systematic design of instruction*. Scott, Foresman, and Company.

Donovan, P. (2017). A threshold concept in managing: What students in introductory management courses must know. *Journal of Management Education, 41*(6), 835–851. https://doi.org/10.1177/1052562917704869

Edutech Wiki. (n.d.). Simulation and gaming. Retrieved July 6, 2020, from http://edutechwiki.unige.ch/en/Simulation_and_gaming

Egenfeldt-Nielsen, S. (2005). Beyond edutainment: Exploring the educational potential of computer games (doctoral dissertation). IT-University of Copenhagen, Copenhagen. Retrieved from https://www.researchgate.net/publication/245584260

Faria, A. J. (2001). The Changing Nature of Business Simulation/ Gaming Research: A Brief History. *Simulation & Gaming, 32*(1), 97–110. https://doi.org/10.1177/104687810103200108

Ferren, A., & Anderson, C. (2016). Integrative learning: Making liberal education purposeful, personal, and practical. *New Directions for Teaching and Learning, 2016*(145), 33–40. https://doi.org/10.1002/tl.20172

Filer, K. & Steehler G. (2018). Lessons learned from a decade of authentic assessment. *Peer Review*, *20*(4). Retrieved July 20, 2020, from https://www.aacu.org/publications-research/periodicals/how-reliable-are-value-rubrics

Fink, L. D. (2003). *Creating significant learning experiences: An integrated approach to designing college courses*. Jossey-Bass.

Finley, A. (2011). How reliable are the VALUE Rubrics? *Peer Review*, Fall/Winter 2011 *13/14*(4/1). Retrieved July 20, 2020, from https://www.aacu.org/publications-research/periodicals/how-reliable-are-value-rubrics

Frank, R., & Genauer, J. (2019). A classroom simulation of the Syrian conflict. *PS: Political Science & Politics, 52*(4), 737–742. https://doi.org/10.1017/S1049096519000556

Fullerton, T., Hoffman, S., & Swain, C. (2004). *Game design workshop: Designing, prototyping, and playtesting games*. CMP Books.

Gee, J. (2005). *What video games have to teach us about learning and literacy*. Palgrave Macmillan.

Gold, S. (2016). Design and effectiveness of a self-study pedagogical approach to using a simulation game in the classroom. *Developments in Business Simulation and Experiential Learning: Proceedings of the Annual ABSEL Conference, 43*(1) Retrieved from https://absel-ojs-ttu.tdl.org/absel/index.php/absel/article/view/3026

Goodrich, K., & Schneider, A. (2010). The classroom can be all fun and games. *Ohio State Journal on Dispute Resolution, 25*(1), 87–103. https://doi.org/10.2139/ssrn.1485532

Hovland, K. (2005). Shared futures: Global learning and social responsibility. *Diversity Digest, 8*(3), 15–24. Retrieved from https://www.aacu.org/publications-research/periodicals/shared-futures-global-learning-and-social-responsibility

Hovland, K. (2006). *Shared futures: Global learning and liberal education*. Association of American Colleges and Universities.

Huizinga, J. (1971). *Homo ludens: A study of the play element in culture*. Beacon Press. (Original work published 1938).

Ifenthaler, D., Eseryel, D., & Ge, X. (2012). In D. Ifenthaler, D. Eseryel, & X. Ge (Eds.), *Assessment in game-based learning foundations, innovations, and perspectives* (first ed.). Springer. https://doi.org/10.1007/978-1-4614-3546-4

Jazeera, A. (2011, April 29). Scores killed on Syria's 'day of rage'. Retrieved July 17, 2020, from https://www.aljazeera.com/news/middleeast/2011/04/201142993412242172.html

Jazeera, A. (2018, April 17). Profile: Bashar al-Assad. Retrieved July 17, 2020, from https://www.aljazeera.com/news/middleeast/2007/07/200852518514154964.html

Klabbers, J. H. G. (2006). *The magic circle: Principles of gaming and simulation*. Sense.

Klein, E. (Director). (2015, December). Syria's War, A 5-minute history (video). Retrieved February 13, 2016, from https://www.youtube.com/watch?v=fGj8V147tOw

Kolb, D. (1984). *Experiential learning: experience as the source of learning and development*. Prentice-Hall. https://doi.org/10.1002/job.4030080408

Kuh, G. D. (2008). High impact educational practices: What they are, who has access to them, and why they matter. American Association of Colleges & Universities. Retrieved July 20, 2018, from https://www.aacu.org/node/4084

Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. American Educational Research Journal, 32(3), 465–491. doi: https://doi.org/10.3102/00028312032003465. Retrieved May 13, 2020, from www.jstor.org/stable/1163320

Lean, J., Moizer, J., Towler, M., & Abbey, C. (2006). Simulations and games: Use and barriers in higher education. *Active Learning in Higher Education, 7*(3), 227–242. https://doi.org/10.1177/1469787406069056. hal-00571951.

Lenhart, A. (2008). Teens, video games and civics: What the research is telling us. Retrieved from https://www.pewresearch.org/internet/2008/11/02/teens-video-games-and-civics-what-the-research-is-telling-us/

Liepman, A., Nichiporuk, B., & Killmeyer, J. (2014). *Alternative futures for Syria: Regional implications and challenges for the United States (Research Report)*. RAND Corporation. Retrieved July 20, 2020, from www.jstor.org/stable/resrep02399

Malave, C., & Figueiredo, R. (2002, August). *Practicing active and cooperative learning using live simulation games in the classroom* (Paper presented at the International Conference on Engineering Education). Manchester.

Männamaa, I. (2013). Simulation game: Taking the horses to water. In A. Moseley & N. Whitton (Eds.), *New traditional games for learning: A case book* (pp. 119–133). Routledge. https://doi.org/10.4324/9780203597514

Männamaa, I., & Leijen, Ä. (2015). The simulated acculturation model in the FOUNTAINS-game. *Simulation & Gaming, 46*(1), 98–112. https://doi.org/10.1177/1046878115591393

Massoth, C., Röder, H., Ohlenburg, H., Hessler, M., Zarbock, A., Pöpping, D., & Wenk, M. (2019). High-fidelity is not superior to low-fidelity simulation but leads to overconfidence in medical students. *BMC Medical Education, 19*(1), 19–29. https://doi.org/10.1186/s12909-019-1464-7

McGonigal, J. (2011). *Reality is broken: Why games make us better and how they can change the world*. The Penguin Press.

McGonigal, J. (2016). *SuperBetter: The power of living gamefully*. Penguin Books.

McLaughlan, R., & Kirkpatrick, D. (2004). Online roleplay: Design for active learning. *European Journal of Engineering Education, 29*(4), 477–490. https://doi.org/10.1080/03043790410001716293

Meyer, J. H. F. (2012). Variation in student learning as a threshold concept. *Journal of Faculty Development, 26*(3), 8–13.

Moniquet, C. (2016, June). The involvement of Salafism/Wahhabism in the support and supply of arms to rebel groups around the world. : Publications Office of the European Union. doi: https://doi.org/10.2861/21042. Retrieved July 20, 2020, from https://op.europa.eu/en/publication-detail/-/publication/37e6841c-d424-4e9f-84c2-c7fbc97a836e

Morrison, G. R., Ross, S. M., Morrison, J. R., & Kalman, H. K. (2019). *Designing effective instruction*. John Wiley & Sons.

Muhamad, J. W., & Yang, F. (2019). Cross-cultural learning in gameplay: BAFÁ, persuasive technology, and the exploration of intercultural sensitivity. *Simulation & Gaming, 50*(6), 848–859. https://doi.org/10.1177/1046878119879742

Munshi, F., Lababidi, H., & Alyousef, S. (2015). Low- versus high-fidelity simulations in teaching and assessing clinical skills. *Journal of Taibah University Medical Sciences, 10*(1), 12–15. https://doi.org/10.1016/j.jtumed.2015.01.008

Nadan, Y. (2014). Rethinking 'cultural competence' in international social work. *International Social Work, 60*(1), 1–10. https://doi.org/10.1177/0020872814539986.

Nair, I., & Henning, M. (2017). *Models of global learning*. Association of American Colleges and Universities. Retrieved July 20, 2020, from https://www.aacu.org/publications/models-global-learning

National Education Agency. (2004). Partnership for 21st Century Skills. Retrieved June 10, 2020, from http://www.nea.org/home/34888.htm

Perry, T., & Laila B. (2017, April). Monitor says Syria drops barrel bombs despite U.S. warning; Syria denies. *Reuters*. Retrieved from https://www.reuters.com/article/us-mideast-crisis-syria-airstrikes-idUSKBN17D105

Pike, G., & McConnell, K. (2018). The dependability of VALUE scores: Lessons learned and future directions. *Peer Review, 20*(4) Retrieved July 20, 2020, from https://www.aacu.org/publications-research/periodicals/how-reliable-are-value-rubrics

Prensky, M. (2007, March). Sims vs. games: The difference defined. *Edutopia*. Retrieved July 20, 2020, from https://www.edutopia.org/sims-vs-games

Preuß, A. K. (2020). The impact of personality and motivation on immersion in simulation games. *International Journal of Game-Based Learning, 10*(2), 1–20. https://doi.org/10.4018/ijgbl.2020040101

Qian, M., & Clark, K. (2016). Game-based learning and 21st century skills: A review of recent research. *Computers in Human Behavior, 63*(50–58). https://doi.org/10.1016/j.chb.2016.05.023

Rathbun, G. A., Saito, R. S., & Goodrum, D. A. (1997). Reconceiving ISD: Three perspectives on rapid prototyping as a paradigm shift. In O. Abel, N. J. Maushak, & K. E. Wright (Eds.), *19th Annual Proceedings of Selected Research and Development Presentations at the 1997 National Convention of the Association for Educational Communications and Technology* (pp. 291–296). Iowa State University. ED # 409832.

Roblyer, M. D. (2015). *Introduction to systematic instructional design for traditional, online, and blended environments*. Pearson.

Rosenblum, J. (2012, June). *Gameful Learning and Global Social Problems*. Paper presented at Games Learning Society 8.0, Madison WI. doi: https://doi.org/10.1184/R1/6686786.

Salen, K., & Zimmerman, E. (2003). *Rules of play: Game design fundamentals*. The MIT Press.

Sauvé, L., Renaud, L., Kaufman, D., & Marquis, J. S. (2007). Distinguishing between games and simulations: A systematic review. *Educational Technology & Society, 10*(3), 247–256.

Schneider, C. G. (2015). The LEAP challenge: Transforming for students, essential for liberal education. *Liberal Education* , Winter/Spring 2015, 101(1/2), 16–21. Retrieved July 20, 2020, from https://www.aacu.org/liberaleducation/2015/winter-spring/schneider

Setrakian, L. (Director). (2012). *Background on the Syria crisis: The global players* (video). Retrieved February 13, 2016, from https://youtu.be/k2icUY71r04

Shearer, R., & Davidhizar, R. (2003). Using role play to develop cultural competence. *Journal of Nursing Education: Educational Innovations, 42*(6), 273–276.

Simkins, D. (2011). Negotiation, simulation, and shared fantasy: Learning through live action role play (Doctoral dissertation). University of Wisconsin-Madison.

Simkins, D. W., & Steinkuehler, C. (2008). Critical ethical reasoning and role-play. *Games and Culture, 3*(3–4), 333–355. https://doi.org/10.1177/1555412008317313

Squire, K. (2003). Video games and education: Designing learning systems for an interactive age. *International Journal of Intelligent Games & Simulation, 2*(1), 49–62. Retrieved July 20, 2020, from https://www.researchgate.net/publication/228731376_Video_Games_and_Education_Designing_learning_systems_for_an_interactive_age

Squire, K. (2006). From content to context: Video games as designed experiences. *Educational Researcher, 35*(8), 19–29. https://doi.org/10.3102/0013189X035008019

Squire, K. (2007). Games, learning and society: Building a field. *Educational Technology, 4*(5), 51–54.

Stenros, J. (2014). In defence of a magic circle: The social, mental and cultural boundaries of play. *Transactions of Digital Games Research Association, 1*(147–185) Retrieved May 14, 2020, from http://todigra.org/index.php/todigra/article/view/10/26

Tanner, J., Stewart, G., Totaro, M., & Hargrave, M. (2012). Business simulation games: Effective teaching tools or window dressing? *American Journal of Business Education, 5*(2), 115–128. https://doi.org/10.19030/ajbe.v5i2.6814

Tejeda, C., Espinoza, M., & Gutierrez, K. (2003). Toward a decolonizing pedagogy: Social justice reconsidered. In P. Trifones (Ed.), *Pedagogies of difference: Rethinking education for social justice* (pp. 10–40). RoutledgeFalmer.

Torner, E., & Jones, K. C. (2014). The parlor sandbox: Counter-players and ephemera in American freeform. In S. L. Bowman (Ed.), *Wyrd Con companion book 2014* (pp. 112–131). Wyrd Con. Retrieved from http://www.wyrdcon.com/2014/05/the-wyrd-con-companion-book

Tornqvist, D. (2014). Exploratory play in simulation sandbox games. *International Journal of Game-Based Learning, 4*(2), 78–95. https://doi.org/10.4018/ijgbl.2014040105

U. N. Human Rights Council. (2016). Out of sight, out of mind: Deaths in detention in the Syrian Arab Republic (A/HRC/31/CRP.1) Retrieved from https://www.ohchr.org/Documents/HRBodies/HRCouncil/CoISyria/A-HRC-31-CRP1_en.pdf

United Nations. (2019). *United Nations seeks negotiated political solution as Syria conflict enters ninth year, Under-Secretary-General tells Security Council (8493RD MEETING (AM), SC/13751)*. United Nations. Retrieved from https://www.un.org/press/en/2019/sc13751.doc.htm

United Nations Development Programme (2015). Regional refugee & resilience plan 2015–2016, in Response to the Syria crisis: Regional strategic overview. Retrieved from http://www.undp.org/content/dam/rbas/doc/SyriaResponse/3RP%20strategic%20overview%20new%20.pdf

United Nations High Commissioner for Refugees (UNHCR), (2018). Seven years on: Timeline of the Syria crisis. Retrieved from https://www.unhcr.org/ph/13427-seven-years-timeline-syria-crisis.html

United Nations High Commissioner for Refugees (UNHCR). (n.d.). Syria emergency. Retrieved from https://www.unhcr.org/en-us/syria-emergency.html

United Nations Secretary-General. (2015). *Note to correspondents: Press statement by the secretary-General's special envoy for Syria*. United Nations. Retrieved from https://www.un.org/sg/en/content/sg/note-correspondents/2015-05-30/note-correspondents-press-statement-secretary-generals

Vaccaro, A., Chartelain, A., Croft, S., D'Aloisio, B., Hoyt, T., & Stevens, B. (2017). "The way I view the world has changed": Student and teacher reflections on transformative social justice education. In D. Liston & R. Rahimi (Eds.), *Promoting social justice through the scholarship of teaching and learning* (pp. 228–240). Indiana University Press. Retrieved July 20, 2020, from www.jstor.org/stable/j.ctt2005zc2.16

Vlachopoulos, D., & Makri, A. (2017). The effect of games and simulations on higher education: A systematic literature review. *International Journal of Educational Technology in Higher Education, 14*(22), 1–33. https://doi.org/10.1186/s41239-017-0062-1

Walz, S. P. (2010). *Toward a ludic architecture the space of play and games*. ETC Press. https://doi.org/10.1184/R1/6686981

Webb, A. S. (2016). Threshold concepts and the scholarship of teaching and learning. In R. Land, J. H. F. Meyer, & M. T. Flanagan (Eds.), *Threshold concepts in practice. Educational futures (Rethinking theory and practice)*. SensePublishers. https://doi.org/10.1007/978-94-6300-512-8_22

Wheeler, S. M. (2006). Role-playing games and simulations for international issues courses. *Journal of Political Science Education, 2*(3), 331–347. https://doi.org/10.1080/15512160600840814

Williams, A. J., & Williams, R. H. (2011). Multiple identification theory: Attitude and behavior change in a simulated international conflict. *Simulation & Gaming, 42*(6), 733–747. https://doi.org/10.1177/1046878111429228

Wilson, C., Myhr, M., Guner, S., & Micklethwait, C. (2016). *Simulation actors*. Retrieved July 20, 2020, from http://sites.stedwards.edu/syriasimulation/student-resources/

Wolfe, J., & Keys, B. (1997). *Business simulations, games and experiential learning in international business education* (first ed.). International Business Press.

Zagal, J. P., & Deterding, S. (2018). Definitions of "role-playing games". In J. P. Zagal & S. Deterding (Eds.), *Role-playing game studies: Transmedia foundation* (pp. 19–51). Routledge.

Zhang, C., Grandits, T., Härenstam, K. P., Hauge, J. B., & Meijer, S. (2018). A systematic literature review of simulation models for non-technical skill training in healthcare logistics. *Advances in Simulation, 15*(3). https://doi.org/10.1186/s41077-018-0072-7

Part II
Inside and Across the STEM Disciplines

Chapter 8
Designing Dynamic Learning Supports for Game and Simulation-Based Learning in STEM Education

Byung-Joo Kim, Fengfeng Ke, Jewoong Moon, and Luke West

8.1 Introduction

Research suggests that digital games or simulations present a realistic framework and a story context for experimentation and situated understanding, and have positive cognitive and motivational effects on the development of multistranded learning outcomes: understanding, problem-solving, and positive disposition (Clark et al., 2011; De Freitas, 2018; Ke, 2008, 2016; National Research Council [NRC], 2011; Qian & Clark, 2016). Yet a critical challenge of using games for learning is to provide dynamic and unobtrusive in-game learning support. Engaged gameplay may not guarantee successful math learning for all players, especially for those who lack the habits and skills associated with critical and reflective thinking. Scaffolds for game action-based learning should be designed via unobtrusive in-game learning support, such as planning and reflection of content-specific gameplay, intrinsic learning prompts, and a balance between regulation and autonomy (Chang et al., 2012; Wouters & Van Oostendorp, 2013).

Learning supports or soft scaffolds (Azevedo et al., 2008; Puntambekar & Hubscher, 2005) in game-based learning can be categorized in terms of their purpose, form of encoding or representation, manifestation, and form of interaction. In terms of the purpose of in-game learning support, Reiser (2004) distinguishes "structuring" and "problematizing" aspects of scaffolding. Task structuring guides "learners through key components and support[s] their planning and performance" (p. 273), whereas content problematizing supports their performance and understanding of the task in terms of key disciplinary content and strategies. The form of

B.-J. Kim · F. Ke (✉) · J. Moon · L. West
Department of Educational Psychology and Learning Systems, Florida State University, Tallahassee, FL, USA
e-mail: fke@fsu.edu

C. Aprea, D. Ifenthaler (eds.), *Game-based Learning Across the Disciplines*, Advances in Game-Based Learning, https://doi.org/10.1007/978-3-030-75142-5_8

in-game learning support can be syntactic, iconic, or symbolic, with its effect mediated by the player's prior knowledge and familiarity with a specific game-based task or problem (Lee & Ke, 2016). The in-game manifestation of learning support relates to its association with the game world or game actions. Research on game-based learning support (Chang et al., 2012; Ke, 2016; Wouters & Van Oostendorp, 2013) indicates considerable diversity in its manifestation, such as written cues embedded in narratives and an end-of-level summary screen, a background game asset (e.g., a collapsible help panel or an in-game scratchpad/calculator), instant visual cues or feedback (e.g., a "ghost model" of a transformed geometrical figure, cueing the next phase of problem-solving), or a rewarded game action (e.g., interacting with an in-game prompt to earn additional material credits). The in-game manifestation of the learning supports moderates its effectiveness. The literature is still inconclusive as to the optimum manifestation of learning support that is both unobtrusive and engaging. Ultimately, the form of interaction (e.g., selection or encoding of an interactive prompt) and the degree of direction (e.g., explicit instruction or prompts for self-explanation and reflection) also vary in in-game learning supports. The literature on scaffolds in technology-rich learning environments documents the challenges in designing a balance between regulation and learner autonomy (Hannafin & Land, 1997; Hmelo-Silver & Azevedo, 2006; Puntambekar & Hubscher, 2005). The time to provide and fade certain manifestations of learning support can be dynamic and associated with the game task performance of individual players. For example, a game could automatically collapse/expand a help panel or display visual feedback when preset threshold values in the stealth assessment are reached (Timms et al., 2014).

In the following sections, we present two design cases in which in-game learning supports mathematical problem representation and STEM-related representational flexibility in simulation game-based learning platforms. The key design challenges, learning support features, and user study findings are described and reported.

8.2 Case 1: Designing in-Game Support for Mathematical Problem Representation

8.2.1 Background

Computer games have been considered a useful tool for fostering students' mathematical learning and problem-solving in the classroom (Byun & Joung, 2018). Notably, it is suggested that game-based math problem-solving interventions allow students to experience real-world problems through multimodal external representations of the problem situation (Ke & Clark, 2020). However, learners may feel cognitively overwhelmed when processing multiple representations while solving complex and multifaceted problems (Duval, 2006). Therefore, in-game learning supports need to be provided effectively to support the translation and integration of information regarding the problem situations.

Solving math problems in realistic situations requires learners to find, analyze, and synthesize information on the problems. Constructing mathematical representations of a problem situation consists of two phases: (a) problem translation—identifying mathematical information from the problem situation, and (b) integration—selecting mathematical information relevant to solutions and structuring it to create a coherent internal representation of the problem (Mayer, 1992). It is reported that the failure to construct meaningful problem representations is due to a direct translation strategy that focuses only on the mathematical quantities presented in the problem description (Hegarty et al., 1995). Researchers have also found that providing a verbal problem representation as a single mode of representation leads to a failure to formulate meaningful problem representations (Hoogland et al., 2016). Thus, instructional supports for problem-solving should involve learners in meaningful interactions with a multimodal system of external problem representation (van Garderen, 2006).

Kirsh (2010) suggested that learners would improve their mental representations of information via interactions (i.e., manipulation and interpretation) with external representations of the information. Goldin (2002) also asserted that students' construction of internal problem representations would be enhanced through interactions with carefully designed external representations of the problem. Research on the visual-spatial representation of math problems showed that using schematic representations of a problem was positively correlated with successful problem solving while the use of pictorial representations was not (Kozhevnikov et al., 2002). However, it should be noted that a system of multimodal problem representations might involve individual problem solvers in the translation process, which is cognitively overwhelming compared to a text-only mode of problem representation (Duval, 2006). Thus, learning supports for mathematical problem representation need to support students' integration of the essential information in a problem by employing schematic spatial representations with no additional cognitive load.

8.2.2 E-Rebuild: Architecture Game-Based Platform for Math Problem Solving

E-Rebuild is a 3D simulation game that allows students to learn mathematical problem solving by performing various architectural design tasks to restore an area destroyed by natural disasters. In this game, students are required to complete a construction task in each game level, such as constructing and positioning structures. The game tasks are designed to represent contextualized math problems aligned with the grade 6–8 Common Core Standards. The 3D game world embodies the tasks using multimodal forms such as written task narratives, 3D game objects, math notation, and interactive math tools. Overall, the game-based environment enables middle school students to investigate and coordinate multimodal representations of the math variables and relations in the problem situation.

However, we encountered challenges in using E-Rebuild in the schools. Some student players could not develop a sound situational representation of the math problem due to a lack of skills and commitment in gathering, translating, and organizing the problem information embedded in the game world (Ke, 2019; Ke & Clark, 2020). Regarding this challenge, in-game learning support is needed to guide players' math problem solving with a focus on problem representation.

After several rounds of implementing E-Rebuild in school, we also faced the need to develop a flexible game-based learning platform that enables continuous development of game tasks (Ke et al., 2019). The scalable platform allows teachers to customize game levels for their students with differing needs and in diverse school settings. Correspondingly, each component of in-game learning support should be redesigned to be integrated into the platform for automatic learning support creation.

8.2.3 Learning Supports Design

We designed action-based, multistep learning support situated in the game world. The support aims to aid student players' cognitive processes for mathematical problem solving during gameplay. In other words, the support encourages students to consciously and deliberately comprehend and coordinate multimodal external representations. In this section, we explain the steps we took to design and develop the in-game mathematical problem-solving support.

The learning support for problem-representation in the previous version of E-Rebuild (Lee & Ke, 2016) was refined and extended into a system of learning supports, including (1) an updated template that enables automatic generation of learning supports along with a game level, (2) an interactive scaffolding of math problem solving, (3) real-time tracking of players' interactions with the in-game scaffold, and (4) real-time assessment of students' math competency.

8.2.3.1 Initial Learning Support Design

8.2.3.1.1 Core Game Actions to Be Supported

Core game actions in E-Rebuild, such as building, allocating, and folding, were designed to engage players in actively maneuvering and constructing math problem representations in the game world. To be specific, via the core game actions players get to organize and integrate task-related information embodied by game objects in multimodal forms. We conducted a cognitive task analysis to identify a core set of problem representation and solving processes underlying the core game actions.

The first core game action is building, which involves (a) decomposing the proposed three-dimensional structure into smaller parts or modules; (b) composing the structure by stacking and joining building blocks or modules. The critical parameters of the building action are (1) the total interior/exterior space to be created by the whole building, (2) the properties of basic building blocks (e.g., length, area, and volume) and materials to be used, and (3) the structural relationships among building modules at various levels. These key variables constitute a structural representation of the mathematical problem framed by a building action.

Another core game action is allocating, which involves (a) securing enough floor space for a certain number of occupants listed in the player inventory and (b) assigning them to a secured space. The key parameters of the allocating-action are the (1) interior space provided by buildings, (2) interior space needed to accommodate occupants, (3) types of occupants, (4) number and unit space of each type of occupant, and (5) ratio of space need between individuals in each occupant group.

An additional core game action is folding, which involves adjusting angles and direction of folding performed on game objects. The key parameters of the folding action are the (1) geometric shape and number of figures that compose the solid figure, (2) folding angle, and (3) folding direction.

8.2.3.1.2 In-Game Scaffolding of Mathematical Problem Representation

The primary goal of the in-game learning support is to scaffold students' mathematical problem-representation processes when they are tackling a game task. Specifically, the support is designed to help the student (1) identify the goal state of the problem situation, (2) decompose the task into sub-tasks, (3) collect task-relevant information distributed in the game world, (4) comprehend the mathematical relationships among the key variables of the problem, and finally (5) make an implementation plan to complete the task.

To achieve these objectives, we conceived three major design elements of the interactive learning support, including: (1) step-by-step scaffolding of mathematical problem representation, (2) schematic representations to enhance students' conceptual understanding, and (3) interactive pictorial representations to reduce students' cognitive load induced by directly manipulating of 3D game objects.

The interactive learning support visually demonstrates the critical problem-solving process required to complete the game-based math task for each game level. This stepwise display of the problem-solving process aims to help learners decompose or analyze the main task and focus on its essential features by modeling the expert's problem-solving process (Reiser, 2004). For example, the learning support for the allocating action displays three subgoals of the game task at the top of the screen (1) identifying floor space needed to place all residents, (2) identifying floor space provided, and (3) comparing space provided and space needed. Figure 8.1 shows a sequential display of these subgoals.

Each step includes multiple sub-steps requiring players to respond to question prompts regarding the math problem representation process, especially problem

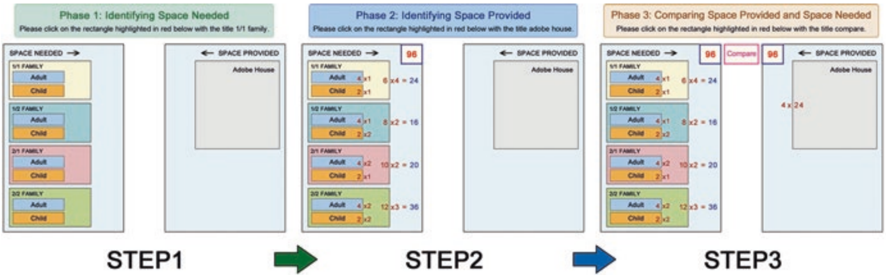


Fig. 8.1 Stepwise scaffolding of a mathematical problem representation

Table 8.1 A list of questions prompted in the allocating-action support

Step	Problem representation	Example question
1. Identifying floor space needed	Floor space needed to place a single unit in each type of family	How much space is needed to place one 2/1 family?
	Floor space needed to place all units in each type of family	How much space is needed to place all 2/1 families?
2. Identifying floor space provided	Floor space provided by a single shipping container	What is the area of one shipping container?
	Number of shipping containers placed in the game	How many shipping containers are placed in the game?
3. Comparing space provided and space needed	Comparing two numbers	Do you think you can allocate all the family units in the inventory to the shipping container provided?

translation and integration (Mayer, 1992). These question prompts aim to facilitate learners' identification and processing of the critical variables of the math problem. Table 8.1 shows a list of questions prompted in the learning support for allocating related game tasks.

The second learning-support element is a schematic representation of the game-based math problem, demonstrating how critical problem information is related. We created a schematic diagram for each core game action. Figure 8.2 shows the schematic representation embedded in the allocating-oriented learning support.

The third element of the learning support is an interactive pictorial representation of the game-based math problem. This iconic problem representation is presented in the support only when a game task requires complex manipulation of 3D objects. Figure 8.3 shows the pictorial problem representation presented in allocating-related learning support. The drag-and-drop activity prompts learners to focus on allocating family units in the containers without spending excessive cognitive effort in manipulating multiple 3D game objects.

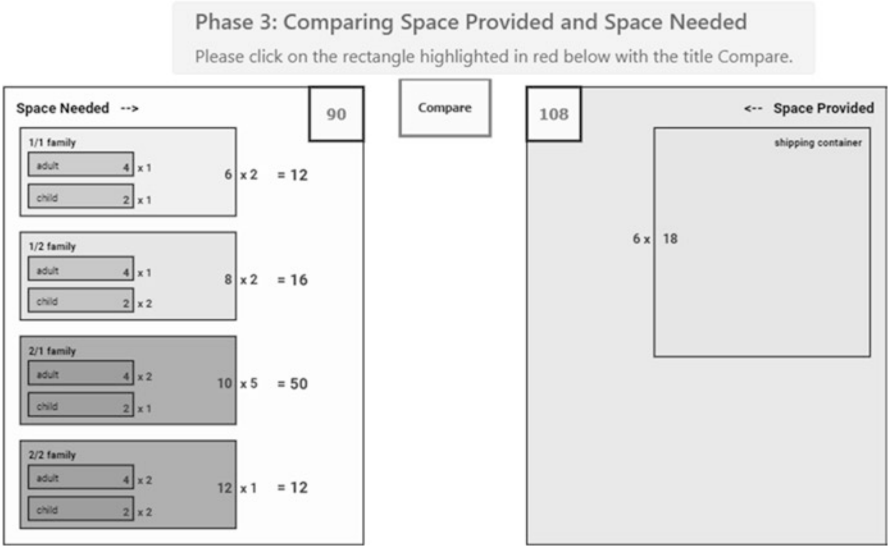


Fig. 8.2 The schematic representation of an allocating-related problem

8.2.3.1.3 Usability Study

The usability study on the initial design of the learning support consists of two phases: one with teachers and the other with students. In the first phase, four mathematics teachers participated in a four-hour user testing session to evaluate the learning support prototype. We focused on gathering qualitative data on teachers' experiences and perspectives of the learning support. In the second phase, nine middle school students participated in a 2.5-hour-long gameplay session. We conducted onsite observation to gather qualitative data on student players' gameplay behaviors and their interactions with the learning support during gameplay.

8.2.3.1.4 Study Findings

Based on our observations and participant interviews, teachers enjoyed using the learning support during gameplay. They accessed the support voluntarily by clicking on a button in the 'Tips' panel in the upper-right corner of the screen (see Fig. 8.4). They were cognitively engaged in processing the problem-solving scaffold while playing the two most challenging game levels: family allocation and stadium seat construction. What they liked most about the support was its usefulness in working out the problems before executing their problem-solving plan. No user-interface-related issues were reported by teachers, although they found it annoying shifting back and forth between the game and the scaffold.

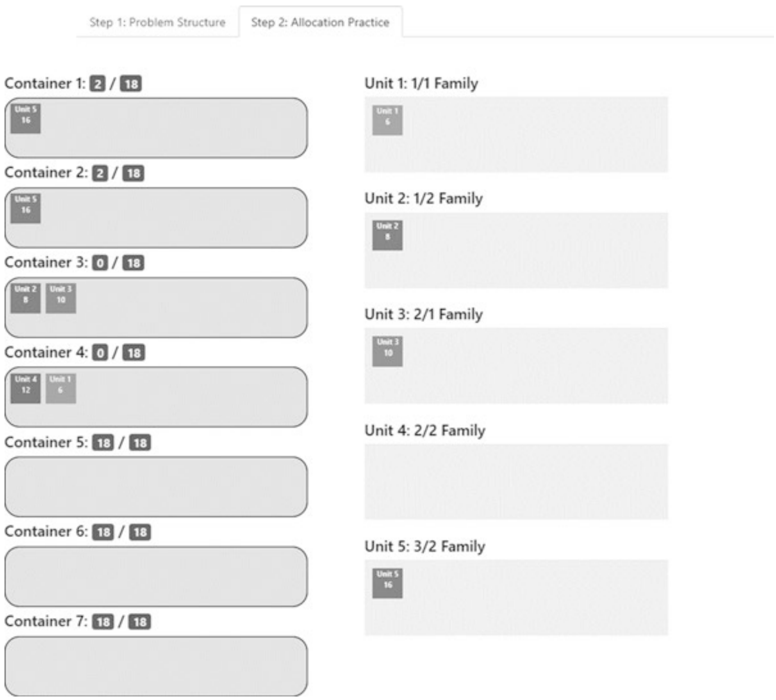


Fig. 8.3 Pictorial representation of an allocating-related problem

The infield observations on students revealed that some players never accessed the problem-solving scaffold voluntarily and they had to be reminded on referring to the tips panel. Based on our observation, a possible reason for this lack of voluntary support usage is that students tended to hide or collapse the tips panel to free up the screen space for gameplay. Given the fact that students typically used low-specification machines (e.g., Chromebooks) in school classrooms, the support access interface needs to be adjusted so as not to hinder students' voluntary access to the learning support.

8.2.3.2 Second-Round Learning Support Design

8.2.3.2.1 Additional Game Actions to Be Supported

To create a parameter-based template for automatic scaffolding generation, we have defined an expanded list of core game actions: collecting, covering, placing, and trading actions, in addition to the original actions of building, allocating, and folding. Hence, we had to conduct an additional, systematic cognitive task analysis with these game actions and their contextualized embodiment in different game tasks.

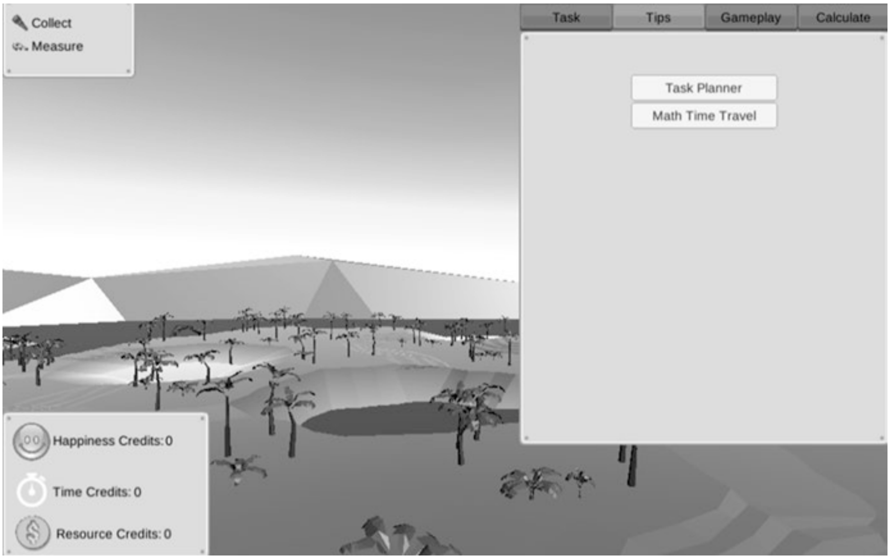


Fig. 8.4 The initial user interface for activating the learning support

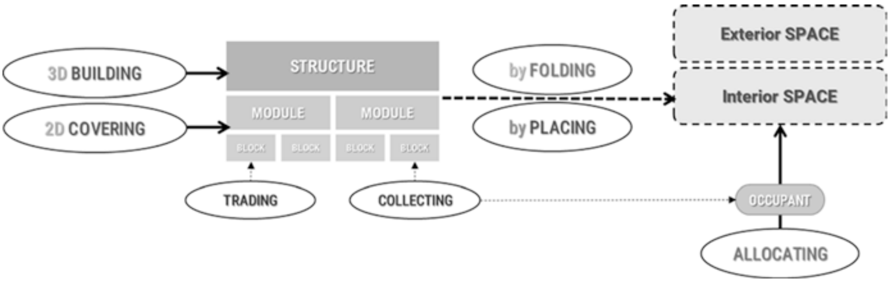


Fig. 8.5 Core game actions and architectural task parameters

Figure 8.5 shows how all core game actions are related to each other, and how they are related to architectural task parameters.

The game action of covering involves the componential actions of (a) decomposing the proposed two-dimensional structure into smaller parts or modules, and (b) composing the structure by tiling or painting. The key parameters of the covering action are (1) the total exterior space to be covered by the whole surface, (2) the properties of basic blocks to be used for covering (e.g., tile and paint), and (3) the structural relationships among covering modules at various levels.

The placing action involves the processes of (a) controlling one target structure's geometrical properties relative to those of another target structure, and (b) creating multiple geometric relationships between the two structures. The key parameters of the placing action are (1) the target architectural structures to be placed, (2) the reference objects in the game, and (3) the geometric relationship between the target and reference.

For the collecting action, one needs to identify the mathematical properties of the game objects that can be collected by players in the game world. The key parameters for the collecting action are determined by the game objects to be collected by players in different game tasks.

The final game action is trading, which involves (a) estimating the total quantity and price of construction materials needed, and (b) purchasing the materials at the store in the game. The key parameters for the trading action are defined by the game objects to be purchased by players in each game task.

8.2.3.2.2 User-Interface Design

The results of the first usability study led us to revise the learning support's user interface. We removed the tips panel and created a small activator on the left-hand side of the screen (see Fig. 8.6a). When a player clicks the button, a small panel slides in from the left side of the screen (see Fig. 8.6b). Players can access the learning support anytime by clicking the 'Task Planner' button during gameplay when the help panels are inactive.

8.2.3.2.3 In-Game Scaffolding of Mathematical Problem Representation

We added an introduction page, with a conversational narrative and action-specific buttons for activating learning supports. An on-screen character or agent was added to the intro page (see Fig. 8.7) to make young student players more motivated by using the problem-solving scaffold.

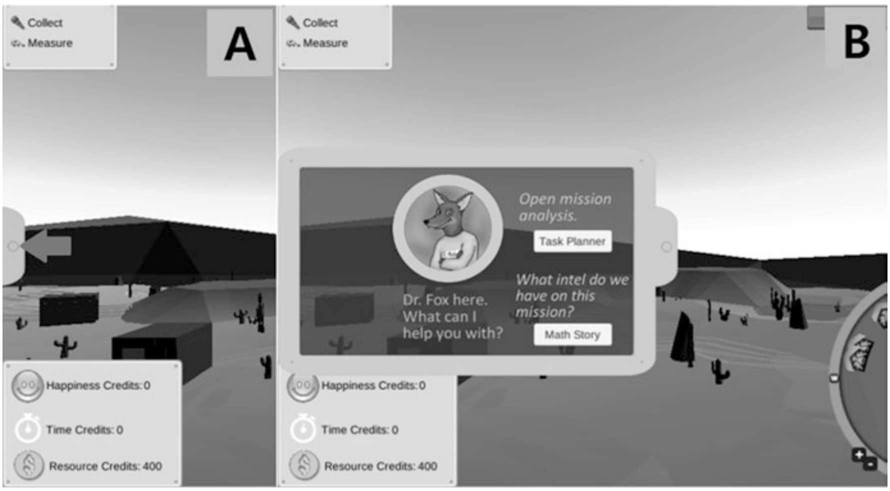


Fig. 8.6 Revised user interface for activating the learning support

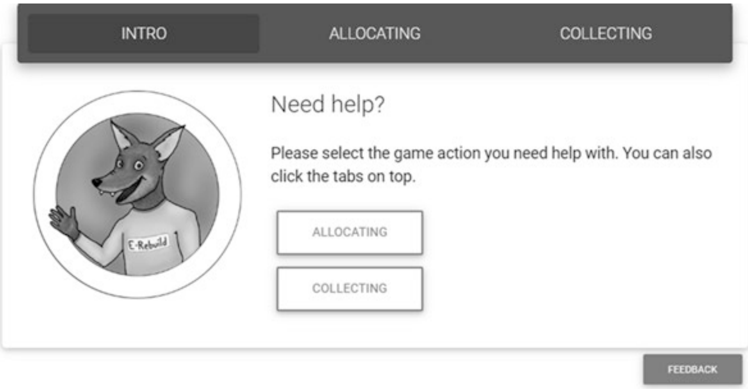


Fig. 8.7 Introduction page in the learning support (second-round design)

8.2.3.2.4 Usability Study

We observed and interviewed eight middle school mathematics teachers for another usability study on the second-round design of the learning support. They participated in a 4-hour user testing session to evaluate the refined learning support prototype. We focused on gathering qualitative data on how teachers experience and perceive the revised learning support.

8.2.3.2.5 Study Findings

We tested the second version of in-game learning support, including the support for five core gameplay actions: allocating, building, folding, collecting, and trading. In particular, we focused on testing the new interface design and the learning support for newly added game actions.

We found that the teachers interacted most with the learning supports related to allocating and building actions. They accessed these supports voluntarily using the activator panel on the left side of the screen. They were found actively processing the question prompts in the problem-solving scaffold when playing the family allocation level and the stadium construction level. What they liked most about these supports was the stepwise problem-solving guide for planning their problem-solving process. They reported that the newly added supports (e.g., the supports for the actions of collecting and trading) were easy to use.

8.2.4 Summary and Implication

Overall, this case study illustrated our design attempts to engage student players in mathematical problem solving through action-based, interactive learning supports in a game-based learning environment. We observed that student players who lack skills and commitment in constructing math problem representation had difficulty completing complex game tasks. To guide their problem representation process, we have designed and implemented interactive cognitive scaffolds for game-based mathematical problem-solving. The interactive scaffold aims to help players model the main task mathematically and motivate them to deliberately process information relevant to mathematics. We found that the revised version of in-game learning support managed to engage players in processing math-related information when they were playing the most complicated game levels. Additionally, we observed that student players frequently gauge the cost and benefit (or value) of specific learning support during gameplay. In other words, the timing of providing and fading the support during a game task should be dynamically adjusted according to a player's gameplay performance.

8.3 Case 2: Designing in-Game Support for Representational Flexibility

8.3.1 Background

Representational flexibility refers to the capability of switching attention and using different modes of representations to comprehend or reproduce knowledge (Herbert & Hayne, 2000). This concept also explains an individual's use of representations to control responses (Zelazo et al., 1998) and adapt behavior or solutions to surrounding situations (Heinze et al., 2009). In prior research, representational flexibility is frequently examined as an individual's capability to understand, interpret, and apply content knowledge to various design problem-solving tasks.

Adolescents with autism spectrum disorder (ASD) have been underrepresented in science, technology, engineering, and math (STEM) education (Wei et al., 2013; Wei et al., 2017). Relevant to this issue, autism research has found that the low representational flexibility of adolescents with ASD explains their difficulty in academic achievement in STEM education. Representational flexibility is related to various STEM subjects that require learners to choose and execute correct representations to design, develop, and implement products. Specifically, tasks in STEM fields inherently require learners to enact representational flexibility in design problem-solving. For example, in engineering education, learners should decompose, identify, and analyze the core features of a design problem and then implement design prototypes based on the analysis results. However, adolescents with ASD have a low sense of attention switching and inhibition (Geurts et al., 2009). Thus, adolescents with ASD are likely to experience challenges in understanding and applying content knowledge to various design tasks in STEM education. This calls for a task or learning environment that will foster representational experiences of adolescents with ASD through visually enriched approaches.

Researchers have introduced and designed virtual reality (VR) based training for developing students' intellectual skills (Didehbani et al., 2016; Parsons & Mitchell, 2002). Hands-on and manipulative exercises in 3D simulations enable learners to better understand design problems. 3D simulations in a virtual world primarily aid learners with ASD in understanding complex and multifaceted design problems through enhanced visual and multimodal representations.

8.3.2 VR-Based Flexibility Training

We designed and developed a virtual reality (VR) based flexibility training program for adolescents with ASD. We used Opensimulator, an open-source VR platform that allows learners to experience interactive simulations and get hands-on practice with 3D simulations. The primary goal of this training program is to enhance the representational flexibility of adolescents with ASD by making them perform multimodal (e.g., text, voice, and nonverbal) interactions through a series of design problem-solving tasks. During this program, participants need to conduct design problem-solving in several authentic scenarios. Each participant in this training program participated in multiple 1-hour training sessions over 8–16 weeks.

This chapter focuses on two VR-based flexibility training modules: elevation bridge design and the Turing test (Fig. 8.8). These two training modules were designed in alignment with the science and engineering practices of the Next Generation Science Standard (NGSS). These training modules require students to engage in diverse inquiries to develop and apply their science and engineering ideas to authentic design problem-solving. Specifically, the first module (i.e., elevation bridge design) asks learners to design a 3D-morphed elevation bridge that includes simulations, while the second (i.e., Turing test) requires learners to design and code non-player characters (NPCs) that perform automated social interactions in a virtual world. In other words, the goal of the former module is to create a bridge design solution concerning mechanical engineering, whereas that the second one is to boost learners' understanding of logic programming that represents human interactions. The first module addresses both science- and math-relevant knowledge on Newton's laws of force and motion. Adolescents with ASD in this module are asked to design a bridge based on the design needs of virtual villagers in the virtual world. The participants need to identify the villagers' needs and come up with design solutions via 3D blocks. To create 3D simulations in a virtual world, participants need to write scripts and apply them to the artifacts. In the second module, participants need to prepare a virtual environment for the Turing test, which is a method for discerning whether artificial intelligence is capable of replicating behaviors as a human being. Participants need to choose an environment theme (e.g., a restaurant and a hotel) that frames NPCs' social interactions. Adolescents with ASD will then code and implement scripts that build adaptive and automatic NPC responses. This module requires adolescents with ASD to arrange a collection of code blocks and evaluate whether it logically represents human interaction paths. Overall, design

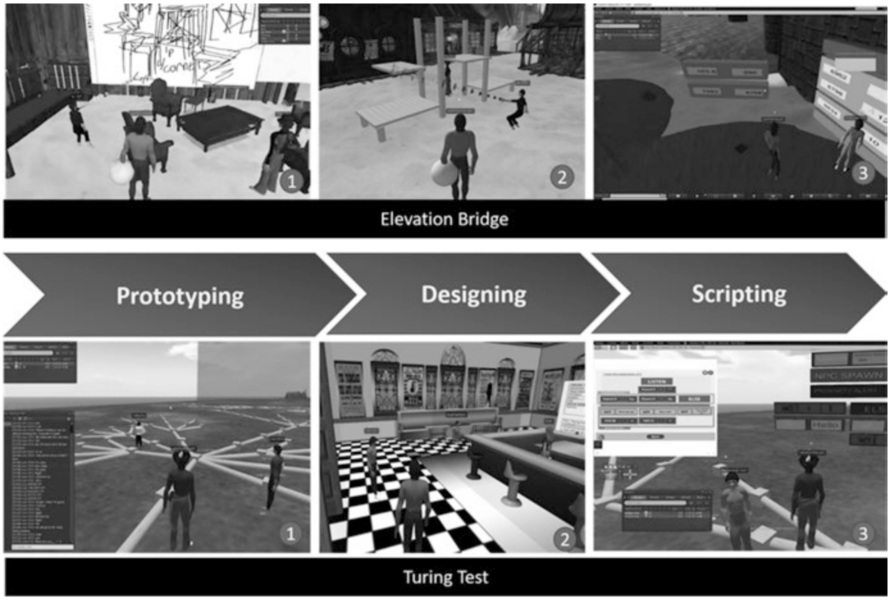


Fig. 8.8 Design exercises in VR-based flexibility training (Upper: Elevation Bridge, Lower: Turing Test)

problems in a training program encourage adolescents with ASD to identify a design problem, collect evidence, draft a design prototype, and finalize a design solution.

As for scripting exercises for 3D simulations, we designed and implemented a block-based programming system that enables adolescents with ASD to use 3D blocks to code and run 3D simulations. Since all adolescents with ASD in training are novice learners in computer programming, we needed to use alternative representations to foster their familiarity with scripting exercises. The proposed block-based programming board enables participants to create and customize multiple code blocks to build 3D simulations in training.

Aligned with the goal of this training, we have prepared an evidence-centered design model to evaluate the competency improvement of adolescents with ASD during the training program. Furthermore, this evidence-centered design model aims to map how given tasks in the training program can promote students' observable actions aligned with our target competency. Figure 8.9 is a tree diagram displaying the structure of our target competency in our VR-based training. There are four significant facets of our competency model: (1) attention-switching or mental set-shifting, (2) alternative representations, (3) pattern identification and development, and (4) pattern contextualization. Attention-switching or mental set shifting is a competency subset that indicates a learner's capability to change perspectives between rules, given contextual demands. Alternative representations denote a learner's use of multiple channels to interact with artifacts. Pattern development refers to a learner's inductive reasoning during problem-solving. Finally, pattern contextualization refers to a learner's deductive reasoning during problem-solving.

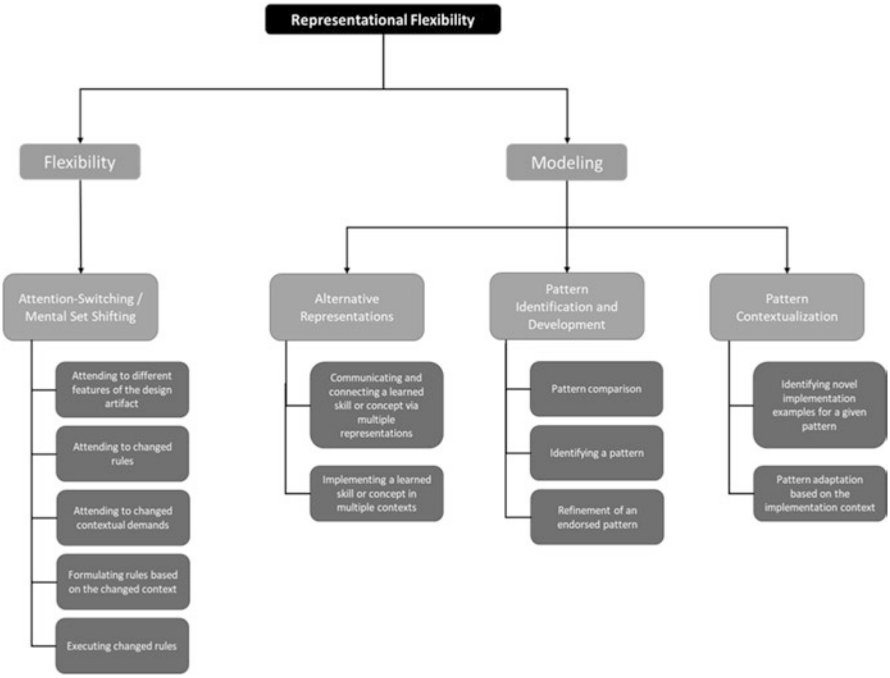


Fig. 8.9 Competency model for VR-based flexibility training

8.3.3 Learning Support Designs

Despite the promise of VR-based training for adolescents with ASD, one concern remains. Although VR motivates and engages adolescents with ASD via inquiry experiences in a 3D world, complex visual stimuli in VR are likely to cause distraction. Design problem-solving in a virtual world can be complicated because it requires learners to attain design skills as well as a deeper understanding of multifaceted design features. Adolescents with ASD are thus likely to experience either intellectual or emotional challenges in VR-based training. For these reasons, it is essential to provide in-time learning supports that can scaffold design problem solving while considering individuals' intellectual capabilities.

8.3.3.1 Iterative Usability Studies

We observed a total of eight adolescents diagnosed with ASD for usability testing on the learning support design. We implemented iterative content analysis with both qualitative observation notes and screen-recorded videos of the training sessions. Based on the content analysis results, we made multiple revisions with the learning supports.

8.3.3.2 Initial Learning Support Design

8.3.3.2.1 Design

In our flexibility training, we initially came up with multiple types of learning supports to assist adolescents with ASD in recalling relevant content knowledge (e.g., physics, mathematics, computer programming) during the training. Table 8.2 shows how each type of learning support functioned during training. Mainly, there are four types of learning supports, namely, environmental arrangement, agent scaffolding, facilitator scaffolding, and direct instruction. Environmental arrangement refers to visual feedback situated in the VR world, which enables adolescents with ASD to attend to significant changes in given 3D-represented circumstances. Agent scaffolding refers to learning supports presented by multiple NPCs, which deliver either training scenarios or design feedback to a learner. NPCs are either puppeteered by training facilitators or automatically run by an embedded LSL script in a virtual world. Facilitator-delivered scaffolding or prompt is aimed to stimulate participants' articulation or reflection of their problem-solving behaviors. Finally, direct instruction includes both verbal and visual presentations of learning concepts that require learners to comprehend before attending to given design problems. Direct instruction is mostly implemented along with visual aids, including interactive drawing boards and web documents.

8.3.3.2.2 Study Findings

Based on the content analysis results, we identified challenges for adolescents with ASD during the VR-based training program. First, the interactive scientific animations embedded into a virtual world (as part of direct instruction) did not aid the participants in recalling their content knowledge. The participants barely used them. Via a virtual media board, we embedded and presented the widely-used PhET simulations—the online interactive 2D simulations that allow learners to experience science experiments via drag-and-drop mouse interactions (Wieman et al., 2008). We encouraged adolescents with ASD to browse and use the related PhET simulations during the design inquiry. However, the participants reported difficulty identifying how the concepts depicted in the selected PhET simulations would relate to the design problem-solving context. For example, when playing the simulation that depicts net forces and distance changes by the force and time variables, most adolescents with ASD failed to recall or apply the relevant knowledge during the actual design exercises. This observation suggested that the instructive simulations need to better bridge the domain-specific concepts and the design problems in the VR training program.

Second, adolescents with ASD faced a challenge in identifying the relationships among multiple variables in physics. For example, they failed to explain interconnections among force, velocity, and distance as to Newton's second laws when designing a prototype of an elevation bridge. Since the elevation bridge module

Table 8.2 A list of learning supports in VR-based flexibility training

Types of learning supports	Design features	Description
Environmental arrangement	Kinematic marker	Automated and responsive text messages from a 3D object inform how the force and motion variable changes over time
	Heads-up display (HUD)	It enables the participants to either access web-based information or co-writes a draft of their code design plan
	Interactive toy (in exercises)	An interactive toy delivers text messages that indicate the change of variable values in relation to the toy's forces and movements when a learner manipulates it
Agent scaffolding	Information presentation	An NPC presents both a scenario and individual needs that a participant takes into consideration
	Feedback	An NPC delivers design suggestions that include individuals' customization needs
Facilitator scaffolding	Questioning	A facilitator delivers questions to remind participants to recall relevant content knowledge or design procedures
	Guidance	A facilitator corrects participants' behavior during either modeling or scripting in exercises
	Modeling	A facilitator shows example procedures of artifact designs that help participants rehearse steps in design problem-solving
	Acknowledgment	When a participant completes a task or has some progression, we acknowledge them to keep them engaged
	Regulation	This prohibits participants from visual distractions and then keeps them focused during training
Direct instruction	Interactive animation	A web-based 2D simulation that enables a learner to run tests on what they have learned
	Advanced organizer	A verbal reminder that recalls participants' prior knowledge as to what they have learned in previous exercises
	Debriefing	This facilitates participants' verbal articulation of what they felt and experienced during design problem-solving
	Explanation	Using interactive media (a drawing board or a web document), a facilitator presents required concepts on domain-specific knowledge

requires learners to adjust the force and time variables while considering the estimated height of the bridge, a task-specific formula was provided for the learners to compute the force and time values. However, most of them did not fully understand it to compute the results. This finding echoes the previous findings that adolescents with ASD need alternative representations that enable them to identify complex and intertwined relationships among multiple variables.

Third, we found that all adolescents with ASD needed more learning support in block-based programming exercises. The goal of block-based programming exercises in our training is to foster learners' comprehension of the underlying relationships among variables via a hands-on manipulation of code blocks. In addition, such block-based programming enables adolescents with ASD to acquire a sense of logic programming via the order of code blocks. However, the content analysis result suggests that adolescents with ASD still failed to fully endorse the rules of block-based programming exercises. Instead, they relied on random changes to guess solutions without data-driven decisions or reasoning. This indicates that additional prompts are necessary to encourage adolescents with ASD to identify the rudimentary rules of logic programming.

8.3.3.3 Second-Round Learning Support Design

8.3.3.3.1 Design

Based on the aforementioned findings, we built two new learning supports: (1) *3D Flow Maker* and (2) *Cheatsheet*. The *3D Flow Maker* (Fig. 8.10) is a network creator that learners can use to build their network model consisting of 3D nodes and links. This tool facilitates learners' understanding of decision trees, which depicts the logic of the programming code via network visualizations. This tool allows adolescents with ASD to create, name, and modify connections of networks to represent the decision trees of scripts beforehand.

Next, the *Cheatsheet* is a 2D and HTML-supported tool that helps participants better retrieve relevant content knowledge (physics, math, and computer programming) for design problem-solving. The *Cheatsheet* presents interactive slideshows that encourage adolescents with ASD to swiftly review and apply the required knowledge to their design cases.

Considering the need for multiple representations in adolescents with ASD, the *Cheatsheet* enables adolescents with ASD to choose multiple modes of representations (i.e., text, visual, and symbolic) on the same concept. The Cheatsheet is presented using a HUD in VR, in an attempt to accommodate learner agency while reducing visual distractions and excessive cognitive load. Figure 8.11 demonstrates how the *Cheatsheet* in this training program was integrated and implemented.

8.3.3.3.2 Study Findings

We tested both the *3D Flow Maker* and *Cheatsheet* in the second training module (Turing test). Overall, the learning supports benefited adolescents with ASD in their performance of design exercises. All adolescents with ASD in our program reported positive feelings of using both learning supports. By using the *3D Flow Maker*, our participants were engaged in hands-on exercises with the 3D network design. They got to draw a structural network that depicts their understanding of the human

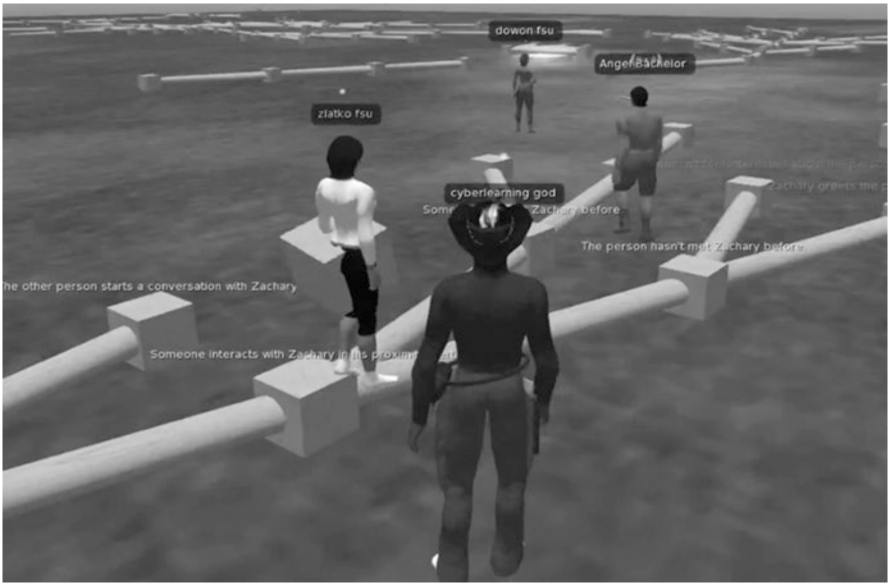


Fig. 8.10 3D Flow Maker in VR-based flexibility training

interactions while embodying the logic of code blocks. The *Cheatsheet*, as expected, was found effective in assisting adolescents with ASD in retrieving relevant knowledge during design problem-solving.

We identified another design issue through the content analysis. Some adolescents with ASD needed additional prompts to process and execute the holistic structure during scripting exercises. These scripting exercises require learners to consider the big picture and align the structure of code blocks with the decision tree self-constructed using the *3D Flow Maker*. However, our qualitative observations revealed that adolescents with ASD faced difficulty in aligning their plan of block-code scripting with the decision trees they initially designed. They tended to focus on localized pieces of the scripting task. Prior research corroborates this observation (Happé & Frith, 2006). Therefore, it is warranted to design learning supports that will scaffold holistic procedure planning and execution by adolescents with ASD.

8.3.4 Summary and Implication

Overall, this case study demonstrated our efforts to design VR-situated learning supports that promote the enactment of representational flexibility in a complex STEM learning task. We found that adolescents with ASD generally experienced challenges in enacting representational flexibility during STEM-related design problem-solving. To visually support their representational flexibility performance

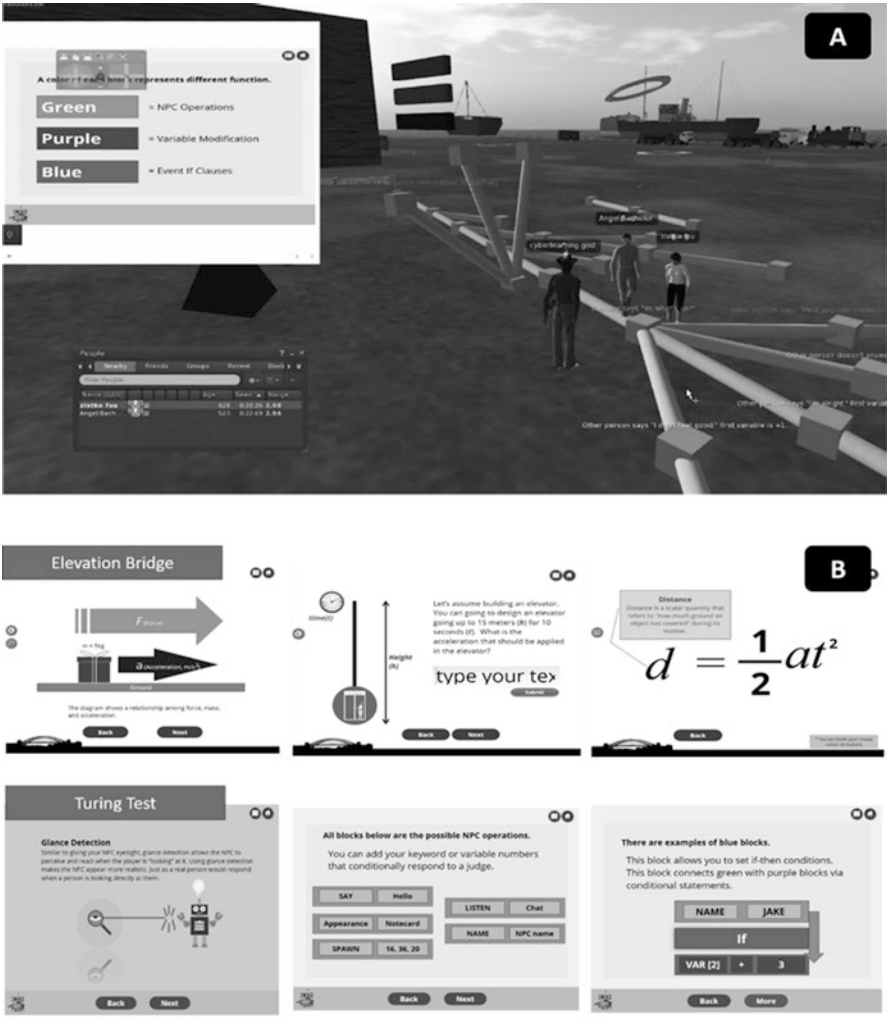


Fig. 8.11 The *3D Flow Maker* in VR-based flexibility training. (**a**) Implementing the *Cheatsheet* in a VR world. (**b**) Interface examples of the *Cheatsheet*

and guide their attention during VR-based training, we designed and implemented two types of learning supports. Specifically, we aimed to foster adolescents' representational flexibility by presenting intuitive and interactive learning support tools (i.e., the *3D Flow Maker* and *Cheatsheet*) designed to promote adolescents' use and construction of multiple representations during design problem-solving.

We found that the revised version of in-game learning supports enables adolescents with ASD to actively interact with multiple representations, thus fostering their representational flexibility for STEM design problem-solving. First, the *3D* *flow maker* enabled adolescents with ASD to practice attention switching/mental set shifting to develop multiple pathways of NPC interactions in a 3D represented network. Second, multiple modes of representation in the *Cheatsheet* allowed adolescents with ASD to explore various representations for the same topic. Third, in terms of pattern identification and development, the two learning supports allowed students to build a holistic view of the design problem when exploring a solution. Finally, as to pattern contextualization, adolescents with ASD analyzed, decomposed, and contextualized NPC interaction pathways in the *3D flow maker* using the template block codes from the *Cheatsheet*.

8.4 Conclusion and Discussion

In this chapter, we presented two design cases demonstrating how iterative design and inquiry of learning support occurred in simulation game-based learning environments. For E-Rebuild, we described the iterative design and development of in-game learning supports to facilitate student players' mathematical problem-solving processes. Through iteratively refining and pilot testing the in-game learning supports, we examine design heuristics in relation to unobtrusive learning supports for a complex problem-solving task. The current design and exploratory study findings could inform on the development of in-game learning support that (a) are game action-oriented to be engaging and context-related, and (b) promotes problem analysis and solving with domain-specific concepts and procedures. A salient design and research implication is that learning supports should be task- and context-relevant to foster learners' agency in selecting and processing these supports, especially when a complex learning task and an open-ended learning environment are involved. A potential design challenge is that learners may differ in their commitment, prior knowledge, and cognitive motivation with a learning task, thus composing different levels of agency in endorsing and processing learning supports. Therefore, future research should further examine the design and impact of learner-adaptive scaffolds in a computer-assisted, complex learning environment.

In our second design case, we reported on the design and implementation of dynamic learning supports that foster the enactment of representational flexibility of adolescents with ASD during VR-based, STEM-related design problem-solving. The current study findings suggested potential design heuristics governing multimodal learning supports suited for adolescents with ASD. Specifically, the learning support that enables adolescents with ASD to externalize and review their mental sets (*the 3D Flow Maker*), as well as the one that presents a multimodal representation of core concepts (the *Cheatsheet*), are found to promote the enactment of representational flexibility. Both learning supports are well integrated into the VR-based learning environment and coherent with the problem-solving task. These design heuristics can transfer to and get further studied in other technology-rich STEM learning environments.

Acknowledgements The research reported in this chapter is based upon work primarily supported by the National Science Foundation (NSF) under awards #1720533 and #1837917. Any opinions, findings, conclusions, or recommendations expressed here are those of the author and do not reflect the official views of the NSF.

References

Azevedo, R., Moos, D. C., Greene, J. A., Winters, F. I., & Cromley, J. G. (2008). Why is externally-facilitated regulated learning more effective than self-regulated learning with hypermedia? *Educational Technology Research and Development, 56*(1), 45–72.

Byun, J., & Joung, E. (2018). Digital game-based learning for K–12 mathematics education: A meta-analysis. *School Science and Mathematics, 118*(3–4), 113–126. https://doi.org/10.1111/ssm.12271

Chang, K. E., Wu, L. J., Weng, S. E., & Sung, Y. T. (2012). Embedding game-based problem-solving phase into problem-posing system for mathematics learning. *Computers & Education, 58*(2), 775–786.

Clark, D. B., Nelson, B., Chang, H., D'Angelo, C. M., Slack, K., & Martinez-Garza, M. (2011). Exploring Newtonian mechanics in a conceptually-integrated digital game: Comparison of learning and affective outcomes for students in Taiwan and the United States. *Computers and Education, 57*(3), 2178–2195.

De Freitas, S. (2018). Are Games Effective Learning Tools? A Review of Educational Games. *Journal of Educational Technology & Society, 21*(2), 74–84.

DeFalco, J. A., Rowe, J. P., Paquette, L., Georgoulas-Sherry, V., Brawner, K., Mott, B. W., … Lester, J. C. (2018). Detecting and addressing frustration in a serious game for military training. *International Journal of Artificial Intelligence in Education, 28*(2), 152–193.

Didehbani, N., Allen, T., Kandalaft, M., Krawczyk, D., & Chapman, S. (2016). Virtual reality social cognition training for children with high functioning autism. *Computers in Human Behavior, 62*, 703–711. https://doi.org/10.1016/j.chb.2016.04.033

Duval, R. (2006). A cognitive analysis of problems of comprehension in a learning of mathematics. *Educational Studies in Mathematics, 61*(1–2), 103–131. https://doi.org/10.1007/s10649-006-0400-z

Geurts, H. M., Corbett, B., & Solomon, M. (2009). The paradox of cognitive flexibility in autism. *Trends in Cognitive Sciences, 13*(2), 74–82. https://doi.org/10.1016/j.tics.2008.11.006

Goldin, G. A. (2002). Representation in mathematical learning and problem solving. In L. D. English (Ed.), *Handbook of international research in mathematics education* (pp. 197–218). Erlbaum.

Hannafin, M. J., & Land, S. M. (1997). The foundations and assumptions of technology-enhanced student-centered learning environments. *Instructional Science, 25*(3), 167–202.

Happé, F., & Frith, U. (2006). The weak coherence account: Detail-focused cognitive style in autism spectrum disorders. *Journal of Autism and Developmental Disorders, 36*(1), 5–25. https://doi.org/10.1007/s10803-005-0039-0

Hegarty, M., Mayer, R. E., & Monk, C. A. (1995). Comprehension of arithmetic word problems: A comparison of successful and unsuccessful problem solvers. *Journal of Educational Psychology, 87*(1), 18–32. https://doi.org/10.1037/0022-0663.87.1.18

Heinze, A., Star, J. R., & Verschaffel, L. (2009). *Flexible and adaptive use of strategies and representations in mathematics education*. Springer.

Herbert, J., & Hayne, H. (2000). Memory retrieval by 18–30-month-olds: Age-related changes in representational flexibility. *Developmental Psychology, 36*(4), 473–484. https://doi.org/10.1037/0012-1649.36.4.473

Hmelo-Silver, C. E., & Azevedo, R. (2006). Understanding complex systems: Some core challenges. *The Journal of the Learning Sciences, 15*(1), 53–61.

Hoogland, K., Pepin, B., Bakker, A., de Koning, J., & Gravemeijer, K. (2016). Representing contextual mathematical problems in descriptive or depictive form: Design of an instrument and validation of its uses. *Studies in Educational Evaluation, 50*, 22–32. https://doi.org/10.1016/j.stueduc.2016.06.005

Ke, F. (2008). Computer games application within alternative classroom goal structures: Cognitive, metacognitive, and affective evaluation and interpretation. *Educational Technology Research & Development, 56*, 539–556.

Ke, F. (2016). Designing and integrating purposeful learning in game play: A systematic review. *Educational Technology Research and Development, 64*(2), 219–244.

Ke, F. (2019). Mathematical problem solving and learning in an architecture-themed epistemic game. *Educational Technology Research and Development, 67*(5), 1085–1104. https://doi.org/10.1007/s11423-018-09643-2

Ke, F., & Clark, K. M. (2020). Game-based multimodal representations and mathematical problem solving. *International Journal of Science and Mathematics Education, 18*(1), 103–122. https://doi.org/10.1007/s10763-018-9938-3

Ke, F., Shute, V., Clark, K. M., & Erlebacher, G. (2019). *Interdisciplinary design of game-based learning platforms*. Springer. https://doi.org/10.1007/978-3-030-04339-1

Kirsh, D. (2010). Thinking with external representations. *AI & SOCIETY, 25*(4), 441–454. https://doi.org/10.1007/s00146-010-0272-8

Kozhevnikov, M., Hegarty, M., & Mayer, R. E. (2002). Revising the visualizer-verbalizer dimension: Evidence for two types of visualizers. *Cognition and Instruction, 20*(1), 47–77. https://doi.org/10.1207/S1532690XCI2001_3

Lee, S., & Ke, F. (2016, April). *The effects of representation format in problem representation on qualitative understanding and quantitative proficiency in a learning game context. Paper to be presented at 2016*. American Educational Research Association Annual Meeting.

Mayer, R. E. (1992). *Thinking, problem solving, cognition* (second ed.). WH Freeman.

National Research Council. (2011). *Learning Science Through Computer Games and Simulations*. Washington, DC: The National Academies Press. https://doi.org/10.17226/13078.

Parsons, S., & Mitchell, P. (2002). The potential of virtual reality in social skills training for people with autistic spectrum disorders. *Journal of Intellectual Disability Research, 46*(5), 430–443. https://doi.org/10.1046/j.1365-2788.2002.00425.x

Puntambekar, S., & Hubscher, R. (2005). Tools for scaffolding students in a complex learning environment: What have we gained and what have we missed? *Educational Psychologist, 40*(1), 1–12.

Qian, M., & Clark, K. R. (2016). Game-based learning and 21st century skills: A review of recent research. *Computers in Human Behavior, 63*, 50–58.

Reiser, B. J. (2004). Scaffolding complex learning: The mechanisms of structuring and problematizing student work. *The Journal of the Learning Sciences, 13*(3), 273–304.

Timms, M., McLaren, B. M., & Luttgen, K. (2014, April). *Using Bayes nets in the voyage to Galapagos intelligent learning environment*. Paper presented at National Council on Measurement in Education.

van Garderen, D. (2006). Teaching visual representation for mathematics problem solving. In M. Montague & A. K. Jitendra (Eds.), *Teaching mathematics to middle school students with learning difficulties* (pp. 72–88). Guilford Press.

Wei, X., Jennifer, W. Y., Shattuck, P., McCracken, M., & Blackorby, J. (2013). Science, technology, engineering, and mathematics (STEM) participation among college students with an autism spectrum disorder. *Journal of Autism and Developmental Disorders, 43*(7), 1539–1546. https://doi.org/10.1007/s10803-012-1700-z

Wei, X., Yu, J. W., Shattuck, P., & Blackorby, J. (2017). High school math and science preparation and postsecondary STEM participation for students with an autism spectrum disorder. *Focus on Autism and Other Developmental Disabilities, 32*(2), 83–92. https://doi.org/10.1177/1088357615588489

Wieman, C. E., Adams, W. K., & Perkins, K. K. (2008). PhET: Simulations that enhance learning. *Science, 322*(5902), 682–683.

Wouters, P., & Van Oostendorp, H. (2013). A meta-analytic review of the role of instructional support in game-based learning. *Computers & Education, 60*(1), 412–425.

Zelazo, P. D., Reznick, J. S., & Spinazzola, J. (1998). Representational flexibility and response control in a multistep multilocation search task. *Developmental Psychology, 34*(2), 203–214. https://doi.org/10.1037/0012-1649.34.2.203

Chapter 9
Fostering Learning Transfer by Employing a Learning App for Future Preschool Educators in Vocational Schools

Jana Heinz and Eva Born-Rauchenecker

9.1 Introduction

While game-based learning (GBL) has been established as an increasingly accepted and widespread approach in international research, only a few projects can be found in the area of Early Childhood Education and Care (ECEC) in Germany (e.g., Beutner & Pechuel, 2015; Bildung durch Sprache und Schrift [BiSS], Staatsinstitut für Frühpädagogik [IFP], & eforce21, 2018; Heininger et al., 2016). Reasons for this may include the teachers' strong focus on the curriculum, their extensive experience in analog teaching, and limited support from the state governments, which is only now slowly increasing for digital teaching formats in vocational schools.

In this paper, we describe the process of designing a learning app until it was programmed. We start with an overview of the project and the differing project tasks, one of which was the conception of an app, built upon international research results on game-based learning and project-internal research on user expectations. We focus on the different groups of people whose expectations and expertise influenced the process of designing the app. We conclude with our learning experience that GBL is well suited to meet students' expectations toward learning and digital media in their professional training as well as to foster learning transfer between vocational schools and practical internship in the kindergarten. Hence, the efforts to develop such GBL applications are multilayered with regard to the necessary resources and expertise.

J. Heinz (✉)
German Youth Institute, Munich, Germany
e-mail: hienz@dji.de

E. Born-Rauchenecker
Rosenheim Technical University of Applied Sciences, Rosenheim, Germany

C. Aprea, D. Ifenthaler (eds.), *Game-based Learning Across the Disciplines*, Advances in Game-Based Learning, https://doi.org/10.1007/978-3-030-75142-5_9

9.2 Project Background

The learning app is part of a third-party-funded practice development project at the German Youth Institute in Munich. The project is called LuPE (Lehr- und Praxismaterial für die Erzieherinnenausbildung). It is funded by Deutsche Telekom Stiftung and ran from October 2014 to December 2020. It aims at providing a teaching concept and teaching materials for future educators in ECEC, especially in kindergarten, with a focus on S and M in STEM (early scientific education and early mathematical education, both mandatory areas in the ECEC specifications in Germany). The outcomes of the project include—besides the app—e.g., two books for vocational teachers, video clips on DVD, and online teaching materials (Born-Rauchenecker et al., 2018; Born-Rauchenecker et al., 2020). The teaching concept was developed by researchers at the German Youth Institute, and the teaching material was produced in close cooperation with teachers of selected vocational schools in Bavaria, Berlin, North Rhine-Westphalia, and Thuringia. The concept for the learning app was the initiative of a small team—including two teachers in Thuringia.

ECEC education in Germany takes place predominantly as dual vocational training, combining more theoretical learning at the vocational schools with several internships at early childhood learning facilities. Thus, the main task of the project was to enhance the knowledge transfer between these two sites, generally accompanied by the main contact persons—a vocational teacher and a practice instructor. Due to the current shortage of skilled ECEC specialists, it is always a challenge to guarantee the necessary personnel resources. Therefore, the app can be seen as a first small contribution to foster cooperation and knowledge transfer. The app includes illustrations of everyday situations showing kindergarten children playing. Selected micro-situations serve as a starting point in asking users to playfully reflect upon these situations, to identify underlying mathematical phenomena, and to find ways of discovering the mathematical aspects together with kindergarten children through interaction. In this way, the app provokes the application of professional skills that are essential elements of an apprenticeship for ECEC educators (such as monitoring, analyzing, reflecting, and interacting in forms of sensitive communication—suitable for the developmental phases and personalities of the children in care).

The teaching concept developed by LuPE's scientific researchers focuses on an approach that integrates STEM education in a kindergarten's daily routine, building upon former projects of the German Youth Institute (Jampert et al., 2006). In the recent LuPE materials, the future kindergarten educators are trained to recognize underlying mathematical phenomena in daily kindergarten routines, for instance, playing with wooden blocks or preparing meals. The materials aim at the development of competencies to support children in gradually mastering their living environment. Therefore, important skills to be taught are the ability to observe and interpret complex situations in pedagogical daily routine (Fröhlich-Gildhoff et al., 2011) and to design and elaborate processes of interaction between teachers and children (Purdon, 2016), falling back on area-specific knowledge and didactics (Duncan et al., 2007).

To help students gain these competencies and knowledge, a vocational teacher has to acknowledge students' prior knowledge. Therefore, LuPE researchers conducted a questionnaire and group discussions with the students at the beginning of the project in 2015 (Drexl et al., 2019). Results showed students' high inhibition threshold and poor comprehension of natural sciences as well as a high necessity for reflection skills. Thus, early mathematical education for the respective teachers requires a holistic perspective for ECEC contexts. Accordingly, the teaching and practice materials take up students' general knowledge, connect to students' own life, start at a low level at vocational schools, and include students' individual experiences with regard to mathematical topics.

The conception of the LuPE app builds on these preconditions. We consider the learning app to be particularly well suited to support future kindergarten educators. It offers a playful approach to learning in early mathematics; it can be adapted to the learners' prior knowledge as well as their individual learning rate. The app includes five illustrated kindergarten situations showing a girl of about four, called Becca. These situations, in particular the first scenes, are the starting point for playing, reflecting upon them, deciding on a move, getting the app's feedback—and thus for learning. At an early stage, we planned to employ videos of real situations in kindergarten. However, as safety standards of the use of data, in particular of children, evolved as nearly insurmountable obstacles to employing these videos in an app, the team decided to use illustrations instead. All five playing situations are combined with three didactic dimensions:

Dimension 1: students can choose ways to start a conversation with the child in the situation. The possible phrases integrate elements of a didactic approach called Sustained Shared Thinking (Purdon, 2016). It is defined as a problem-solving form of communication, including elements such as active listening and positive questioning. "An episode in which two or more individuals 'work together' in an intellectual way to solve a problem, clarify a concept, evaluate activities, extend a narrative, etc. Both parties must contribute to the thinking and it must develop and extend" (Siraj-Blatchford et al., 2002, p. 8). The interaction format Sustained Shared Thinking has been proven to have an impact on the later academic performance of children.

Dimension 2: the users are asked to identify the mathematical competencies of the child and mathematical phenomena underlying the illustrated situations. Here we build on subject-specific knowledge of early daily life-based mathematical education (Purdon, 2016).

Dimension 3: users are offered the possibility to analyze and reflect on the learning situations with regard to their own professional experiences. This feature is based on a raster of analyses and reflection used in the training of ECEC professionals (Best et al., 2017). Five levels of a complex pedagogical situation are distinguished (each listing stimulating questions with regard to the child, the educator, the surrounding, etc.) and adapted to the requirements of ECEC apprenticeship with an STEM focus by LuPE researchers (Born-Rauchenecker & Drexl, 2018).

Thus, users (students in ECEC) are invited to assume the role of a kindergarten teacher and start interactions with the children based on the illustrated playing and learning situations in the app. Here they can choose between given options or create their own individual ones. Depending on the interaction chosen, the learning situation can change or stop. Moreover, users are asked to identify the mathematical competencies of children from a variety of options suggested in the app. Finally, after having played the situations, they can reflect on their choices, interactions, and ideas. Their individual answers and responses are saved to a file, which can be shared via a screenshot with other users and the teacher in the classroom. With regard to whether this learning app is a game, it integrates the main features of GBL, such as fictional stories, roles, and challenges, although some features are missing, such as winning the game with a first/second place, instant rewards, and collecting points. As the learning app was designed to motivate students to create individual responses, reflect on a multitude of possible answers as well as anticipate many possible ways children can react, we considered such right/wrong feedback demotivating and thus did not integrate it.

9.3 Theoretical Context

Digital games have been perceived as a potentially engaging form of learning in almost all levels of education. Shaffer, e.g., states, "Computer-based games expand the range of what players can realistically do—and thus the worlds they can inhabit and obstacles they can overcome" (Shaffer, 2006, p. 127). At the same time, however, games in education, in particular digital games, have constantly evoked critical attitudes, emphasizing possible harm such as addiction and loss of motor skills. In their article "The Benefits of Playing Video Games," Granic et al. (2014) argue that for too long, research has only looked at the possible negative effects. They demand that more balance is needed to identify the benefits of playing these games. The authors summarize research on the positive effects of playing video games, focusing on four main domains: cognitive, motivational, emotional, and social.

9.3.1 Terminology

Frequent terms employed in research on digital games in education are "game-based learning," "educational games," and "serious games." Witt, for instance, defines "serious games" as a term that refers to the games as such, while seeing "game-based learning" as a term that highlights the associated learning processes in users (Witt, 2013, p. 29). Boyle and colleges, who carried out a review on educational games, find the term "serious games" has become mainstream and has been used interchangeably with "game-based learning" (Boyle et al., 2016). However, serious games and game-based learning can be differentiated from entertainment games that are designed with commercial interests and often lack a didactic context. According to the majority of definitions on digital games in education, they include typical game elements (e.g., a story, game rules, elements of suspense and challenge), didactic concepts, and the absence of commercial interests (Ge & Ifenthaler, 2018).

Thus, in a study on serious game attributes, Bedwell and colleagues collected features that characterize serious games. These features were given to subject matter experts to discuss. These expert panels resulted in a game attribute taxonomy, including nine categories along which serious games can be characterized. These are action language, assessment, conflict/challenge, control, environment, game fiction, human interaction, immersion, and rules/goals (Bedwell et al., 2012, p. 737). In conclusion, the authors ask for further investigations into the relationship between particular attributes and specific learning outcomes (such as motivation, declarative knowledge, or cognitive strategies) emphasizing the isolation of individual constructs to reveal links in attributes and outcomes.

Similarly, most researchers in the area of game-based learning demand more comprehensive and systematic studies. To strengthen GBL as an approach in education, there seems to be a need for empirical analyses on specific game features and their effects on engagement, learning, and learning outcomes (Boyle et al., 2016).

9.3.2 Research on Effects of GBL on Learning and Learning Outcomes

Accordingly, the first systematic literature reviews have been carried out in the last decade, analyzing features of GBL that influence learning and learning outcomes. As early as 1999, Amaroy and colleagues investigated game types, looking for those most suitable for teaching and most interesting to students. Although carried out based on a small sample of 20 participants, the authors developed a detailed model of interrelations between specifics of a game and educational goals. They emphasized the further development of educational games that include visualization and problem-solving skills. These tools are regarded as sufficient stimulation to engage learners in knowledge discovery while at the same time developing new skills (Amory et al., 1999).

In a more recent review, Hainey et al. (2016) analyze studies from 2000 to 2013 to find which kind of knowledge GBL can produce. The authors specifically looked at quality empirical studies associated with the application of GBL in primary education. They categorized studies according to their learning outcomes and differentiated between studies with foci on behavioral change, affective and motivational outcomes, perceptual and cognitive skills, and knowledge acquisition and content understanding (Hainey et al., 2016).

Another review (Boyle et al., 2016) investigates empirical evidence of the impacts and outcomes of computer games and serious games. In their study, the authors included games for entertainment and games for learning. Their analyses showed that the most frequently occurring outcome was knowledge acquisition, followed by perceptual and cognitive, affective, and behavior change, with fewer papers reporting physiological, skills, and soft and social skills outcomes. They furthermore found that entertainment games and games for learning address different kinds of outcomes with knowledge and skill acquisition almost exclusively studied in games for learning, with affective behavior change and physiological outcomes more likely to be studied with entertainment games. In conclusion, the authors see progress, on the one hand, with regard to understanding features that make games more engaging and thereby support learning. Thus, experimental studies found features, such as competition, uncertainty of information, and varying training schedules. Additionally, the authors state more precise definitions of subjective experience constructs, such as flow, engagement, and appeal. On the other hand, however, they criticize that research on game features is "still quite piecemeal" and thus demand further research including more comprehensive and systematic programs studying game features for engagement and learning (Boyle et al., 2016, p. 22).

Eseryel et al. (2014) investigated the interrelationships between motivation, engagement, and complex problem-solving in game-based learning. The authors found that a game's design feature affects student engagement, motivation, and problem-solving competencies, in particular, their self-efficacy and perceived competence. However, educational games by themselves do not lead to better learning outcomes. Therefore, there is a need for more evidence-based knowledge about effectively situated learning environments that can engage learners and support their development of complex problem-solving competencies. The authors emphasize designing educational games with opportunities for "complexity for students to engage in problem-solving tasks, with sufficient autonomy for students to make choices and attainable challenges to help them move closer to their intended goals" (Eseryel et al., 2014, p. 51).

9.3.3 Users' and Teachers' Involvement

A review by Jabbar and Felicia (Abdul Jabbar & Felicia, 2015) investigates how engagement is characterized in games and how it can affect learning. They find a multitude of influencing factors, as engagement and learning depend on players' individual differences. To meet the individual gamers needs and competencies, Jabbar and Felicia thus suggest "the active contribution of the participants to the research design is important: Researchers should collaborate fully with participants to identify matters that contribute to (or decrease) engagement and should propose suitable elements to foster engagement and learning" (Abdul Jabbar & Felicia, 2015, p. 769).

In addition to involving the participants and users of the game, teachers play a major role in employing games and thus in participating in designing games

(Cojocariu & Boghian, 2014). Research, focusing on the role of teachers, often emphasizes teachers' roles as barriers to using digital media in the classroom and how to overcome them. Thus, teachers often seem to show negative attitudes toward its use and difficulties in using them in classrooms (Stieler-Hunt & Jones, 2019). Rather than focusing on such "teacher-deficit models," Linderoth and Sjöblom (2019) investigate the role of pedagogical content knowledge (PCK) in noncommercial serious games production. The authors compared two case studies of game development without any form of commercial agenda. They ask how PCK and the noncommercial aspect of the games being developed structured the production. They find different sets of skills and experiences provide a naturally organized frame for studying divergent approaches to game design, enabling contrastive analysis of decision-making practices and approaches to tensions between goals of design and education (Linderoth & Sjöblom, 2019). In particular, their results show that serious games production with a focus on teachers' pedagogical content knowledge (PCK) "tends to put the educational goal at the forefront of the development process. The educational goal takes precedence over other aspects of the game. This means that established ways of developing games can come into conflict with serious game development" (Linderoth & Sjöblom, 2019, p. 784). To meet both educational goals and game features, the authors suggest involving people with pedagogical content knowledge and knowledge about game development.

9.3.4 Fun and/versus Learning

These results point to another challenge in employing games in education: the frictions between users' expectations toward games as being entertaining and fun, and didactic features of serious games that aim at stimulation learning. As shown above, Granic et al. (2014) started their study of video games in the area of medical education by stating that research about video games is biased, as it shows a strong emphasis on its harmful effects. However, at the same time, the authors warn of a hype surrounding gamification. One of the shortcomings, the authors explain, is that "medical practitioners, teachers, and researchers are not game designers, and as a result, they often develop products that miss the most essential mechanism of engagement in games: the fun. In an effort to pull together a set of valid principles or lessons, games for health and education often end up with the 'chocolate-covered broccoli' problem—the games look great, they are good for you, but they ultimately fail to work because the creative game dynamics that induce transportation and immersion are missing, making them simply not fun" (Granic et al., 2014, p. 74).

Similarly, Witt, for instance (Witt, 2013), describes the positive effects of employing game-based education in vocational training, such as fostering social skills and occupational competencies. However, she also warns that "it also emerges that gamers associate gaming with relaxation from the stress of work, and are not necessarily keen on seeing their game instrumentalized for work-related purposes" (Witt, 2013, p. 30).

In addition, Eseryel et al. (2014) find that students' interest and engagement dropped after their initial excitement in playing a Massively Multiplayer Online Game (MMOG) when they realized that the tasks were of didactic nature. The authors found the decrease in the students' motivation was due to a considerable extent to the digital game design.

Summarizing the research shows how GBL has been established by systematic research on the effects of learning. There has been robust knowledge created on the influence of individual elements of games on specific learning outcomes and attitudes. Moreover, the challenges of developing GBL applications have become more visible. Thus, finding a compromise between the users and the persons involved in developing GBL has shown to be challenging. The process and outcomes of matching different stakeholders' views, experiences, and expectations to develop a GBL application—our app—is the focus of our contribution. In the following, we present these different groups of persons, their input, and how we have integrated it into the development of the app.

9.4 Methods

The following three research questions guided our study:

1. Which basic conditions are necessary to exploit the specific potentials of the app in contrast to conventional teaching materials (worksheets, books, etc.)?
2. How can the expectations of users (who use digital apps in their everyday life primarily for gaming and social media) be met in the vocational training context?
3. How can didactic and STEM requirements in ECEC that have been developed within the research project be implemented in the learning app?

To answer these questions, and then to incorporate the results into the design of the app, we conducted workshops and online surveys. Data collection included the following different stakeholder groups:

(a) Workshops with experts in the field of digital learning and software programmers.
(b) A formative evaluation with the target groups (vocational school teachers and students) and experts in the field of early mathematics education.

(a) Workshops with experts in the field of digital learning as well as experts in didactics and science

Two expert workshops were conducted in 2018 and 2019. Besides the researcher team of the German Youth Institute, two software developers who had already developed digital learning games participated as well as two experts for digital teaching and learning.

(b) Formative evaluations with the target groups

The formative evaluation with the target groups (vocational school teachers and students) was conducted based on online questionnaires. The questionnaires' items focused on the following three dimensions: attitudes toward digital media, attitudes toward early STEM education in kindergarten, and an evaluation of the apps' planned features with the opportunity to suggest changes and improvements. The questionnaire was individually adapted to the different target groups (students and teachers) as well as experts in the area of early STEM education in kindergarten. Thus, slightly different versions of the questionnaire were employed. We combined quantitative items and questions leaving room for longer open answers. After preliminary testing (n: 9), the questionnaire was sent to all participating teachers (who were already involved in developing the books for teachers and thus were familiar with the project and its didactical concept) of the LuPE project in Bavaria, Thuringia, Berlin, Brandenburg, and North Rhine-Westphalia (n: 53). The teachers were asked to send their students the link to the student questionnaire. Furthermore, questionnaires for experts in early STEM education were employed and filled in by ten participants.

According to the research question, the aim of the analysis was to summarize and generalize the results and answers to use them for the development of the app and its refined adaption to target group expectations. The meetings and survey results are presented in detail in the following paragraphs.

9.5 Results

1. Which basic conditions are necessary to exploit the specific potentials of the app in contrast to conventional teaching materials (worksheets, books, etc.)?

   The two expert panels started with the input of the LuPE researchers. They presented initial concepts, the didactic background of the project, and who would teach and learn with the app. Following, an exchange of the various ideas, expectations, didactic objectives, and limitations due to data security took place. First, a consensus was developed to align the app's software architecture with the didactic concepts already established in the project (a focus on everyday early mathematics education, didactic concepts to develop considerate and meaningful communication with children, and to strengthen analytical and reflective skills). Second, the digital experts' suggestions to connect digital learning with analog classroom activities were discussed. The team agreed upon these characteristics as an essential component when putting the app design into practice. In particular, the app should be seen as a tool for individual learning and, at the same time, as a tool for communicative exchange about the learning activities, results, and questions. Moreover, the suggestion was taken up for developing the app with interfaces to enlarge the originally five learning situations with additional situations, supplied and fed in by the users. Finally, the software developers showed ways how playing and learning can be enriched with elements of gamification. Thus, for instance, by playing several rounds in the app, badges are activated, giving the user feedback on their state of learning and their gaming status, e.g., which parts were already played and which are still to play.

These workshops resulted in the decision to develop the app with differing menus that support users' skills in the field of knowledge, their analytical skills, and pedagogical skills. Moreover, the users' individual answers and their choices in the game can be saved into a file and thus be shared with other students and teachers. This feedback can be discussed in classrooms. Hence, the app can be employed for individual learning and initiating exchange with other students and teachers. However, it was not possible to integrate additional playing and learning situations into the app after its finalization. These enlargements would have required constant updating and further development of the software code and were not included in our budget.

2. How can the expectations of users (who use digital apps in their everyday life primarily for gaming and social media) be met in the vocational training context?

   The students filling in the questionnaire were between 23 and 39 years old. The answers show that mainly women participated. Most of them had high school certificates or similar higher education entrance qualifications as their highest degree; one participant obtained a secondary school certificate.

All of them use apps in their daily life. Before the coronavirus pandemic and the transition from in-person to digital teaching, students reported on the following digital tool in teaching and learning: the digital learning campus (a platform providing content for digital teaching and learning as well as support for developing digital teaching resources) of their school. Since digital and online teaching has replaced in-person instruction, students learn with the learning campus to a larger extent, employ digital tools, such as "Zoom" and "Big Blue Button" (an open-source web conferencing system designed for online learning), and recorded online lectures.

The majority of the students welcome the shift toward an extension of digital media in teaching and learning, in particular when digital tools offer avenues for interactions between them. Some emphasize the importance of digital media in teaching and learning for times like the coronavirus pandemic, as it ensures they can continue their study. However, few students seem tired of digital media in teaching and learning, stating they prefer face-to-face lessons. They explained that "regular, analog seminars" would offer "more lively discussions, easier contact with other students and more motivation to actually participate in a lecture."

All of the participants agree with the statement that learning apps can support them in building key competencies for the digital transformation, in particular when the digitals tools "have a clear and well-structured design," "can convey relevant knowledge in a playful way," and be "integrated into everyday life."

With regard to their expectations toward a learning app, the questioned students express wishes with regard to an app's usability and content. Thus, the app should be "easy to handle," "well structured," "easy to understand," "coherent," "self-explanatory," "visually appealing," and "be uncomplicated to use in everyday life." The content should be "relevant," "be enriched with examples," have "references to practical situations," "links to students' daily lives," and should be "taught in a playful way."

The last part of the questionnaire focuses on individual features of the app. Answers to the question of how students would describe the app with one word, include the following terms: "helpful," "unique," and "structured." All of the participants would like to learn with the app in their vocational training. Furthermore, we asked participants to rate the didactic components, which include exercises to (a) practice communication with kindergarten children, (b) identify underlying mathematical phenomena, and (c) strengthen reflective and analytical skills. Compared to the other groups of participants (teachers, experts of early STEM education, and experts of digital media), the students show the highest degrees of approval. In particular, the app's feature to strengthen the users' analytical and reflective skills was very positively evaluated. There was less agreement received only on items asking for evaluations of the app's interactivity.

When we asked for features to improve the app with regard to playfulness, interactivity, and further add-ons, the participants suggested the following: "better graphics" and "more vivid illustration." Furthermore, they suggested features that "enable users to continue with the last example scene in case of an interruption" and "to convert answers into a word document."

3. How can didactic and STEM requirements in ECEC that have been developed within the research project be implemented in the learning app?

   Questionnaires were sent to all vocational teachers who participated in the project and the development of the teaching materials. Results from the teachers' questionnaires show that the majority of participants were female (about 80%). They were between 20 and 60 years old. Most of the participants in the group of teachers (80%) had high school certificates as their highest school certificate and some (20%) secondary schools certificates. Most teachers have undergone professional training in the area of social work and social education. Their main subject responsibilities in schools were very broad, ranging from a focus on math to art.

The feedback for questions focusing on digital media in teaching and learning shows that the majority have already used digital media. All of the respondents use apps on their smartphones. With regard to teaching, 8 of 10 report having used tools such as e-mail, apps, eBooks, YouTube, PowerPoint, Google, and language learning apps. However, 30% say they had not employed any digital tools. Since the coronavirus pandemic and the switch from in-person to online teaching, teachers have additionally employed digital tools in their lessons and communication with students, including YouTube, school clouds, e-teaching books, and tools for video conferences. Still, 20% say they have not used any digital tools. Furthermore, the majority of teachers welcome digital teaching and learning (90%), particularly formats such as apps, eBooks, digitally recorded seminars, and school clouds. Teachers furthermore agree that digital media, such as apps, can support students' key qualifications necessary for the digital transformation (90%) if they are seen as instruments for learning and are combined with classroom learning.

In the last part of the questionnaire, we asked the participants to evaluate individual parts of the app. First, we asked for the teachers' expectations toward an app. The results could be summarized in the following three dimensions: usability, learning, and learning attitudes. Thus, with regard to the apps' usability, we summarized wishes such as "easy to handle and to understand," "clearly designed," "colorful," "not so much text," "stable," and "interactive."

The "learning" category includes the following statement: "giving feedback," "control over content and time to learn," "support of self and distance-learning," "control over learning," "answering questions," "help and stimuli to learn," and "giving examples."

"Learning attitudes" comprise the following expectations: "positive effects on students' motivations to learn" and "stimulation of curiosity for topics in early childhood teacher education."

Finally, we presented individual parts of the app and asked for the teachers' assessments. When asked to evaluate the app with one word, these were "super," "inspiring," "partially to much text," and "helpful." Moreover, participants could rate individual characteristics within a 4-point scale (strongly agree, agree, disagree somewhat, disagree). In 90% of the items, the box "agree" was ticked.

Exceptions were the dimensions: support of analytical and reflective skills. Here the agreement was even higher (ticked "strongly agree"). However, less agreement was expressed when asked if the users would like to employ the app. Only 70% of the respondents agreed with this statement.

9.6 Discussion

In this paper, we discuss the process of designing a learning app, in particular how we incorporated students' and teachers' expectations as well as pedagogical and programming experts' suggestions. While not a massive users' game, the learning app includes important features of GBL, such as imaginary scenes, immersing users into a new role, solving problems, and getting feedback. In the process of developing the app, we drew on the knowledge of the effects of GBL and the associated challenges. Thus, the scientifically confirmed positive effects of GBL on students' motivation and affective attitudes was the main reason to employ a learning app for the education of prospective kindergarten teachers. We thus hope to improve their predominantly negative attitudes toward mathematics, which were evident in the first survey. Similarly, positive effects on the increase of didactical competencies are expected through experiencing problem-solving situations that require students to actively reflect on ways (and prior knowledge) of interacting with the children in the app's playing situations. Moreover, we were strongly conscious of the appeals of researchers to involve future users in the process of designing GBL. Thus, two teachers were part of the working group designing the app, and we asked for teachers' and students' feedback on the app and suggestions for improvement before finalizing the programming.

Summarizing the results of the questionnaires and the expert panels, the variety of ideas and expectations about a learning app has become visible. Students expressed many wishes with regard to the apps' usability and content. Compared to the other groups, they showed the highest rate of approval for the app, its features, and digital teaching and learning. Students expressed wishes to improve the app by including more appealing graphic elements and animations. The teachers' approval of the apps' individual features was still high; however, about 30% stated they have not used any digital media in teaching and still 20% since the coronavirus pandemic. Teachers' expectations toward the app included more dimensions in comparison with the group of students, focusing on aspects such as usability, learning, and attitudes toward learning. Thus, while the apps' ability to strengthen reflective and analytical skills was evaluated very positively, the apps' interactivity received lower scores. These judgments guided several improvements of the app to enhance the interactivity, leading to several possible ways to play the app. Experts on digital media in particular emphasized ways to employ the app as a means not only for individual learning but also for further activities, such as ways for students to create and upload their own ideas. Thus, the app contains a menu that saves the users' own suggestions and ideas that can be shared with other users, students, and teachers. Finally, we kept in mind the challenge to design an app that both is a game and stimulates specific ways of learning (about mathematics and empathic and cognitive activating interactions between teachers and children in childcare organizations). While the didactic expectations were largely incorporated, the gaming character is somewhat less pronounced (in particular, in contrast to commercial games).

9.7 Conclusion

The development of the app has been a process involving many cycles to meet the users' expectations (vocational students and their teachers). Additionally, expert knowledge in the area of digital media, specific legal expertise with regard to data security as well as gamification skills contributed to the conception of the app—even before the step of finally programming it. Thus, developing the app included much time, coordination, and expertise. However, as there are hardly any people who simultaneously possess didactic STEM knowledge for children and vocational students, knowledge on digital media and didactics as well as expertise in gamification of learning professional competencies, these coordination efforts are necessary to develop an app that is welcomed by students and teachers. Although we tried to incorporate the expectations of all targeted user groups, we had to make compromises. Thus, the students' answers in the questionnaire indicate that the illustrations we integrated in the app might be assessed as somewhat antiquated since students have grown up as "digital natives" with sophisticated animations and app surfaces in digital gadgets. However, we were able to integrate teachers' and didactic experts' knowledge as well as digital media experts and software programmers' expertise to a large extent. Nevertheless, some of the teachers—even in times when pandemics impede regular teaching—expressed a general refusal to employ digital media in their teaching. Thus, regardless of how well the app has been aligned with didactic dimensions, the app will not find its way into these teachers' classrooms.

Interestingly enough, the entire conception process of the learning app was a prototype at the German Youth Institute; accordingly, our team was perceived as pioneers in the field of GBL in ECEC. While GBL has been well established in international research, it is just starting in Germany. Large-scale comparative studies reveal German lessons repeatedly near the last place with regard to the extent digital media is employed as well as teachers' positive attitudes toward digital media. Additionally, since there are no compulsory curricula for all 16 states of Germany to comprehensively implement digital media, individual teachers' and administrators' efforts determine to a large extent whether digital media and thus GBL is part of the lessons or not. Accordingly, only limited research on GBL in ECEC can be found while at the same time the discipline itself is evolving (Smidt, 2017). Thus, for instance, the dual education system with a strong professional practical focus—proven over decades—is increasingly accompanied by academic alternatives (Beher et al., 2019). The teaching concepts and material, such as the learning app, are part of efforts to foster learning transfer for future preschool educators' in vocational schools. The app addresses these basic skills and basic knowledge, such as individual competence as well as analytical and reflective skills that future ECEC educators need whether to be attained in dual or academic training programs.

With regard to future research on GBL, we suggest investigating how students play and learn with games, such as in the app presented here and on how students and teachers integrate them in learning and teaching routines at school. These research questions point to the influence of traditional and cultural teaching patterns of individual educational systems on the ways learning and teaching are organized in schools. Hence, research is needed to show how GBL can be implemented in these routines. In Germany, we see a widening gap between students' informal digital competencies and dispositions on the one hand and predominantly inflexible school structures with a strong focus on books, handouts, the dominant role of the teacher as well as a predominance of noncooperative learning forms on the other hand. Integrating GBL to a larger degree gives students a tool for individual learning and thus opposes these structures. Research, accompanying the resulting frictions and changes following the integrating of GBL into teaching can yield insights into factors that influence changes in school structures. Scientific inquiries answering these questions should contribute to adjusting learners' and teachers' expectations in the digital age.

Acknowledgments The project LuPE (Lehr- und Praxismaterial für die Erzieherinnenausbildung) was funded by the Deutsche Telekom Stiftung. In particular, we would like to thank Jens Daniel and Iris Kahlau at the Marie-Elise-Kayser-Schule in Erfurt (Thuringia) for their work and support in our LuPE-App workgroup.

References

Abdul Jabbar, A. I., & Felicia, P. (2015). Gameplay engagement and learning in game-based learning. *Review of Educational Research, 85*(4), 740–779. https://doi.org/10.3102/0034654315577210

Amory, A., Naicker, K., Vincent, J., & Adams, C. (1999). The use of computer games as an educational tool: Identification of appropriate game types and game elements. *British Journal of Educational Technology, 30*(4), 311–321. https://doi.org/10.1111/1467-8535.00121

Bedwell, W. L., Pavlas, D., Heyne, K., Lazzara, E. H., & Salas, E. (2012). Toward a taxonomy linking game attributes to learning. *Simulation & Gaming, 43*(6), 729–760. https://doi.org/10.1177/1046878112439444

Beher, K., Gessler, A., Hanssen, K., Hartwich, P., König, A., Peucker, C., et al. (2019). *Fachkräftebarometer Frühe Bildung 2019. WiFF: Arbeitsmarkt: Vol. 2019*. Deutsches Jugendinstitut e.V..

Best, P., Bosch, K., Jampert, K., & Zehnbauer, A. (2017). Kinder-Sprache stärken!: Ergänzungsmaterial: Beobachtung. In *Dokumentation und Reflexion sprachlicher Bildung und Förderung in der Kita*. verlag das netz.

Beutner, M., & Pechuel, R. (2015). App-based interactive language learning – Pedagogy, implementation and evaluation with the AGnovel tool. In Proceedings of E-Learn: World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education (pp. 1408–1414). Kona, Hawaii, United States.

Bildung durch Sprache und Schrift, Staatsinstitut für Frühpädagogik, & eforce21. (2018). Sprachspiele mit BiSS. Retrieved from https://play.google.com/store/apps/details?id=de.bayern.ifp.spielesammlung

Born-Rauchenecker, E., & Drexl, D. (2018). LuPE- analyse- und Reflexionsbogen. In E. Born-Rauchenecker, D. Drexl, K. Weber, & J. Wolfsperger (Eds.), *Frühe alltagsintegrierte naturwissenschaftliche Bildung: Handreichung für Lehrende: LuPE - Lehr- und Praxismaterial für die Erzieherinnenausbildung* (1st ed., pp. 175–181). Klett/Kallmeyer.

Born-Rauchenecker, E., Drexl, D., Weber, K., & Wolfsperger, J. (Eds.). (2018). *Frühe alltagsintegrierte naturwissenschaftliche Bildung: Handreichung für Lehrende : LuPE - Lehr- und Praxismaterial für die Erzieherinnenausbildung*. (1. Auflage. Klett/Kallmeyer.

Born-Rauchenecker, E., Vogtländer, A., & Weber, K. (2020). Frühe alltagsintegrierte mathematische Bildung: Handreichung für Lehrende.

Boyle, E. A., Hainey, T., Connolly, T. M., Gray, G., Earp, J., Ott, M., et al. (2016). An update to the systematic literature review of empirical evidence of the impacts and outcomes of computer games and serious games. *Computers & Education, 94*, 178–192. https://doi.org/10.1016/j.compedu.2015.11.003

Cojocariu, V.-M., & Boghian, I. (2014). Teaching the relevance of game-based learning to preschool and primary teachers. *Procedia - Social and Behavioral Sciences, 142*, 640–646. https://doi.org/10.1016/j.sbspro.2014.07.679

Drexl, D., Born-Rauchenecker, E., & Kalicki, B. (2019). Naturwissenschaftliche Einstellungen angehender pädagogischer Fachkräfte. *Frühe Bildung, 8*(1), 30–36. https://doi.org/10.1026/2191-9186/a000408

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., et al. (2007). School readiness and later achievement. *Developmental Psychology, 43*(6), 1428–1446. https://doi.org/10.1037/0012-1649.43.6.1428

Eseryel, D., Law, V., Ifenthaler, D., Ge, X., & Miller, R. (2014). An investigation of the interrelationships between motivation, engagement, and complex problem solving in game-based learning. *Journal of Educational Technology & Society, 17*(1), 42–53. Retrieved from www.jstor.org/stable/jeductechsoci.17.1.42

Fröhlich-Gildhoff, K., Nentwig-Gesemann, I., & Pietsch, S. (2011). *Kompetenzorientierung in der Qualifizierung frühpädagogischer Fachkräfte: Eine Expertise der Weiterbildungsinitiative Frühpädagogische Fachkräfte (WiFF). Ausbildung: Vol. 19*. München: Dt. Jugendinst.

Retrieved from http://www.weiterbildungsinitiative.de/uploads/media/WiFF_Expertise_Nr_19_Froehlich_Gildhoff_ua_Internet__PDF.pdf

Ge, X., & Ifenthaler, D. (2018). Designing engaging educational games and assessing engagement in game-based learning. In I. R. Management Association (Ed.), *Gamification in education* (Vol. 17, pp. 1–19). IGI Global. https://doi.org/10.4018/978-1-5225-5198-0.ch001

Granic, I., Lobel, A., & Engels, R. C. M. E. (2014). The benefits of playing video games. *The American Psychologist, 69*(1), 66–78. https://doi.org/10.1037/a0034857

Hainey, T., Connolly, T. M., Boyle, E. A., Wilson, A., & Razak, A. (2016). A systematic literature review of games-based learning empirical evidence in primary education. *Computers & Education, 102*, 202–223. https://doi.org/10.1016/j.compedu.2016.09.001

Heininger, R., Utesch, M., & Krcmar, H. (2016). Schülerakademie Serious Gaming mit ERPsim zur Förderung der Studierfähigkeit. In V. Nissen, D. Stelzer, S. Straßburger, & D. Fischer (Eds.), *Multikonferenz Wirtschaftsinformatik (MKWI) 2016: Technische Universität Ilmenau, 09. - 11. März 2016* (pp. 751–762). Universitätsverlag Ilmenau.

Jampert, K., Leuckefeld, K., Zehnbauer, A., & Best, P. (2006). Sprachliche Förderung in der Kita. In *Wie viel Sprache steckt in Musik, Bewegung, Naturwissenschaften und Medien?* Weimar.

Linderoth, J., & Sjöblom, B. (2019). Being an educator and game developer: The role of pedagogical content knowledge in non-commercial serious games production. *Simulation & Gaming, 50*(6), 771–788. https://doi.org/10.1177/1046878119873023

Purdon, A. (2016). Sustained shared thinking in an early childhood setting: An exploration of practitioners' perspectives. *Education. 3–13, 44*(3), 269–282. https://doi.org/10.1080/03004279.2014.907819

Shaffer, D. W. (2006). *How computer games help children learn*. Palgrave Macmillan US. https://doi.org/10.1057/9780230601994

Siraj-Blatchford, I., Sylva, K., Muttock, S., Gilden, R., & Bell, D. (2002). *Researching effective pedagogy in the early years*. Research Report No. 356. o.O.: Queen's Printer.

Smidt, W. (Ed.). (2017). *Contemporary issues in early childhood education in Germany*. Taylor & Francis Ltd.

Stieler-Hunt, C., & Jones, C. (2019). A professional development model to facilitate teacher adoption of interactive, immersive digital games for classroom learning. *British Journal of Educational Technology, 50*(1), 264–279. https://doi.org/10.1111/bjet.12679

Witt, C. D. (2013). New forms of learning for vocational education: Mobile learning - social learning - game-based learning. In *Federal Institute for Vocational Education and Training (Ed.), Vocational education and training – new challenges. BWP – Journal of the Federal Institute, Special Edition 2013* (pp. 27–30). W. Bertelsmann Verlag.

Chapter 10
A Naturalistic Inquiry Into Digital Game-Based Learning in Stem Classes From the Instructors' Perspective

Yun Li, Armanto Sutedjo, Suzanna J. Ramos, Hector Ramos Garcimartin, and André Thomas

10.1 Introduction

Digital games have shown much promise in their ability to support learning. Evidence indicates that digital games have positive effects on learning such as engagement, motivation, and knowledge construction (Clark, 2016; Jong et al., 2010; Martens et al., 2004; Prensky, 2006; Tobias & Fletcher, 2011; Wouters et al., 2013; Wouters & van Oostendorp, 2017). Compared to the amount of money invested in digital games and significant research interest in game-based learning (Granic et al., 2014), it is roughly estimated that only about 10% of the classroom uses digital games as part of the instruction (Takeuchi & Vaala, 2014). Moreover, although the majority of adolescents playing video games (Lenhart et al., 2008), digital games used for learning purposes seem to fail to capture the hearts and minds of young learners the same as what commercial games do. Therefore, extensive research studies have been focusing on investigating how to design and develop the best games for educational use (Aylett, 2006; Ip et al., 2007; Jong et al., 2006; Lee et al., 2006; Shaffer, 2006).

However, apart from the educational game design, the actual adoption and integration are also critical factors to effective game-based learning. Thus, the issues that exist in integrating digital games in the classroom also need to be addressed (Halverson, 2005; Jong et al., 2010). In this study, we tend to identify the patterns in instructors' teaching practices of instructional integration of digital games in the classroom and explore the possible reasons that influence instructors' behavior within the framework of the Technological Pedagogical Content Knowledge (TPCK). Our study is conducted in the discipline of mathematics which requires

Y. Li (✉) · A. Sutedjo · S. J. Ramos · H. R. Garcimartin · A. Thomas
Texas A&M University, College Station, TX, USA
e-mail: liyun215@tamu.edu

C. Aprea, D. Ifenthaler (eds.), *Game-based Learning Across the Disciplines*, Advances in Game-Based Learning, https://doi.org/10.1007/978-3-030-75142-5_10

both conceptual and procedural understanding. Game is regarded as a great tool in helping students master abstract concepts and transfer knowledge (Boyle et al., 2011). The digital game used in this study is Variant: Limits, designed and developed by a group of professors and students from the Department of Mathematics, the Department of Visualization, and the Department of Educational Psychology at Texas A&M University. We aim to raise educators' interest in using digital games as a tool to facilitate learning, particularly for those who are still skeptical about the educational value of digital games and to provide suggestions on game integration to the instructors who are interested in digital game-based learning.

This chapter is structured into six distinct sections. Section one presents the background and the focus of this study. Section two briefly reviews the relevant literature on game integration, theoretical foundation, and Variant: Limits game used in this study. Section three details the methodology of this study including a description of the participants, data collection procedures, and the method used for data analysis. Section four reports the findings that emerged from thematic analysis. Section five discusses the possible reasons that influence instructors' game integration. The conclusion section additionally offers the limitations of the current study, implications for the educational practices, and recommendations for future research.

10.2 Technology Integration and the Variant game

10.2.1 Digital Games and Game Integration

Digital games, mostly in the form of serious games in education, are technological tools with which learners gain their knowledge and practice their skills by solving a set of challenges during gaming (Backlund & Hendrix, 2013; Vandercruysse & Elen, 2017; Wouters & Van Oostendorp, 2013; Zhonggen, 2019). Serious games contribute to the achievement of defined educational goals rather than entertainment purposes (Nazry & Romano, 2017; Zhonggen, 2019; Zyda, 2005). Learners receive constant feedback (e.g., scores and badges) to monitor their learning progress (Prensky, 2006; Zhonggen, 2019). Effective digital games can foster learning by changing learners' cognitive processes and affect their learning motivation (Wouters & van Oostendorp, 2017).

Instructional integration of digital games is essential to achieve effective learning (Garris et al., 2002; Liu & Rojewski, 2013; Vandercruysse & Elen, 2017; Wouters & Van Oostendorp, 2013). The complexity of digital game learning environments can overwhelm learners, for example, overloaded multimodal information, complicated game dynamics, and challenging learning tasks (Wouters & van Oostendorp, 2017). Additionally, knowledge gained through gaming is intuitive that learners may struggle with knowledge retention and learning transfer (Leemkuil & de Jong, 2011; Wouters et al., 2008; Wouters & van Oostendorp, 2017). Therefore, instructional support (e.g., guidance, reflection, and class discussion) is considered as a necessary part to facilitate effective game-based learning (Tobias & Fletcher 2011; Vandercruysse & Elen, 2017; Wouters & van Oostendorp, 2013; Wouters & van Oostendorp, 2017).

10.2.2 Technological Pedagogical Content Knowledge

Technology integration is a complex process that involves three key components: content, pedagogy, and technology (Koehler & Mishra, 2009). According to Koehler and Mishra (2009), content knowledge discusses the actual subject matter. Pedagogical knowledge refers to the processes and methods of teaching and learning to make the knowledge transfer happening. Technology knowledge displays the fluency of technology that requires a deeper and more essential understanding of the technological tools to solve teaching and learning tasks in an adaptive way. These three components interact with one another that creates a diverse context for educational technology integration.

Koehler and Mishra's (2009) TPCK framework describes teachers' understanding of how technologies interact with pedagogical and content knowledge to produce effective teaching with technology (See Fig. 10.1). Pedagogical Content Knowledge explains the knowledge of pedagogy that can be applied to teach specific content. Technological Content Knowledge discusses how technology and content can influence and constraint one another (Koehler & Mishra, 2009). Technological Pedagogical Knowledge describes how a change in teaching and learning when technologies are used (Koehler & Mishra, 2009). Teachers need to know how to utilize the technology for pedagogical purposes and its limitations to teach content knowledge.

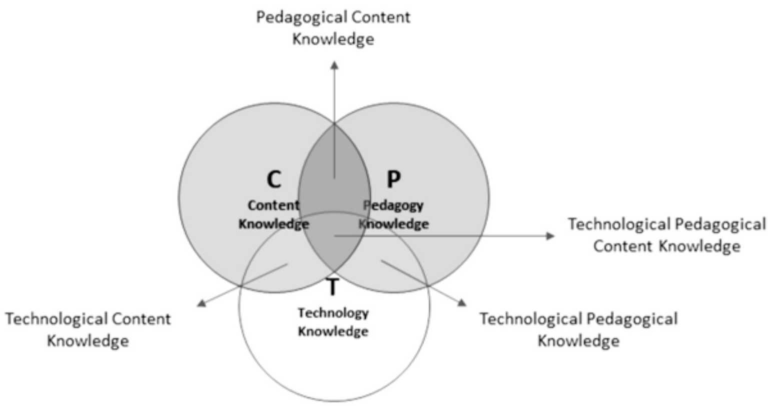


Fig. 10.1 The TPCK model

Fig. 10.2 An example of the game zone

10.2.3 The Variant: Limits

Variant: Limits (Thomas et al., 2017) used in this study is an educational game that is designed specifically to teach Limits. In this three-dimensional adventure, game players take on the role of an explorer on an alien planet and are trying to figure out what happened to the civilization on that planet. Variant: Limits comprises four zones (1) the nature of points, (2) functions, relationship to Limits, & Limit Laws, (3) relating continuity to limits, and (4) asymptotes. Each zone has a series of unique problems and the players need to solve these problems to move forward (See Fig. 10.2 as an example).

A short tutorial is provided at the beginning of zone 1 to let the players get familiar with game mechanics. While progressing in the game, the players get instant feedback for what they do in the game to help them build their understanding of the mathematical concept. Meanwhile, instructors can monitor students' progress in the game. An integrated assessment is built in the Variant: Limits to help the players apply what they have learned during the gaming process (See Fig. 10.3 as an example).

10.3 Method

A naturalistic inquiry was chosen based on the type and features of the research questions set in this study that allowed the researchers to investigate the phenomena in a specific context (Denzin & Lincoln, 2000; Erlandson et al., 1993; Guba & Lincoln, 1982). This qualitative research provided the opportunity for the instructors to share their stories of integrating the Variant game in Calculus classes. This method also guided the researchers to understand and interpret the experience and actions of instructors who adopted the game-based learning approach in teaching.

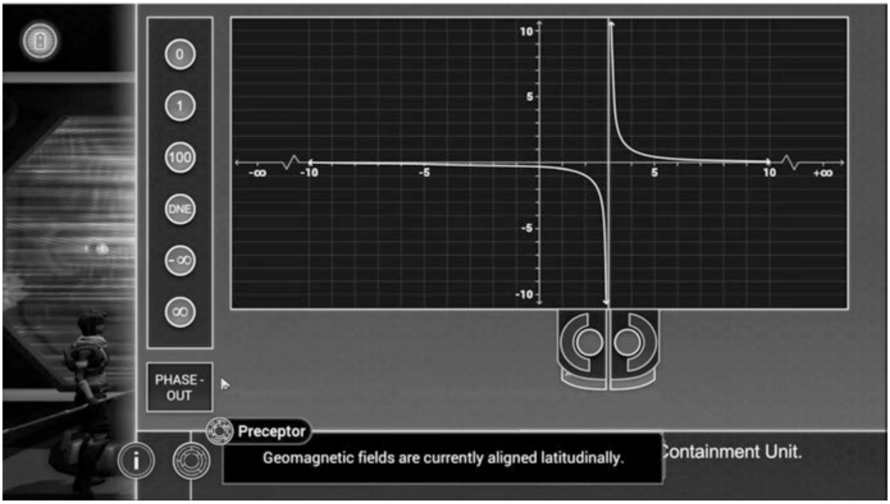


Fig. 10.3 An example of the integrated assessment

Through the lens of naturalistic inquiry, researchers sought to assess the patterns in instructors' actions to establish plausible inferences about the effective implementation of game-based learning in classroom instruction from the instructors' perspective.

This study used Braun and Clarke's (2006) thematic analysis framework to guide the data analysis process. The purpose of thematic analysis is to identify themes in qualitative data to explain the phenomenon in a specific context (citation). Braun and Clarke (2006) classified themes into semantic and latent. Semantic themes are the summary of "the explicit and surface meaning of the data" (p. 84), and latent themes capture "underlying ideas, assumptions, and conceptualizations - and ideologies" (p.84) in qualitative data. In this study, researchers aimed to analyze the patterns in instructors' teaching practices and behavior of integrating digital games in classroom instruction (semantic level) and to discover the underlying factors of the effective implementation of digital games (latent level). Therefore, the thematic analysis approach was appropriate to guide the data analysis process.

The target population was the instructors who used the Variant game to facilitate teaching in their classroom. A formal invitation e-mail along with a research information sheet was sent to Triseum, the company where the Variant game was designed and developed. Triseum forwarded the research invitation to all 14 instructors who purchased the Variant game. In the end, four instructors accepted the invitation and participated voluntarily in this research study. These participants came from a high school, community colleges, and a university, and they all had positive attitudes toward game-based learning. The following table provided a more detailed background of the participants. A pseudonym was assigned to each participant and was used throughout the rest of this paper (Table 10.1).

Table 10.1 Demographics of participants

Participants	Gender	Degree background	Teaching experience (years)	Where to teach
Anna	Female	Engineering	16	High School
Ben	Male	Mathematics	37	University
Cody	Male	Mathematics	15	College
Sammy	Female	Mathematics	15	College

Data were collected using semi-structured interviews that allowed the participants to fully express themselves within a framework of themes to be explored (Merriam, 2009). Four participants were interviewed between October 2019 and February 2020. Each interview session lasted 1 h. One interview was done in person and the other three were conducted online via Zoom. The interviews were videotaped and observational notes were taken for data analysis.

Data analysis was guided by a six-phase thematic analysis that consisted of familiarizing the data set, generating initial codes, searching for preliminary themes, reviewing themes, defining themes, and producing the reports (Braun & Clarke, 2006). The data analysis fell into three stages in this study. In the first stage, researchers reviewed all transcripts and observational notes to get familiar with the data; meanwhile, the reflective memo was made to record initial impressions when reviewing the data. Two researchers subsequently engaged in open coding using Nvivo. The next stage was to search for themes and review them. Four researchers held regular meetings to organize the categories and discover the preliminary themes during this stage. The last stage was to "identify the 'essence' of what each theme is about" (Braun & Clarke, 2006, p. 92), after which researchers reported this thematic analysis of game-based learning in STEM classes from the instructors' Perspective.

Trustworthiness in qualitative research was equivalent to reliability and validity in quantitative research. Lincoln and Guba (1985) proposed four criteria for establishing the trustworthiness of data: credibility, transferability, dependability, and confirmability, according to which, Nowell et al. (2017) outlined a practical procedure that guides researchers to meet trustworthiness criteria in each phase of thematic analysis. This study followed Nowel's (Nowell et al., 2017) practical procedure to ensure the trustworthiness of data analysis (Table 10.2).

10.4 Results

The following section reports the primary categories and emerging themes derived from our data analysis. We generate our categories and themes in accordance with the thematic analysis proposed by Braun and Clarke (2006). The report below represents data analyzed from the interviews, observations, and reflective memos. We use quotes from our participants to provide an in-depth description of our findings.

Table 10.2 Means of Establishing Trustworthiness

Phase of thematic analysis	Means of establishing trustworthiness
Familiarizing data	Reflective memo
Generating Initial Codes	Peer debriefing Documentation of all team meetings and debriefings
Searching for Themes	Peer debriefing Diagraming theme connections Reflective memo
Reviewing Themes	Peer debriefing Theme review by team members
Defining Themes	Peer debriefing Team consensus on themes

10.4.1 Perception of the Value of Digital Games

Participants have teaching experience as math teachers from 15 years to greater than 30 years. Three of them have been using the Variant to teach Limits for more than 1 year, and one participant has been implementing the game in teaching for over 5 years. From the four participant's narratives, they were all game players on different levels yet had little experience and knowledge about game-based learning methods. While these instructors all showed strong interest in using the Variant to teach Limits, it indicated in the narratives that perception of the value of digital games determined how the instructors would use the game in their teaching. When instructors only considered the game as an extra fun tool, they spent little time investigating the best practices of using the tool in teaching. For example, Sammy described the Variant game as "a possibility" and all she did was to play the game herself before the class to be able to answer the questions if any. She shared,

> It (the Variant game) was only like the support, not mandatory offering... So there are no other plans than just providing the possibility at this very moment...But I went through the game twice before I gave it to my students, if they don't understand, just ask me.

When instructors perceived the game as a learning tool, in addition to the immersive experience, fun activity, and self-paced learning experience, they believed "you can learn while you play." Moreover, instructors noted that the Variant game offered a different learning context. Before integrating the Variant game in teaching, it was common practice to teach math with traditional teacher-centered methods, i.e., lecturing, class activities, and homework. "It's a pattern...that's what you do and it's your lecture..." Cody commented. In a lecture-based learning context, students learned math by listening to the lectures in the classroom and practicing analytical problems at home. The Variant game provided a different learning context in which students learned with a trying method. Cody explained,

> It needs to be an immersive experience and all those things you take from normal video game playing, right, like repeatedly tried, don't mind failing here, and get into it, and bring that over to the mathematics side.

Given this significant change in the learning context, instructors put effort into examining the tool and modifying teaching methods, applying various strategies to facilitate the game-based learning process, and evaluating the implementation process of GBL for improvement.

10.4.2 Examining the Tool and Modifying Teaching Methods

Before integrating the Variant game into the classroom, instructors examined this learning tool in various ways. They spent time playing the game to get familiar with the content, structure, and rules of the game, piloted the game to collect feedback from the students, and searched for how other teachers use the game.

Ben spent quite a significant amount of time playing the game on his sabbatical leave. He explained, "I need to understand completely before I integrate it into my classroom." Cody played through the game several times; additionally, he piloted the game with his business Calculus class. He recalled, "I set it up as an optional assignment...and did a survey to understand what students liked and what they didn't in video games…" Similarly, Anna also piloted the game and realized the necessity of modifying her teaching method for the appropriate use of this learning tool. She explained,

> I did lectures and would supplement with the game. Kids love the game. They absolutely loved playing the game. And I just felt like I wasn't doing it. If you are using the game and not changing the way you teach, for me that doesn't make sense. The whole point of the game is to do something different. And I needed to change the way I taught the materials.

After examining the tool, instructors further analyzed the challenges and opportunities with the Variant game to modify their teaching method accordingly. They discovered two major issues if using the Variant game to teach. One was the content mismatch. The Variant game built the content in its storyline, but most of the textbook didn't match the game structure. The other was teaching goals misalignment between the game and the school curriculum. The learning goal set in the Variant game was for students to understand the conceptual part of Limits, yet learning objectives designed in the school curriculum focused on algebraic operations. To address these issues, instructors tailored their teaching methods to meet the learning goals for students as follows:

- Revising course structure. Ben rearranged the topics and matched reading materials to follow the game structure. To make the game more meaningful to the students, he taught the topics, had the students playing the game in the class, and created some quizzes that were similar to the game puzzles as the homework.
- Chunking the variant game. Cody aligned the learning objectives for each of the four zones with the topics required by the school curriculum. When he was teaching those particular topics, he plugged the Variant game in the teaching process. Considering the concepts of Limits were covered in the Variant game,

Cody pushed this part of learning out of the classroom teaching and focused on tackling more advanced math problems in the class.

- Using the variant game only. Anna abandoned the textbook and used the Variant game as the main learning material. She had the students immersed in the Variant game to learn Limits at their own pace by themselves in the class. At the end of each class, she required the students to reflect on what they learned or named one thing they struggled with during the game playing.

Regarding the teaching goals misalignment, instructors recognized the discrepancies between what was being taught in the game and what was being tested in exams. They all acknowledged playing the Variant game might not help students pass the exams directly. However, they all believed that the understanding of the concepts was the foundation of the algebraic application. Cody shared,

> As I explained to my students, it is like a foreign language, right? Learning basic vocabulary is really boring. But you can't speak, you can't have a conversation without the vocabulary. But to get to the interesting stuff you've got to learn the basic thing. The concepts of Limits will be useful for the rest of their lives, but the particular algebraic operations may not…

Therefore, in addition to modifying their teaching methods as a whole, instructors reflected on how they applied specific strategies to help students connect the game playing with learning. These strategies were part of how the instructors integrated the digital game in the classroom.

10.4.3 Applying Various Strategies to Facilitate the Learning Process

The instructors used a variety of strategies to connect game playing with learning. The instructors explained that they implemented these instructional strategies to increase students' understanding that gaming was a part of the learning process. The most frequent strategies used were classroom discussion, peer collaboration, and reflection:

- Classroom Discussion. Instructors utilized this strategy in the classroom after students playing the Variant game. They brought up the questions that guided the students to discover the connections between the game playing and the textbook content. Cody shared,

  > When they come out of the game and I say, "OK now let's do this analytically. You've been doing this graphically. Now you have an equation that you don't know what the graph is. Before, [in the game] you had a graph, [but] you didn't know the equation was. Now, you have an equation that you don't know what the graph is. Now, what do you do with this?"

- Peer Collaboration. Instructors monitored the game level of the class as a whole, and they encouraged peer collaboration when necessary. The interactions between the students allowed those who weren't gamers to learn from their peers and provide opportunities to those who were gamers to be reflective about what they had learned in the Variant game. To promote real collaboration, instructors advised students to help their peers discover the solutions but not to tell them the answers:

> If somebody is stuck, the first thing they do is who's been on this puzzle before. They help each other. The two kids who finished, I told them they had the hardest job because what their job was to help people without telling them what to do. They were allowed to sort of guide other students through, and maybe give them a little hint, but they weren't allowed to tell them how to solve the puzzle. Because I've said if you're just getting them through the puzzle, they can't really understand why the puzzle works.

- Reflection. Instructors used this strategy to allow the students to share their game experiences as well as their struggles and confusion in the Variant game. Anna applied this strategy in her classes as she had the students learn Limits at their own pace by themselves in the class. She posted reflection questions in a system called Grokspot.org at the end of each class. Students could answer the reflection questions or share one thing that they had struggled with from the game playing. By doing this, she explained,

> Just something at the end to give them so it didn't seem like we just played a game for a whole class and then everybody left and forgot everything. So just to hold them accountable for their learning a little bit.

10.4.4 Evaluating the Implementation Process for Improvement

In general, instructors assessed their implementation in two ways: class observation and reflective note-taking. The class observation was used as an informal assessment method that observed student reactions to game-based learning and addressed the problems in a timely manner in the classroom. For example, noticing when many students were stuck in particular puzzles, instructors pulled up the game and walked through that puzzle in the class; recognizing the students who didn't like playing games got frustrated, instructors talked through the first puzzle to help them understand how the Variant game worked; spotting when the gamers played fast, instructors created teams and assigned roles to them so that they could allocate their time to help teammates.

Reflective note-taking was used by Anna. She constantly took notes so that she could "go back and look at it again before implementing the game next time." Reflective note-taking was helpful to document her thoughts, experiences, and failures to implement changes and guide future teaching practices.

10.4.5 Emergent Themes from the Study

Two major themes emerged from the data analysis: (1) Educational digital games are designed for learning purposes and should be incorporated into lesson plans to facilitate teaching and learning. (2) Purposeful implementation is essential to make game-based learning effective.

Within the TPCK framework, the first emerging theme highlighted a key idea that the digital game is a type of educational technology. The purpose of educational digital games is to assist instructors to achieve their teaching goals. Similar to other technologies, digital games can influence and constraint the type of content that can be taught. Therefore, it is critical to understand the affordances and constraints of the targeting digital game to identify if it is the appropriate tool for the designated teaching goals. This type of understanding is called Technological Content Knowledge in the TPCK framework.

In this study, three instructors played the Variant game before integrating it into their classroom. They recognized that the choice of the Variant game could impact their practices and the learning content they teach. As described earlier, they reconfigured the Variant game and tailored their teaching method to meet the established teaching goals. Unlike the other three instructors, Sammy played the game twice to get familiar with the tool before integrating it into her class. She noticed how the Variant game could help students better understand the concepts of Limits, but she strictly followed what she was required by the school curriculum:

> My goal is to help them with the knowledge or show them the knowledge so that they are able to do what the exam requires. So in fact, they don't need it (the Variant game). But I know personally that if they go through the understanding, not only through the calculations, they will be better in mathematics in general. But it's not the goal of what I am doing at my work. I would say my teaching goal is to push students through the exam.

She recognized the affordances and constraints of the Variant game but seemed to lack the skills to look beyond the common use of digital games. Therefore, she used the Variant game as a "possibility" to attract students' attention to Limits. When she was asked if she had any plans to teach with the Variant game, she explained,

> It (the Variant game) was only like homework or volunteering support for those who are willing to do something more...I don't have other plans because I don't have enough time to do things. So there are no other plans but just providing the possibility at this very moment.

The second emerging theme outlined the importance of pedagogical knowledge in integrating digital games for educational use. The Variant game is designed with the constructivist learning paradigm in which learners construct their understanding and knowledge of Limits through solving the learning tasks in an interactive adventure. Although the constructivist learning approach emphasizes student-centered learning, the teacher's role as a facilitator is equally important for this learning approach to be effective (Bada & Olusegun, 2015). The teacher's role is particularly important for constructivist learning through digital games (Jong et al., 2010).

Without any scaffolding, students have difficulties in knowledge transfer and application (Jonassen et al., 2003; Jong et al., 2010).

As aforementioned, three instructors applied various strategies to facilitate game-based learning, for example, peer collaboration, reflection, and class discussion. These instructors were actively involved in these activities to guide students to integrate learning experience into the gaming experience. Anna recalled,

> The kids see learning through the game and they appreciate that. They know that it's different. They notice that they are learning differently and they notice that they are using the game to learn instead of being lectured to.

Compared to the above three instructors, Sammy got involved but in a limited way in students' learning construction process:

> I went through the game twice before I gave it to my students, so I was quite experienced. So I told my students, if they don't understand, just ask me. But they didn't use this possibility. So they rather go to YouTube to see the solution than asking the teacher.

As a result, her students played the game for fun. "They took it like fun. The game was fun." Sammy commented.

10.5 Discussion

Research on game-based learning has been emphasizing a balanced design of educational digital games that aims to integrate learning goals into game mechanics for an effective learning game experience (Betz, 1995; Jong et al., 2010; Kirriemuir & McFarlane, 2004; Squire, 2003). Apart from the well-designed educational digital games, the actual implementation of game-based learning in the classroom is also the main determinant of an effective game-based learning experience. Our analysis of the 4 instructors in this study suggests that integrating digital games into the classroom is dynamic and complex, it particularly requires a deep understanding of the relationship between teaching and this specific technology. High implementers were acutely aware of the connections of knowledge among content, teaching, and the Variant game. These instructors had established their best practices that helped students connect learning experience with gaming experience. Low implementers overlooked the interaction between content, teaching, and the Variant game. These instructors used the Variant game as a standalone activity that resulted in a weak connection between the learning experience and gaming experience.

We observed that high implementers tended to be more flexible with the affordances and constraints of the Variant. They leveraged the affordances of the Variant game to improve learning experiences and performance and adapted instruction to accommodate the constraints. On the other hand, low implementers were relatively rigid when working with the Variant game. Their focal point rested on the constraints that prevented them from the full integration of the Variant game in the classroom. This inflexibility led to the Variant game being used as an optional resource in their traditional teaching method, and consequently, the degree of integration, to be limited.

What we have learned from this study suggested that what is central to the effective integration of digital games in the classroom is a deep understanding of the relationship between content, teaching, and the game. This requires technological content knowledge and technological pedagogical knowledge, according to the TPACK framework. Most digital games are not designed to meet the specific learning context or goals (Koehler & Mishra, 2009). As such, it is essential to overcome functional fixedness (Duncker, 1945) and reconfigure digital games in alignment with educational purposes.

10.6 Conclusions

When being integrated effectively in the classroom, games can motivate learners and help students master learning outcomes for motor skills, technical skills, affective, and cognitive skills (Garris et al., 2002). The results of this study indicate that digital games can be used as an effective tool to facilitate learning when instructors: (1) aware educational digital games are designed for learning purposes; (2) reconfigure the game or modify the teaching method before the implementation; (3) facilitate the game-based learning process during the implementation; and (4) evaluate the implementation process for future improvement.

Although this study has reached its research goal, there are some unavoidable limitations. First, the goal of a qualitative study is to provide a thick description of a phenomenon (Merriam, 2009); therefore, a generalization of the findings is not the purpose of this study. Second, the information gathered is based on a small sample size. Due to limited time and resources, we have only interviewed four instructors, but it would help to mitigate some of the bias and validity threats if more instructors were interviewed. Third, the study is limited to the data generated from semi-structured interviews. The semi-structured interview allows participants to fully express themselves within a framework of themes (Merriam, 2009). The questions for each participant are not the same that might lead to inconsistent results and biases.

While this study is specific for the discipline of mathematics, information gathered in the study could be useful for researchers and instructors from other disciplines who are interested in integrating digital games in a similar setting. In light of the findings discussed above, the following implications are recommended:

First, a deep understanding of the interaction between technologies and content knowledge is critical for the success of effective game integration. According to our findings, an important part of a successful game integration in the classroom is the result of instructors' awareness of educational affordances in digital games and instructors' purposeful implementation of digital games. Therefore, we propose integrated training to help instructors understand how technology and content can influence and constraint one another and how teaching and learning could be different when technologies are used (Koehler & Mishra, 2009).

Second, more research attention to game integration is needed for a more comprehensive understanding of effective game-based learning. Research in game-based learning has mainly focused on examining game effectiveness as the main contributor that affects the learning outcomes (Aylett, 2006; Ip et al., 2007; Jong et al., 2006; Lee et al., 2006; Shaffer, 2006). Compared to game effectiveness, game integration in the classroom, as the other major factor that contributes to effective game-based learning, has not yet been investigated systematically (Clark, 2016; Halverson, 2005; Sitzmann, 2011). Therefore, we call for more qualitative research to investigate instructors' practices and behavior of game integration across various disciplines, thereby identifying a set of applicable guidelines for game integration. Subsequently, quantitative research should be carried out to evaluate and improve the effectiveness of the applicable guidelines summarized from qualitative research.

References

Aylett, R. (2006). And they both lived happily ever after? In G. Dettori, T. Giannetti, A. Paiva, & A. Vaz (Eds.), *Technology-mediated narrative environments for learning* (pp. 5–25). Sense Publishers.

Bada, S. O., & Olusegun, S. (2015). Constructivism learning theory: A paradigm for teaching and learning. *Journal of Research & Method in Education, 5*(6), 66–70.

Backlund, P., & Hendrix, M. (2013, September). Educational games-are they worth the effort? A literature survey of the effectiveness of serious games. In *2013 5th international conference on games and virtual worlds for serious applications (VS-GAMES)* (pp. 1–8). IEEE.

Betz, J. A. (1995). Computer games: Increase learning in an interactive multidisciplinary environment. *Journal of Educational Technology Systems, 24*(2), 195–205.

Boyle, E., Connolly, T. M., & Hainey, T. (2011). The role of psychology in understanding the impact of computer games. *Entertainment computing, 2*(2), 69–74.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*, 77–101.

Clark, D. B.-S. (2016). Digital games, design and learning: a systematic review and meta-analysis. *Review of Educational Research, 86*(1), 79–122.

Denzin, N. K., & Lincoln, Y. S. (2000). *Handbook of qualitative research* (2nd ed.). Sage Publications, Inc.

Duncker, K. (1945). On problem solving. *Psychological Monographs, 58*(5), 1–110.

Erlandson, D. A., Harris, E. L., Skipper, B. L., & Allen, S. D. (1993). *Doing naturalistic inquiry: A guide to methods*. Sage Publications, Inc.

Garris, R., Ahlers, R., & Driskell, J. E. (2002). Games, motivation, and learning: A research and practice model. *Simulation & Gaming, 33*(4), 441–467.

Granic, I., Lobel, A., & Engels, R. C. (2014). The benefits of playing video games. *American Psychologist, 69*(1), 66.

Guba, E. G., & Lincoln, Y. S. (1982). Epistemological and methodological bases of naturalistic inquiry. *ECTJ, 30*(4), 233–252.

Halverson, R. (2005). What can K-12 school leaders learn from video games and gaming? *Innovate: Journal of Online Education, 1*(6), 3.

Ip, C. W. H., Luk, E. T. H., Cheung, K. K. F., Lee, J. H. M., & Lee, F. L. (2007). A gamebased computer supported collaborative learning environment: Learning Villages (LV). In *Proceedings of the 11th Annual Global Chinese Conference on Computers in Education* (pp. 289–292).

Jonassen, D. H., Howland, J., Moore, J., & Marra, R. M. (2003). *Learning to solve problems with technology: A constructivist perspective* (2nd ed.). Merrill/ Prentice Hall.

Jong, M. S. Y., Shang, J. J., Lee, F. L., & Lee, J. H. M. (2006). A new vision for empowering learning and teaching with IT: The VISOLE approach. In *Proceedings of the Hong Kong international IT in education conference 2006: Capacity Building for Learning through IT* (pp. 18–25). 6–8 February, HKSAR, China.

Jong, M. S., Shang, J., & Lee, F. L. (2010). Constructivist learning through computer gaming. In *Technologies shaping instruction and distance education: new studies and utilizations* (pp. 207–222). IGI Global.

Kirriemuir, J., & McFarlane, A. (2004). *Literature review in games and learning (No.8)*. Futurelab.

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary issues in technology and teacher education, 9*(1), 60–70.

Leemkuil, H., & de Jong, T. (2011). Instructional support in games. In S. Tobias & D. Fletcher (Eds.), *Computer games and instruction* (pp. 353–369). Information Age Publishing.

Lee, J. H. M., Lee, F. L., & Lau, T. S. (2006). Folklore-based learning on the web—pedagogy, case study, and evaluation. *Journal of Educational Computing Research, 34*(1), 1–27.

Lenhart, A., Kahne, J., Middaugh, E., Macgill, A. R., Evans, C., & Vitak, J. (2008). Teens, video games, and civics: Teens' gaming experiences are diverse and include significant social interaction and civic engagement. Pew Internet & American Life Project. Retrieved from the Pew Internet & American Life Project. http://www.pewinternet.org/Reports/2008/Teens-Video-Games-and-Civics.aspx.

Lincoln, Y. S., & Guba, E. G. (1985). Establishing trustworthiness. *Naturalistic inquiry, 289*(331), 289–327.

Liu, Y., & Rojewski, J. (2013, March). Effects of instructional support in game-based learning: An analysis of educational games from design and application perspectives. In *Society for Information Technology & Teacher Education International Conference* (pp. 43–50). Association for the Advancement of Computing in Education (AACE).

Martens, R., Gulikers, J., & Bastiaens, T. (2004). The impact of intrinsic motivation on e-learning in authentic computer tasks. *Journal of Computer Assisted Learning, 20*(5), 368–376.

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation*. Jossey-Bass.

Nazry, N. N. M., & Romano, D. M. (2017). Mood and learning in navigation-based serious games. *Computers in Human Behavior, 73*, 596–604.

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods, 16*(1), 1609406917733847.

Prensky, M. (2006). *Don't bother me mom – I'm learning*. Paragon House.

Shaffer, D. W. (2006). *How computer games help children learn*. Palgrave Macmillan.

Sitzmann, T. (2011). A meta-analytic examination of the instructional effectiveness of computer-based simulation games. *Personnel psychology, 64*(2), 489–528.

Squire, K. (2003). Video games in education. *International Journal of Intelligence Games & Simulation, 2*(1), 49–62.

Takeuchi, L. M., & Vaala, S. (2014). *Level up learning: A national survey on teaching with digital games*. The Joan Gantz Cooney Center.

Thomas, A., Lima-Filho, P., Pederson, S., Ramadan, H., & Bologan, A. (2017). *Variant: Limits*. Triseum. https://hdl.handle.net/1969.1/188002

Tobias, S. E., & Fletcher, J. D. (2011). *Computer games and instruction*. IAP Information Age Publishing.

Vandercruysse, S., & Elen, J. (2017). Towards a game-based learning instructional design model focusing on integration. In *Instructional techniques to facilitate learning and motivation of serious games* (pp. 17–35). Springer.

Wouters, P., Paas, F., & van Merriënboer, J. J. M. (2008). How to optimize learning from animated models: A review of guidelines based on cognitive load. *Review of Educational Research, 78*, 645–675.

Wouters, P., & Van Oostendorp, H. (2017). Overview of instructional techniques to facilitate learning and motivation of serious games. In *Instructional techniques to facilitate learning and motivation of serious games* (pp. 1–16). Springer.

Wouters, P., Van Nimwegen, C., Van Oostendorp, H., & Van Der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games. *Journal of Educational Psychology, 105*(2), 249.

Wouters, P., & Van Oostendorp, H. (2013). A meta-analytic review of the role of instructional support in game-based learning. *Computers & Education, 60*(1), 412–425.

Zyda, M. (2005). From visual simulation to virtual reality to games. *Computer, 38*(9), 25–32.

Zhonggen, Y. (2019). A meta-analysis of use of serious games in education over a decade. *International Journal of Computer Games Technology, 2019*, 1–9.

Chapter 11
Designing an Augmented Reality Digital Game for Adaptive Number Knowledge Development

Jiaqi Yu and André R. Denham

11.1 Introduction

In recent decades, the emphasis on arithmetic education has shifted from routine expertise to adaptive expertise (Blöte et al., 2000; Hatano & Oura, 2003). Adaptive expertise is the ability to flexibly and creatively apply procedures in a meaningful way to solve mathematics problems. To strengthen students' adaptive expertise with arithmetic, instructors should encourage students to explore the underlying relations between numbers and operations and practice with different number–operation combinations. Students also need to develop a stronger network of numerical relations and form a better mental representation of the system of natural numbers (Blöte et al., 2000; Brezovszky et al., 2019; Rittle-Johnson & Star, 2009; Star & Seifert, 2006). While constructivists tend to put more emphasis on the development of conceptual knowledge, it is important to recognize that one still needs the computational skills involved in procedural knowledge to master the basic regularities and concepts in arithmetic problem-solving (Geary, 1994; Siegler & Shrager, 1984).

Adaptive expertise in arithmetic demands a rich, malleable, and interconnected network of numerical knowledge and relations that are transferable to novel scenarios. McMullen et al. (2016) define such abilities as adaptive number knowledge. Adaptive number knowledge encompasses a wide range of mathematical skills, such as the ability to recognize factors and multiples of a number, locate magnitude representation, and conduct estimations. Research suggests that the adaptive use of multiple strategies is associated with general mathematic abilities (Rittle-Johnson & Star, 2007; Star & Seifert, 2006). Expert mathematicians tend to show more adaptivity in mathematics problem-solving since they have mastered a greater

J. Yu (✉) · A. R. Denham
The University of Alabama, Birmingham, AL, USA
e-mail: jyu53@crimson.ua.edu

C. Aprea, D. Ifenthaler (eds.), *Game-based Learning Across the Disciplines*, Advances in Game-Based Learning, https://doi.org/10.1007/978-3-030-75142-5_11

repertoire of strategies for problem-solving, and they are equipped with a more advanced level of mental arithmetic (McMullen et al., 2016). Moreover, the mastery of adaptive number knowledge can predict later pre-algebra skills and account for the disparities in students' algebra learning (McMullen et al., 2017).

The traditional approach to arithmetic instruction in a classroom setting is often insufficient in developing students' adaptive expertise in arithmetic. The confinements of time and curriculum often limit the teaching of arithmetic to a finite number of problem-solving strategies and procedures (Baroody, 2003; Siegler & Lemaire, 1997; Verschaffel et al., 2009). Digital Game-based learning (DGBL) can offer a viable solution to address the issues related to the development of arithmetic adaptive expertise by providing an alternative instructional tool for building students' adaptive number knowledge and training their adaptive expertise in arithmetic.

Many scholars and educators have investigated the use of digital games for learning purposes (Gee, 2003; Prensky, 2007; Squire, 2003). DGBL can enhance motivation, engagement, and interest among learners (Prensky, 2010; Shaffer et al., 2005). Elements such as interactive graphics, storytelling, animation, rewards, and competition contribute to increasing learners' external motivation (Prensky, 2010; Shaffer et al., 2005). Players can also gain internal motivation when they find the connection between learning and the game (Whitton, 2014). Educational games can also reduce learners' cognitive load through embedded instructional scaffolding and meaningful feedback embedded in gameplay (Pellas et al., 2018; Whitton, 2014).

Another affordance of DGBL is its ability to provide situated and experiential learning (Squire, 2008; Hainey et al., 2011). Digital games provide an authentic context for learning, as games can situate the knowledge in a meaningful environment and add value and purpose to the act of learning (Whitton, 2014). Moreover, learners can gain a greater sense of agency in an educational game, as they provide learners control over the pace of their learning experience (Whitton, 2014). Furthermore, well-designed educational games are effective at cultivating learners' higher order thinking skills, collaborative learning skills, and decision-making abilities (Arnseth, 2006; Whitton, 2014).

The implementation of DGBL in mathematics education offers exciting pedagogical opportunities (Devlin, 2011). Through interactive gameplay, DGBL can provide an engaging training ground for students to practice their burgeoning mathematical skills (Denham, 2013). DGBL can also help ease the understanding of abstract concepts in mathematic learning since it allows students to interact with the metaphoric representation of mathematical concepts in a situated context (Devlin, 2011). Beavis (2015) suggests that DGBL can enhance students' higher level understanding of mathematics learning since it can help them master the complex conceptual and procedural knowledge. Furthermore, DGBL supports transfer as it can expose students to a wide range of problems in different contexts (Fregola, 2015).

It is important to point out that DGBL is by no means a panacea for all. The effectiveness of DGBL depends considerably on the game's ability to integrate the learning content into the gameplay (Arnab et al., 2014; Devlin, 2011; Habgood & Ainsworth, 2011). Denham (2013) points out that the intrinsic integration of learning content in DGBL is the key to facilitating conceptual understanding in mathematics education. Unfortunately, in mathematics education, the majority of educational games available focus on training basic mathematics skills at a lower level, and there is a paucity of effective game-based learning applications tailored to develop students' higher order number sense and application skills (Rothschild & Williams, 2015).

Considerable research effort has been devoted to the study of DGBL. At the same time, recent advancements in technology have brought new possibilities and challenges for digital game-based learning. As augmented reality (AR) technology becomes more accessible to average consumers, an increasing number of AR game-based learning applications are emerging in various educational fields (Fotaris et al., 2017).

Augmented reality encompasses a variety of technological applications that superimpose virtual content upon real-world objects (Azuma, 1997). There is a growing body of research investigating the affordances of implementing augmented reality in education settings. Studies show that AR can impact learning gains and improve students' interest, engagement, and motivation in the learning content (Arvanitis et al., 2007; Chen et al., 2011; Di Serio et al., 2013; Radu, 2012). Leighton and Crompton (2017) posit that augmented reality can promote the development of twenty-first-century thinking skills since AR learning environments can support the practice of authentic learning, self-learning, contextualized learning, and collaborative learning.

Moreover, by combining digital information with the physical objects, AR can facilitate embodied, situated, and multisensory learning while cultivating a deeper understanding of the learning content (Arvanitis et al., 2007; Dunleavy et al., 2009). There are two ways one can implement AR in learning environments—image-based or location-based (Chen & Tsai, 2012). Image-based AR projects virtual content upon a 2D or 3D marker. Location-based AR superimposes digital information upon location coordinates identified by GPS. A systematic analysis review found that image-based AR applications are more effective in facilitating conceptual understanding, spatial training, and hands-on skills. Location-based AR helps support ubiquitous and inquiry-based learning activities (Broll et al., 2008; Dunleavy et al., 2009; Klopfer, 2008).

Despite the increasing recognition of the affordances of AR in education, there is a lack of systematic investigations into the implementation of AR in digital game-based learning (Koutromanos et al., 2015; Pellas et al., 2018). Moreover, researchers point out that the design and development of AR applications should be informed by learning science theories and sound pedagogical practices (Chen et al., 2017; Sommerauer & Müller, 2018). To further probe the implementation of augmented reality in digital game-based learning, we have designed and developed *The Nomads,* an augmented reality mathematics board game that builds students' adaptive number knowledge. To better connect the design of the game with what we know about how people learn, we take into account three key learning theories—cognitive load, multimedia, and sociocultural theory. This chapter will provide an in-depth description of *The Nomads*; furthermore, we will elaborate on the design process and how the aforementioned theories informed the design of the game.

11.2 The Game

11.2.1 The Design Process

The Nomads was designed and developed using a design-based approach. Design-based research is a systematic but flexible methodology that addresses the gap between traditional research methodology and applied research. It employs an iterative process of design, development, analysis, and implementation in real-world settings with the ultimate goal of improving educational practices (Wang & Hannafin, 2005). *The Nomads* aims to provide a pragmatic real-world solution to the lack of instructional resources in adaptive expertise in mathematics (Verschaffel et al., 2009). An iterative process that takes into account the complex factors and emerging properties contingent to the real-world context (Brown, 1992) was implemented in the design and development of The Nomads. Also, detailed accounts of the context-based evidence were documented to inform the iterative design and development of the game (Wang & Hannafin, 2005).

The initial design of *The Nomads* was as an analog board game. The analog version of the game contains a game map, 2 dice, 12 character cards, buffalo pieces, log pieces, 6 player tokens, tipi pieces, and resource cards (buffalos, buffalo meat, berries, spears, and arrows). At the beginning of the gameplay, each player needs to choose a character card. Character cards are a vital game component as they inform players of the resources they will start the game with, the band they belong to, and the energy they need to spend at each step. The player then needs to gather resource cards and pieces according to the instructions on his or her character card (see Fig. 11.1).

At the beginning of each round, players first need to throw the dice to generate the steps they need to take. After moving their tokens forward according to the number generated by the dice, players are to calculate the energy their tribe has spent by multiplying the energy they need to spend at each step (provided by the character card) and the steps they have taken. Players need to feed their tribe using meat and berry cards. There are four types of cards they can use—one portion of meat (100

Fig. 11.1 Analog version

energy points), half a portion of meat (50 energy points), one portion of berries (20 energy points), and half a portion of berries (10 energy points). Each player needs to replenish the tribe with the exact amount of energy they have spent in each round. The players also need to build tipis once every 12 steps. They need to use 3 logs and 2 buffalo skins to build a tipi. Starting from one tipi initially, they need to build an increasing number of tipi until they have a total of six tipis (see Fig. 11.1).

The game map contains three geographical areas—the mountains, plains, and deserts. Players can harvest logs and berries in the mountains, hunt buffalos in the plains, and mine ore and stones in the desert. Every time players land on the square for buffalo hunting, they need to engage in battles. They are to draw a buffalo card from the deck, which informs them of attack points required to hunt this buffalo. The players are to hunt the buffalo using the weapon cards they have. Each weapon card contains an attack point the weapon carries. This is important as the cumulative attack points of the weapon cards they use need to match the attack points required by the buffalo card. Resources tend to be depleted quickly in the gameplay, so players need to rely on their teammates to successfully win the game (see Fig. 11.1).

A playtest of the analog version of the game took place at a summer camp for indigenous Native Americans. The playtest explored students' gameplay experience, their feedback on the gameplay, and the game's impacts on students' arithmetic performances. Thirty campers ranging from 9 to 12 years participated in the study. Video recording of the gameplay, focus group interview data, and pre- and post-tests on students' arithmetic performances were collected in playtesting. A repeated measure *t*-test of the pre- and post-test scores showed significant learning improvements after students played the game ($P < 0.001$). The video analysis and focus group interview analysis showed that most of the students found it challenging to participate in the entire gameplay—the participants often forgot the tasks they needed to complete in the game and needed constant guidance from the facilitator. Also, most participants were not adept at conducting the mental arithmetic required in the gameplay and needed scratch paper to complete tasks. Some participants used their fingers to conduct basic multiplication and they would get frustrated when they could not keep up with the gameplay. It was also observed that some participants would lose interest in the gameplay while waiting for others to finish their turns. This would result in them losing track of their analog resource pieces and cards. The methods used in the playtest did not have any predefined methodological structure or guidelines, making it difficult to form generalizable claims. Also, there was not a control group to compare the test results.

The need to address the problems discovered in the pilot study led to the creation of an augmented reality version of *The Nomads*. AR provides a means of reducing external distractions by presenting information, such as the game rules, exchange rates, and player's storage of resources onto the augmented reality interface. Additionally, an AR interface can provide just-in-time feedback on gameplay procedures and integrate learning scaffolds into the game mechanic to help students who are struggling with basic arithmetic facts. For example, those students who still need to count fingers to perform basic multiplication are provided with a digital drag and drop multiplication scaffold to reinforce their mastery of the multiplication

Table 11.1 Comparing features between analog and AR versions

Augmented reality version	Analog version
Simultaneous gameplay	Turn-based
Digital Scaffolds and feedback	Mental math/scratch paper/finger counting
Digital Resource Organizer	Analog pieces and cards

facts. Furthermore, the AR version of the game allows players to play simultaneously—an individual player doesn't have to wait for the other players to finish before proceeding with the next round of the gameplay. Table 11.1 compares the different features between the analog version and the AR version.

11.2.2 Describing The Nomads

Development of the AR version of *The Nomads* took place within the Unity3D Game Engine using C# programming language. Implementation of the AR function takes place through the Vofuria development kit embedded in the Unity3D game engine and the Photon framework handles the multiplayer functionality. There are two main components in *The Nomads*—the analog and the digital interface. The analog portion of the game consists of a game board, 6 tokens (6 players can play together at one time), resource cards, and exchange cards. Players need an iOS or an Android device (iPad, iPhone, or Android phone) to access the AR game digital interface needed to generate virtual graphics, 3D models, and interactive interfaces upon the analog elements of the game.

The Nomads grounds itself in the cultural context of a nomadic Native American Plains Indian tribe—the Lakota. The Lakota are one of the three tribes that constitute the Sioux Nation. Traditional Lakota lifestyle centers around buffalo hunting. The buffalo was important to the Lakota as buffalo meat was the main source of food, clothing, and tools. The tribe led a nomadic lifestyle in which they followed buffalo herds across the continent. *The Nomads* attempt to simulate this aspect of the traditional Lakota lifestyle, as players assume the roles of tribal leaders tasked with leading their tribes across three distinct geographical areas—the mountains, the plains, and the desserts. Each geographical area presents specific opportunities and challenges for the tribes.

There are two teams in the game—the Oglala band and the Brule band. Players of the same band need to work together to ensure each other's survival and gain points for the team. The final points are determined by three parameters—health, morale, and wisdom. The target points will vary at each game depending on the number of players in each team. The team that first reaches the target total points will win the game. Oftentimes, the success of the gameplay depends on the collaboration among team members.

Fig. 11.2 Select characters and main game interface

At the beginning of the game, players have to select their own avatar/character. There are 12 characters in the game, six of them are girls and the other six are boys. Each character will start the game with different storages of raw resources (see Fig. 11.2). There are buttons on the main interface—throw dice, calculate energy, feed tribe, make things, resources, exchange, and exit game. To start the gameplay, players first need to roll their dice. The player then needs to move their token on the board forward according to the number on the dice (see Fig. 11.2).

After that, the player needs to calculate the amount of energy the tribe has spent walking the distance for the round. The AR game interface randomly generates the amount of energy the tribe has consumed for each step and the player needs to calculate the total amount of energy the tribe has spent by multiplying the number with the steps taken (see Fig. 11.3).

The second step is to recuperate the tribe by providing tribal members with food, that is, buffalo meat and berries. Players must be precise in their use of resources as the journey forward is long and daunting. For example, each portion of meat and berries contain a set amount of energy. This requires that the total energy consumed should be equal to the amount of energy spent during this round of the game. If players overconsume food, they will lose wisdom points; if they don't consume enough food, they will lose health points (see Fig. 11.4).

Also, the player needs to build tipis every 12 steps they take. When it is time to build the tipis, the computer will randomly generate the number of logs and buffalo skins needed to build a tipi and the tipis required for the night. If the players don't build enough tipis, they will lose health points. If they build too many tipis, they will lose wisdom points (see Fig. 11.5).

On the main interface, the players can check the resources they have, exchange resources with the other players, and build weapons anytime during the gameplay (see Fig. 11.6).

Every square the player lands on the map contains a task they need to accomplish. The tasks include hunting buffalos, collecting berries, mining ore and stones, harvesting logs, and trading goods. To complete tasks, the player needs to hold their device over the pattern of the task on the square. A 3D model symbolizing the task and a game button will then show up on the AR interface. Students can start working

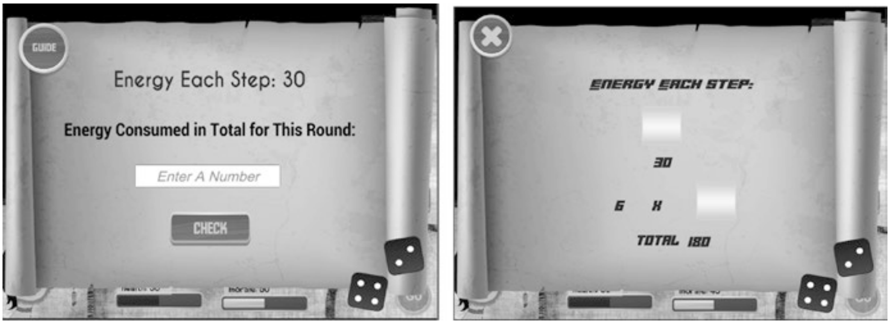


Fig. 11.3 Calculating energy and scaffolding

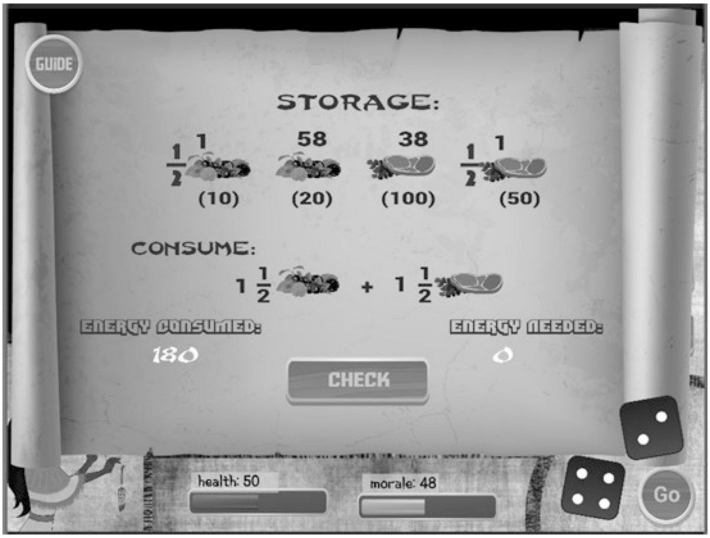


Fig. 11.4 Feed tribe

on the task once they press the game button (see Fig. 11.7). After completing the tasks, the player can repeat the same cycle in another round. Unlike traditional board games, players can perform the tasks simultaneously, so they don't have to wait for the others to finish before proceeding with their round of gameplay.

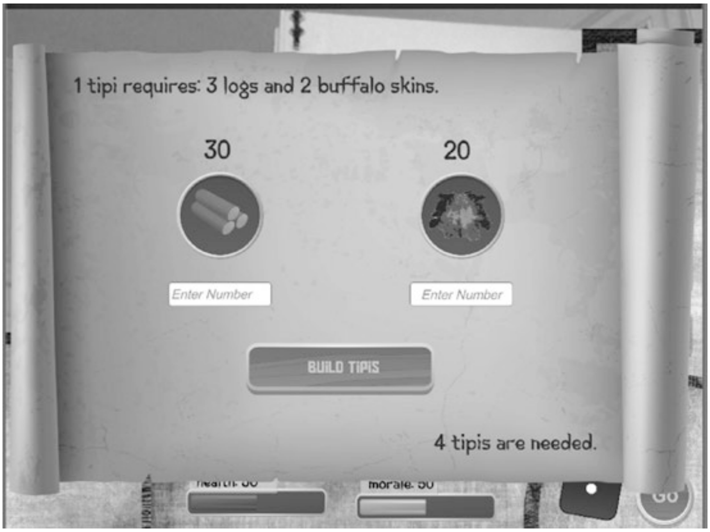


Fig. 11.5 Building tipis

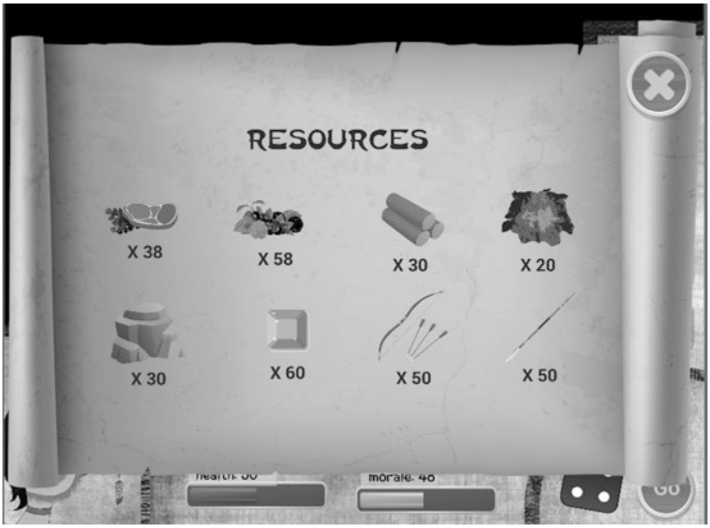


Fig. 11.6 Resource panel

11.2.3 Embedded Mini-games

11.2.3.1 Collecting Berries

To collect berries, students need to use the six numbers and four arithmetic symbols provided on the interface to produce arithmetic sentences. The final result of the

Fig. 11.7 AR registration

arithmetic sentence should amount to the number on the berry. Players can press the number and symbol buttons to produce the arithmetic sentences and press check to find out if they have successfully collected the berries (see Fig. 11.8).

11.2.3.2 Hunting Buffalos

In the buffalo hunting mode, players need to use arrows and spears to hunt the buffalos. Each spear and arrow have inherent attack points at each round, which require different amounts of attack points to hunt each buffalo. There are a limited number of weapon cards at each round, so players need to use the cards strategically. Ideally, the cumulating amount of attack points of the used weapon cards should be equal to the attack points needed to hunt the buffalo. To hunt the buffalo, players need to drag and drop the weapon cards on the attack area and press the attack button (see Fig. 11.9).

11.2.3.3 Collecting Logs

To collect logs, players first need to calculate the desired volume of the log produced by an arithmetic sentence and displayed at the bottom of the interface. The area of the log is automatically generated by the game and displayed at the top left corner of the interface. The player needs to adjust the length of the log by moving the saw on the interface so that the total volume of the log is approximately equal to the desired volume of the log. The game makes it so that the volume of the log can

Fig. 11.8 Collecting berries

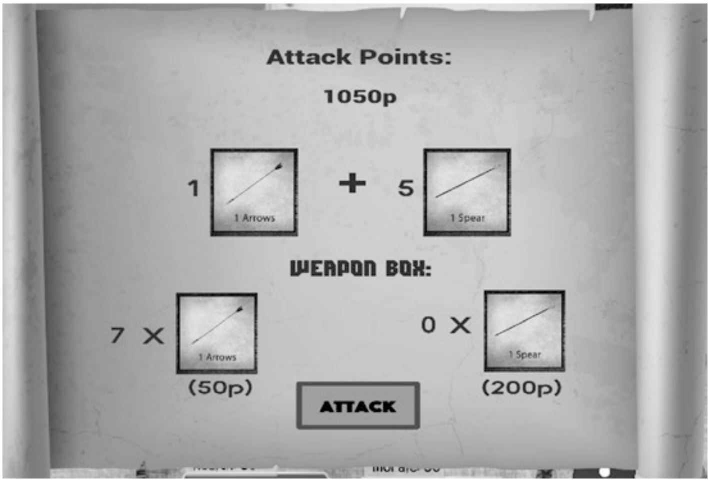


Fig. 11.9 Hunt buffalos

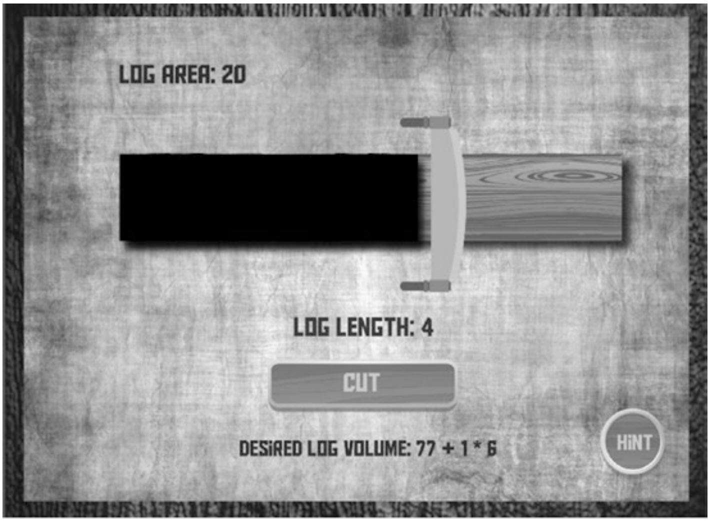


Fig. 11.10 Cutting logs

never be the same as the desired volume of the log. The game mechanic uses a difference ranging from 1 to 4 between the desired log volume and the correct log volume a player can produce (see Fig. 11.10).

11.2.3.4 Mining Ore and Gems

In mining the ore and gems mode, the player's position and the position of the ore/gems will be automatically generated. To mine the ore and gems, players need to produce an arithmetic sentence so that it can take them from where they are to the position of the ore/gems. The number on the player's position should be the first number in the arithmetic sentence which should amount to the number on the ore/gem's position. To produce the arithmetic sentence, the players can use any of the six numbers and the four arithmetic symbols provided on the left column of the interface. For example, if you want to move from 1 to 55 as shown in Fig. 11.11, you can add 1 by 5 and 49 (1 + 5 + 49 = 55).

11.2.4 Building Adaptive Number Knowledge

All tasks in the game attempt to build students' adaptive number knowledge. In the game, students have to apply multiple steps of arithmetic operations constantly in problem-solving which will facilitate their abilities to perform mental mathematics in the advanced mode of gameplay. Mathematics problem-solving is integrated into

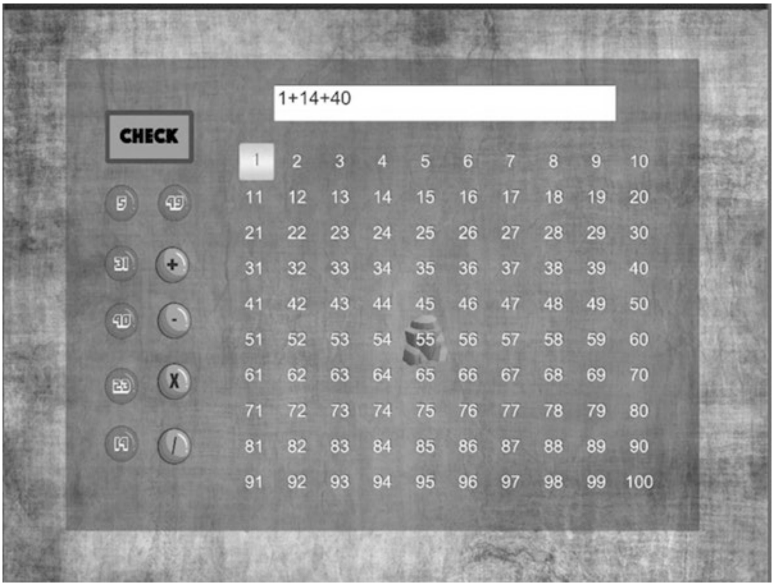


Fig. 11.11 Mining ore and gems

the game tasks as players migrate from place to place to gather resources, sustain their journey with limited food and supplement, and barter and exchange goods with other players. As Denham (2013) emphasizes, the success of DGBL depends on the intrinsic integration of learning content into the gameplay. In *The Nomads*, mathematical problem-solving is integrated into the various modes of gameplay. For example, in feeding the tribe and hunting buffalos, students have to think procedurally to come up with the most appropriate answer, which can subsequently improve their procedural fluency in arithmetic problem-solving. Successful gameplay requires students to come up with multiples of the values attached to the representatives, which will facilitate students' mental math ability at calculating multiples. The two modes of gameplay can also develop students' algebraic thinking skills as they need to associate numerical values such as energy amount and attack points with symbolic representations (buffalo meat, berries, arrows, and spears).

None of the tasks in the game demand one absolute solution. Students have to flexibly and adaptively use the resources they have to arrive at the best solution for a given scenario. For example, in two of the gameplay modes, collecting berries and mining ore and gems, students are to use any of the six numbers provided to produce arithmetic sentences that amount to the number of the target objects (berries, ore, or gems). In each scenario, there are several ways to acquire the target number. Students are to evaluate the characteristics and relations of all the numbers provided and find an optimal solution for themselves. In cutting the log mode, students are to adjust the log length so that the product of the log length and the log area (log

Table 11.2 How *the Nomads* trains adaptive number knowledge

Game task	Game mechanic	Training adaptive number knowledge
Feeding the Tribe Hunting Buffalos	Drag and drop two objects that carry two separate inherent numerical values so that they accumulate to a desired numerical value	There is no prescribed answer; students have to think in reverse procedurally to come up with the answer, it trains procedural flexibility; facilitates students' mental math ability at calculating multiples; develops algebraic thinking skills (McMullen et al., 2017)
Collecting the berries Mining ore and gems	Use two to three numbers provided in the interface to produce an arithmetic sentence account for the desired value.	There is no absolute solution; students need to flexibly and adaptively use what they are given to come up with the best solutions; students need to evaluate the characteristics and relations of all the numbers given (McMullen et al., 2016)
Cutting logs	Determine the length of the log given the area so that the volume is approximately equal to the desired volume on the interface	It trains students' ability to find the "nice number" (produce approximation based on the characteristics of the numbers) (McMullen et al., 2016)

volume) is closest to the desired volume of the log. This task trains students' ability to find the "nice number" (produce approximation based on the characteristics of the numbers). Below is a table demonstrating how different game tasks train players' adaptive number knowledge (Table 11.2).

11.3 Augmented Reality Game Design and Learning Science Theories

This section will provide an in-depth analysis of how learning science theories, namely, cognitive load, multimedia, and sociocultural theory, informed the design of *The Nomads*. Cognitive load theory and multimedia learning theory are often correlated with each other in scholarly discussions (Mayer & Moreno, 2003), so discussion of these two theories will take place in the first part of the discussion. The second part of this section will focus on the role sociocultural theory played in the design of *The Nomads,* as it is the guiding principle in the incorporation of collaborative multiplayer features within the game.

11.3.1 Cognitive Load Theory and Multimedia Theory

Cognitive load theory grounds itself in Atkinson and Shiffrin's (1968) information-processing model. The model categorizes the process of cognitive machinery into three processes—sensory memory, working memory, and long-term memory.

Cognitive load theory focuses on the information processing capacity of working memory and recommends that instructional designers design learning environments that mediate the learner's limited working memory to avoid causing cognitive overload (Sweller, 1988; Kirschner et al., 2018; Sweller et al., 2019; Van Merriënboer & Sweller, 2005).

There are three types of cognitive load: intrinsic, extraneous, and germane cognitive load (Sweller, 2010). Intrinsic cognitive load (ICL) is the mental effort required to process the information inherent to the learning task. ICL depends on the nature of the learning assignment and learners' capacity to process new information. A learner's mastery of task-relevant prior knowledge and their ability at knowledge transfer can determine their ICL while acquiring new information. Extraneous cognitive load (ECL) refers to the cognitive demands used to process instruction external to the learning task and is not essential to the acquisition of new knowledge. Germane cognitive load (GCL) helps to construct knowledge schemas and to form long-term memory (Sweller et al., 2019). Cognitive load theory promotes the development of quality instruction that minimizes extraneous cognitive load and facilitates the construction of schemas through germane cognitive load.

Similar to cognitive load theory, the cognitive theory of multimedia learning also seeks to address issues related to learners' limited working memory. Multimedia learning theory proposes a learners' information processing system consists of two channels—visual and auditory channels. The activation of both channels can "reduce extraneous processing, manage essential processing, and fostering generative processing" (Mayer, 2009, p. 57). Mediating learner's limited cognitive processing capacity has been one of the key challenges of multimedia learning research. Mayer (2005) posits that multimedia instructional designers should pay special attention to learners' cognitive capacity to avoid causing cognitive overload. In his canonical work, "Multimedia Learning," Mayer (2005) offered 12 principles of multimedia learning that can reduce extraneous processing and avoid cognitive overloads in instructional design. *The Nomads* incorporated 6 of the 12 principles within its design:

1. The Coherence Principle: humans learn best when extraneous, distracting material is not included.
2. The Signaling Principle: humans learn best when they are shown exactly what to pay attention to on the screen.
3. The Spatial Contiguity Principle: humans learn best when relevant text and visuals are physically close together.
4. The Segmenting Principle: humans learn best when information is presented in segments, rather than one long continuous stream.
5. The Pre-Training Principle: humans learn more efficiently if they already know some of the basics.
6. The Split-attention Principles: when designing instruction, including multimedia instruction, it is important to avoid formats that require learners to split their attention between, and mentally integrate, multiple sources of information. (Ayres & Sweller, 2005).

Through augmented reality, *The Nomads* seeks to offload the procedural knowledge of the board game onto the digital interface in an attempt to reduce the extraneous cognitive load associated with recalling rules and procedures. Doing so helps to implement the coherence principle (reducing extraneous and distracting information). For example, instead of memorizing the tasks linked to each square on the map, players can use their device to scan the pattern associated with the square. This results in a 3D model representing the task and an interface inviting players to complete the task appearing on the player's device. After accepting the invitation, players will have access to the rules and the procedures of the task on the AR interface.

Moreover, players do not need to keep track of the tasks they need to complete to be successful in the game. For example, every time a player reaches a 12-step cycle in the gameplay, the AR interface displays a prompt that the tribe needs to build lodging. The AR interface also offers players a more organized viewport to monitor their resources so that they can make better strategic choices throughout the gameplay. By keeping the external cognitive load associated with the gameplay to the minimum, *The Nomads* allows players to spend the majority of their working memory on performing mathematics problem-solving.

The AR interface also provides a variety of instructional scaffolds to alleviate the cognitive load inherent to the mathematics tasks in the game. Element interactivity in the learning task is often considered a major contributor to learners' intrinsic cognitive load (Sweller, 2010). Element interactivity depends on the complexity of the problem and the learners' prior knowledge. High element interactivity occurs when learners have to process several new informational elements simultaneously in one's working memory (Sweller, 2019). Prior knowledge of each element would alleviate the cognitive load required to process element interactions (Pollock et al., 2002). By breaking down the conceptual segments in the learning task, one can reduce the intrinsic cognitive load associated with element interactivity (Sweller, 2010). Mayer (2005) also promotes the importance of segmenting learning material as an efficient and effective way to present material to learners.

When performing problem-solving associated with adaptive number knowledge, learners need to flexibly and adaptively use a repertoire of conceptual and procedural knowledge in arithmetic (McMullen et al., 2017) and carry out tasks that have a high degree of element interactivity. *The Nomads* seeks to train students' adaptive number knowledge, so most of the tasks in the game demand a certain degree of element interactivity. Through the AR digital interface, players can use the hints and the support settings embedded in the gameplay to break down elements so that they efficiently complete tasks. For example, many participants in the pilot study had trouble recalling basic multiplication facts. In the AR version of *The Nomads*, players have the choice to use scaffolds to help them perform multiplication. For example, players can drag and drop a symbolic representation of the value as many times as the multiplier to produce the product.

There are two contributors to intrinsic cognitive load: the complexity of the learning task and learners' cognitive processing abilities. Also, a learner's task-relevant prior knowledge can affect his or her cognitive processing abilities when performing a new task (Sweller, 2019). Similarly, Mayer's (2005) pre-training principle posits that learners' mastery of the basics is important to the efficient acquisition of new knowledge. Based on this knowledge of cognitive load, the design of levels in two gameplay modes took place via collecting berries and mining of ore/gems. In these two game activities, players need to use the numbers provided to produce an arithmetic sentence that can amount to the number on the target objects. At the beginning of the gameplay, players can choose the complexity of the tasks by selecting a difficulty level. Higher levels allow students to collect more resources if they can provide a solution, but players also risk not gaining anything if they cannot successfully solve the problem. The numbers in the lower difficulty levels tend to have lower digits and simpler structures. This subsequently reduces the intrinsic cognitive load inherent to the mathematics tasks in the level and better accommodates students with lower cognitive processing capacity and less task-relevant prior knowledge.

Besides the coherence, segmenting, and pre-training principles, the design of the AR interface in *The Nomads* was also informed by Mayer's (2005) split-attention, signaling, and spatial contiguity principles. To avoid dividing learners' attention between the events happening on the physical board, and the game tasks they are to perform at each square, the task interface is opaque so that they can block the viewport of the AR camera as the signaling principle posits we should make apparent to learners what information they need to attend to. Signaling the importance of information within the game takes place by using different graphic design techniques such as changing the size and color of the fonts. For example, the game provides players with procedural hints until the player chooses not to have them (see Fig. 11.12).

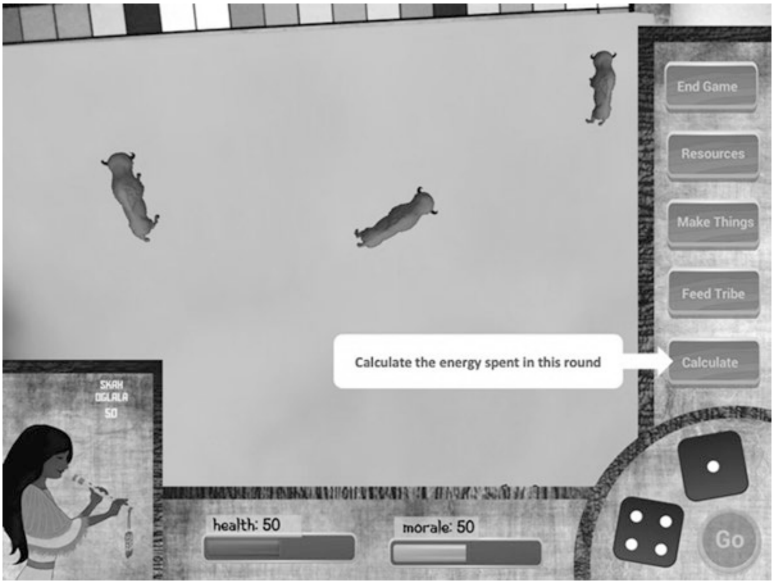


Fig. 11.12 Procedural Hints

Fig. 11.13 Centered Caption

Each time a player completes a task, a window will appear in the center of the screen informing players if they have got the answer correct. If the students did not get the correct answer, the feedback window will inform them of a possible solution to the problem. The spatial contiguity principle recommends placing relevant text and images close together in multimedia learning. With that in mind, the fonts in these windows will be relatively large and centered (see Fig. 11.13).

When applied to AR game design, this principle translates into the precise alignment of virtual content with the target image/object in the real-world setting. In *The Nomads*, digital content was seamlessly registered onto the analog game board, pieces, and cards (see Fig. 11.14). Also, in-game tasks require students' recognition of the relationship between numerical values and their symbolic representatives (feeding the tribe, hunting buffalos). The numerical value (energy values of meat/berries) the object represents is closely placed to the image of the object(meat/berry) on the game interface.

Table 11.3 demonstrates multimedia learning principles and cognitive load theory informs the game mechanics in *The Nomads*.

11.3.2 Collaborative Learning Theory and Sociocultural Theory

Collaborative learning is a pedagogical approach in which two or more people work together to achieve a learning goal. Individuals engaged in collaborative learning

Fig. 11.14 AR registration

Table 11.3 Game mechanics informed by multimedia learning theory and cognitive load theory

Multimedia learning principles	Cognitive load	Game mechanics
Coherent	Reduce extrinsic cognitive load	The procedural knowledge and the rules of the board game are offloaded onto the AR game interface
Signaling	Reduce extrinsic cognitive load	Important information is emphasized using different graphic design techniques such as changing the size and color of the fonts
Spatial Contiguity	Reduce extrinsic cognitive load	The digital content was seamlessly registered onto the target analog game board, pieces, and cards in the game The numerical value (energy values of meat/berries) the object represents is closely placed to the image of the object (meat/berry) on the game interface
Segmenting	Reduce element interactivity to minimize intrinsic cognitive load	Built-in scaffolds that allow students to tackle one problem/concept at a time
Pre-training	Reduce intrinsic cognitive load	Players can choose the complexity of the gameplay, the easier levels provide them with the necessary prior knowledge and skills to succeed in the more advanced levels
Split-attention	Reduce extrinsic cognitive load	The digital gameplay interfaces are designed to be opaque so that players are not distracted by the content in the AR camera

are not only responsible for their learning but each other's learning as well (Dillenbourg, 1999). Crook (2000) points out that humans have a natural tendency to experience mutual understanding and cognitive synchrony; thus, individuals are more likely to experience prolonged cognitive engagements and participate in academic exploration beyond what they can achieve individually in a collaborative learning setting.

Collaborative learning theory is often associated with sociocultural learning theory. The theory considers human learning as an inherently social and cultural process. The zone of proximal development, one of the fundamental concepts in sociocultural theory, refers to the difference between what individuals can learn by themselves and what they can learn with the assistance of experts or peers. An expert or a more experienced peer can provide learners with the necessary scaffolding to advance their knowledge and skills in the target area (Vygotsky, 1978). Rogoff (1993) defines this process as guided participation in which new knowledge and the acquisition of skills take place in a meaningful and collaborative activity with a more skilled partner. Vygotsky (1978) posits that the zone of proximal development is a more dynamic indicator of cognitive development since it evaluates the learner's capacity in the process of learning. He also highlights the significance of collaborative learning in the process of peer learning. In a collaborative learning setting, students serve as the others' learning sources, where the shifted responsibility allows them to gain more initiative, engagement, and responsibility in the learning process (Grabinger et al., 2007).

The affordances of collaborative learning have been widely explored. Research suggests collaborative learning can promote more active interaction among the students and facilitate a deeper understanding of the learning content (Kuo et al., 2012a, b; Schellens & Valcke, 2005). Moreover, collaborative learning can promote students' interests, engagements, and socioemotional performances. Furthermore, it can advance students' critical thinking skills (Chen et al., 2017; Kuo et al., 2012a, b; Johnson & Johnson, 2009; Lipponen, 2002; Schellens & Valcke, 2005, Stahl et al., 2006). Successful implementation of collaborative learning encourages knowledge co-construction and integration (Feltovich et al., 1996).

Developments in computing technology have made the practice of computer-supported collaborative learning (CSCL) more accessible and effective (Stahl et al., 2006). Computer-supported collaborative learning refers to the practice of using information technology to support group learning (Cerratto & Belisle, 1995). CSCL is effective in supporting students' communication with each other and helps them better manage and monitor collaborative learning. Also, CSCL offers efficient tools to share learning resources, engage in co-construction, build learning communities, etc. (Jeong & Hmelo-Silver, 2016).

It is important to point out that not all forms of collaborative learning are effective in facilitating learning gains. The successful implementation of collaborative learning requires several internal and external factors, such as the setting of the learning environment, the nature of the learning activity, the quality of the peer interaction, etc. (Crook, 2000). Dunbar (1997) argues that people's shared prior knowledge is a significant contributor to the effective implementation of collaborative learning, people are more likely to engage in successful collaboration if they share similar experiences, analogies, and frames of reference.

AR can be an effective tool to enhance the collaborative learning experience (Bujak et al., 2013). By blending reality and digital content, AR can combine the benefits of face-to-face collaboration and computer-supported collaborative learning. It can offer users a greater sense of agency and control over the learning content using a digital interface while maintaining in-person contact with the group members (Bujak et al., 2013). In game-based learning, AR can provide an ideal platform for multiple players to participate in in situ face-to-face collaborative gameplay while benefiting from the affordances provided by digital games (Kotranza et al., 2009; Squire & Jan, 2007).

Collaborative learning is an integral part of the game design in *The Nomads.* By classifying the tribes into two bands—the Oglala and the Brule—the game allows participants to form two teams at the beginning of the gameplay. Players on the same team are to work together to compete against the other team. AR allows students to access digital content while playing in the same physical space around the same game board, which is important as proximity among the players can promote more efficient communication and encourage them to provide more quality learning support to each other.

Collaborative teamwork is the key to success within *The Nomads,* while competition between the two teams can motivate players to achieve greater success in the collaborative team play. Players on a team are not only responsible for the survival and success of their tribe but also the other tribes in their band. During gameplay within *The Nomads*, resources tend to get depleted at a rather fast pace, so players have to rely on the support of their teammates to ensure the survival of each tribe. Also, since the game will account for the cumulative performance of each member in the team instead of the individuals, players have to communicate with their team constantly to come up with the best strategic solution for the team as a whole. *The Nomads* game mechanic incentivizes players to help their teammates in mathematics problem-solving since each person's performance can contribute to the success of the team. The performance of each team is dependent on the accumulation of three parameters—health, morale, and wisdom points. Although students can get access to instructional scaffolds within the game, they will have to sacrifice their wisdom points and morale points. This encourages players to assist their teammates in the process of problem-solving as the team will have a better overall performance if they do so. Table 11.4 describes how the different game features in *The Nomads* can facilitate collaborative learning.

11.4 Discussion

To further explore the combination of augmented reality and game-based learning, this chapter provides a thorough description of the design and development of an augmented reality math board game, *The Nomads.* A design-based iterative approach

Table 11.4 Collaborative learning features

Game Feature	Collaborative Learning
Players are separated into two teams—Oglala and Brule.	Players of the same team need to collaborate to earn points for their team.
The resources get depleted at a fast rate in the game	Players need to rely on team members to sustain the survival of their tribes.
The final scores are determined by the cumulative scores of the three parameters (Health, morale, and wisdom) of all team members.	Players are incentivized to communicate with their team constantly to come up with the best strategic solution for the team as a whole.

was implemented in the development of the game. Students' feedback in the explorative study of the analog version of the game provides essential design guidelines for the AR version of the game. Learning science theories and principles were implemented in the design of the AR version of the game to address students' cognitive overload while playing the analog version of the game. The design of the AR game channels the gap between the theoretical and the practical as it consults the theoretical to find practical solutions.

The iterative design-based approach implemented in the development process of *The Nomads* can be replicated to design a more student-centered and context-based learning experience in mathematics education and many other subjects. Also, this article illustrates how the design and development of the game leverage learning science theories, which can help inform educators, instructional designers, and educational game developers to produce instructional designs that are centered on learning science theories.

Also, as a game that trains adaptive number knowledge, *The Nomads* can potentially provide a sound solution for mathematics educators who lack the instructional resources to train students' adaptive expertise in mathematics (Verschaffel et al., 2009), which is essential to students' development of higher order mathematics skills (Hatano & Oura, 2003).

11.5 Future Directions

Digital game-based learning has attracted considerable scholarly attention of late. Advancements in mobile technology have created new possibilities in the development of educational games such as the integration of augmented reality. However, there is still a need to determine the specific learning benefits and challenges brought by the incorporation of augmented reality technology in DGBL. Furthermore, more research is needed to connect AR scholarship with learning science theories and sound pedagogical practices (Chen et al., 2017; Saltan & Arslan, 2017; Sommerauer & Müller, 2018).

While the design of *The Nomads* leverages three learning science theories within its design, it is important at this stage to begin evaluating the direct impact of this approach. It remains an unanswered question as to whether or not the added AR design features will have the intended impact on arithmetic adaptive knowledge, cognitive load, and learning through collaboration. In the process, student participants will be given the opportunities to provide feedback and suggestions on the game design and game mechanics. Additionally, there is always a need to conduct multiple playtesting sessions of the game to determine if learners find the game enjoyable and engaging. Not only must educational games be good for learning they must be enjoyable to play to maximize their effectiveness.

For that reason, we intend to conduct a series of empirical investigations into the impact of the game on student learning outcomes, cognitive load, and learning motivation. Doing so would provide much-needed insights into the use of AR in DGBL and inform the iterative redesign of game features and mechanics. More importantly, these investigations will provide the needed data to inform educators, learning experience designers, and instructional designers on the context, populations, instructional activities, knowledge domains, and subject areas that are best suited to leverage the majority of the augmented realities affordances. Furthermore, as a design-based research project, it is important to involve mathematics educators in the iterative research/design process (Wang & Hannafin, 2005). Middle school and upper elementary middle school mathematics teachers will be recruited to further evaluate the game and provide feedback on how to make the game more useful to them. Also, one or two knowledge experts will be recruited to contribute to the design of the game on the next stage. Since the game involves active mathematics problem-solving, there are possibilities of implementing a learning assessment system into the game which will allow teachers to evaluate their students' learning progress and students to assess their learning in the gameplay process.

References

Arnab, S., Freitas, S. D., Bellotti, F., Lim, T., Louchart, S., Suttie, N., Berta, R., & Gloria, A. D. (2014). Mapping learning and game mechanics for serious games analysis. *British Journal of Educational Technology, 46*(2), 391–411. https://doi.org/10.1111/bjet.12113

Arvanitis, T. N., Petrou, A., Knight, J. F., Savas, S., Sotiriou, S., Gargalakos, M., et al. (2007). Human factors and qualitative pedagogical evaluation of a mobile augmented reality system for science education used by learners with physical disabilities. *Personal and Ubiquitous Computing, 13*(3), 243–250. https://doi.org/10.1007/s00779-007-0187-7

Atkinson, R. C., & Shiffrin, R. M. (1968). Chapter: Human memory: A proposed system and its control processes. In K. W. Spence & J. T. Spence (Eds.), *The psychology of learning and motivation* (Vol. 2, pp. 89–195). Academic Press.

Azuma, R. T. (1997). A survey of augmented reality. Virtual and Augmented Reality, 1054–7460.

Arnseth, H. C. (2006). Learning to play or playing to learn – a critical account of the models of communication informing educational research on computer gameplay. *The International Journal of Computer Game Research*, 1604–7982.

Ayres, P., & Sweller, J. (2005). The split-attention principle in multimedia learning. *The Cambridge handbook of multimedia learning, 2*, 135–146.

Baroody, A. J. (2003). The development of adaptive expertise and flexibility: The integration of conceptual and procedural knowledge. In A. J. Baroody & A. Dowker (Eds.), *The develop-*

ment of arithmetic concepts and skills: Constructing adaptive expertise (pp. 1–33). Lawrence Erlbaum.

Beavis, C. (2015). Multimodal literacy, digital games and curriculum. *Mathematics Education in the Digital Era Digital Games and Mathematics Learning,* 109–122. https://doi.org/10.1007/978-94-017-9517-3_7

Blöte, A. W., Klein, A. S., & Beishuizen, M. (2000). Mental computation and conceptual understanding. *Learning and Instruction, 10*, 221–247. https://doi.org/10.1016/S0959-4752(99)00028-6

Brezovszky, B., McMullen, J., Veermans, K., Hannula-Sormunen, M. M., Rodríguez-Aflecht, G., Pongsakdi, N., ... & Lehtinen, E. (2019). Effects of a mathematics game-based learning environment on primary school students' adaptive number knowledge. *Computers & Education, 128*, 63–74.

Broll, W., Lindt, I., Herbst, I., Ohlenburg, J., Braun, A. K., & Wetzel, R. (2008). Toward next-gen mobile AR games. *Computer Graphics and Applications, IEEE, 28*(4), 40–48. https://doi.org/10.1109/MCG.2008.85

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of the Learning Sciences, 2*(2), 141–178.

Bujak, K. R., Radu, I., Catrambone, R., Macintyre, B., Zheng, R., & Golubski, G. (2013). A psychological perspective on augmented reality in the mathematics classroom. *Computers & Education, 68*, 536–544. https://doi.org/10.1016/j.compedu.2013.02.017

Cerratto, T., & Belisle, C. (1995). Reframing learning in CSCL environments. *The First International Conference on Computer Support for Collaborative Learning – CSCL'95*. https://doi.org/10.3115/222020.222052

Chen, Y.-C., Chi, H.-L., Hung, W.-H., & Kang, S.-C. (2011). Use of tangible and augmented reality models in engineering graphics courses. *Journal of Professional Issues in Engineering Education and Practice, 137*(4), 267–276.

Chen, P., Liu, X., Cheng, W., & Huang, R. (2017). A review of using Augmented Reality in Education from 2011 to 2016. *Innovations in smart learning*, 13–18.

Chen, C.-M., & Tsai, Y.-N. (2012). Interactive augmented reality system for enhancing library instruction in elementary schools. *Computers & Education, 59*(2), 638–652. https://doi.org/10.1016/j.compedu.2012.03.001

Crook, C. (2000). Motivation and the ecology of collaborative learning. In R. Joiner, K. Littleton, D. Faulkner, & D. Miell (Eds.), *Rethinking collaborative learning* (pp. 161–178). Free Association Books.

Denham, A. R. (2013). Strategy instruction and maintenance of basic multiplication facts through digital game play. *STEM Education*, 290–309. https://doi.org/10.4018/978-1-4666-7363-2.ch016

Devlin, K. (2011). *Mathematics education for a new era: video games as a medium for learning*. CRC Press.

Dillenbourg, P. (1999). What do you mean by collaborative learning? In P. Dillenbourg (Ed.), *Collaborative learning: Cognitive and computational approaches* (pp. 1–19). Elsevier.

Di Serio, Á., Ibáñez, M. B., & Kloos, C. D. (2013). Impact of an augmented reality system on students' motivation for a visual art course. *Computer Education, 68*, 585–596. https://doi.org/10.1016/j.compedu.2012.03.002

Dunbar, K. (1997). Conceptual change in science. In T. B. Ward, S. M. Smith, & J. Vaid (Eds.), *Creative Thought: An investigation of conceptual structure and process* (pp. 461–494). American Psychological Association.

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of Science Education and Technology, 18*(1), 7–22. https://doi.org/10.1007/s10956-008-9119-1

Feltovich, P. I., Coulson, R. L., & Peltovich, J. (1996). Complexity, indivitually and in groups. *CSCL, Theory and Practice of an Emerging Paradigm, 25*, 25–44.

Fotaris P, Pellas N, Kazanidis I, Smith P (2017). A systematic review of augmented reality game-based applications in Primary education. In: Proceedings of the 11th European conference on games-based learning (ECGBL17). Graz, Austria (pp. 181–190).

Fregola, C. (2015). Mathematics and educational psychology: Construction of learning environments. In *Digital Games and Mathematics Learning* (pp. 175–200). Springer, Dordrecht.
Geary, D. C. (1994). *Children's mathematical development: Research and practical applications*. American Psychological Association.
Gee, J. P. (2003). *What video games have to teach us about learning and literacy*. Palgrave Macmillan.
Grabinger, S., Aplin, C., & Ponnappa-Brenner, G. (2007). Instructional design for sociocultural learning environments. *Electronic Journal of Instructional Science and Technology (e-JIST), 10*(2007).
Hainey, T., Connolly, T., Stansfield, M., & Boyle, E. (2011). The differences in motivations of online game players and offline game players: A combined analysis of three studies at higher education level. *Computers & Education, 57*(4), 2197–2211.
Jeong, H., & Hmelo-Silver, C. E. (2016). Seven affordances of computer-supported collaborative learning: How to support collaborative learning? How can technologies help? *Educational Psychologist, 51*(2), 247–265. https://doi.org/10.1080/00461520.2016.1158654
Kotranza, A., Lok, B., Deladisma, A., Pugh, C. M., & Lind, D. S. (2009). Mixed reality humans: evaluating behavior, usability, and acceptability. *IEEE Transactions on Visualization and Computer Graphics, 15*(3), 369–382.
Habgood, M. P., & Ainsworth, S. E. (2011). Motivating children to learn effectively: Exploring the value of intrinsic integration in educational games. *Journal of the Learning Sciences, 20*(2), 169–206. https://doi.org/10.1080/10508406.2010.508029
Hatano, G., & Oura, Y. (2003). Reconceptualizing school learning using insight from expertise research. *Educational Researcher, 32*(8), 26–29.
Johnson, D. W., & Johnson, R. T. (2009). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher, 38*(5), 365–379. https://doi.org/10.3102/0013189x09339057
Klopfer, E. (2008). *Augmented learning: Research and design of mobile educational games*. MIT Press.
Kirschner, P. A., Sweller, J., Kirschner, F. ., & Jimmy Zambrano, R. (2018). From cognitive load theory to collaborative cognitive load theory. *International Journal of Computer-Supported Collaborative Learning, 13*(2), 213–233. https://doi.org/10.1007/s11412-018-9277-y
Kuo, F., Hwang, G., & Lee, C. (2012a). A hybrid approach to promoting students' web-based problem-solving competence and learning attitude. *Computers & Education, 58*(1), 351–364. https://doi.org/10.1016/j.compedu.2011.09.020
Koutromanos, G., Sofos, A., & Avraamidou, L. (2015). The use of augmented reality games in education: A review of the literature. *Educational Media International, 52*(4), 253–271. https://doi.org/10.1080/09523987.2015.1125988
Kuo, F., Hwang, G., & Lee, C. (2012b). A hybrid approach to promoting students' web-based problem-solving competence and learning attitude. *Computers & Education, 58*(1), 351–364. https://doi.org/10.1016/j.compedu.2011.09.020
Leighton, L. J., & Crompton, H. (2017). Augmented reality in K-12 education. Mobile technologies and augmented reality in open education. *Advances in Educational Technologies and Instructional Design*, 281–290. https://doi.org/10.4018/978-1-5225-2110-5.ch014
Lipponen, L. (2002). Exploring foundations for computer-supported collaborative learning. *Proceedings of the Conference on Computer Support for Collaborative Learning Foundations for a CSCL Community - CSCL '02*. https://doi.org/10.3115/1658616.1658627
Mayer, R. E., & Moreno, R. (2003). Nine Ways to reduce cognitive load in multimedia learning. *Educational Psychologist, 38*(1), 43–52.
Mayer, R. E. (2005). *The Cambridge handbook of multimedia learning*. University of Cambridge.
Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). Cambridge University Press.
McMullen, J., Brezovszky, B., Rodríguez-Aflecht, G., Pongsakdi, N., Hannula-Sormunen, M. M., & Lehtinen, E. (2016). Adaptive number knowledge: Exploring the foundations of adaptivity

with whole-number arithmetic. *Learning and Individual Differences, 47*, 172–181. https://doi.org/10.1016/j.lindif.2016.02.007

McMullen, J., Brezovszky, B., Hannula-Sormunen, M. M., Veermans, K., Rodríguez-Aflecht, G., Pongsakdi, N., & Lehtinen, E. (2017). Adaptive number knowledge and its relation to arithmetic and pre-algebra knowledge. *Learning and Instruction, 49*, 178–187. https://doi.org/10.1016/j.learninstruc.2017.02.001

Pellas, N., Fotaris, P., Kazanidis, I., & Wells, D. (2018). Augmenting the learning experience in primary and secondary school education: a systematic review of recent trends in augmented reality game-based learning. *Virtual Reality, 23*(4), 329–346. https://doi.org/10.1007/s10055-018-0347-2

Pollock, E., Chandler, P., & Sweller, J. (2002). Assimilating complex information. *Learning and Instruction, 12*(1), 61–86. https://doi.org/10.1016/s0959-4752(01)00016-0

Prensky, M. (2007). *Digital game-based learning*. Paragon House.

Prensky, M. (2010). *Teaching digital natives: Partnering for real learning*. Corwin.

Radu, I. (2012) Why should my students use AR? A comparative review of the educational impacts of augmented-reality. In: *ISMAR 2012—11th IEEE international symposium on mixed and augmented reality 2012, science and technology papers*. pp. 313–314. https://doi.org/10.1109/ISMAR.2012.6402590

Rittle-Johnson, B., & Star, J. R. (2007). Does comparing solution methods facilitate conceptual and procedural knowledge? An experimental study on learning to solve equations. *Journal of Educational Psychology, 99*, 561–574. https://doi.org/10.1037/0022-0663.99.3.561

Rittle-Johnson, B., & Star, J. R. (2009). Compared with what? The effects of different comparisons on conceptual knowledge and procedural flexibility for equation solving. *Journal of Educational Psychology, 101*(3), 529.

Rothschild, M., & Williams, C. C. (2015). Apples and coconuts: Young children 'Kinecting' with mathematics and sesame street. *Mathematics Education in the Digital Era Digital Games and Mathematics Learning,* 123–139. https://doi.org/10.1007/978-94-017-9517-3_8

Rogoff, B. (1993). Children's guided participation and participatory appropriation in sociocultural activity. *Development in context: Acting and thinking in specific environments*, 121–153.

Saltan, F., & Arslan, K. (2017). A comparison of in-service and pre-service teachers' technological pedagogical content knowledge self-confidence. *Cogent Education, 4*(1), 1311501.

Schellens, T., & Valcke, M. (2005). Collaborative learning in asynchronous discussion groups: What about the impact on cognitive processing? *Computers in Human Behavior, 21*(6), 957–975. https://doi.org/10.1016/j.chb.2004.02.025

Shaffer, D. W., Squire, K. R., Halverson, R., & Gee, J. P. (2005). Video games and the future of learning. *Phi delta kappan, 87*(2), 105–111.

Siegler, R. S., & Lemaire, P. (1997). Older and younger adults' strategy choices in multiplication: Testing predictions of ASCM using the choice/no-choice method. *Journal of Experimental Psychology: Gênerai, 26*, 1–92.

Siegler, R. S., & Shrager, J. (1984). Strategy choices in addition and subtraction: How do children know what to do? In C. Sophian (Ed.), *The origins of cognitive skills* (pp. 229–293). Hillsdale, NJ: Lawrence Erlbaum.

Sommerauer, P., & Müller, O. (2018). Augmented reality for teaching and learning–a literature review on theoretical and empirical foundations.

Squire, K. (2003). Video games and education: designing learning systems for an interactive age. *International Journal of Intelligence Games & Simulation*, 2.

Squire, K. D. (2008). Video game–based learning: An emerging paradigm for instruction. *Performance Improvement Quarterly, 21*(2), 7–36.

Squire, K., & Jan, M. (2007). Mad city mystery: developing scientific argumentation skills with a place-based augmented reality game on handheld computers. *Journal of Science Education and Technology, 16*(1), 5–29. https://doi.org/10.1007/s10956-006-9037-z.

Stahl, G., Koschmann, T., & Suthers, D. (2006). Computer-supported collaborative learning: An historical perspective. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 409–426). Cambridge University Press.

Star, J. R., & Seifert, C. (2006). The development of flexibility in equation solving. *Contemporary Educational Psychology, 31*, 280–300. https://doi.org/10.1016/j.cedpsych.2005.08.001

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12*(2), 257–285. https://doi.org/10.1207/s15516709cog1202_4

Sweller, J. (2019). *Cognitive load theory. Advances in cognitive load theory: Rethinking teaching*, 1–11.

Sweller, J., Merriënboer, J. J., & Paas, F. (2019). Cognitive architecture and instructional design: 20 years later. *Educational Psychology Review, 31*(2), 261–292. https://doi.org/10.1007/s10648-019-09465-5

Sweller, J. (2010). Element interactivity and intrinsic, extraneous, and germane cognitive load. *Educational Psychology Review, 22*(2), 123–138. https://doi.org/10.1007/s10648-010-9128-5

Van Merriënboer, J. J., & Sweller, J. (2005). Cognitive load theory and complex learning: Recent developments and future directions. *Educational psychology review, 17*(2), 147–177.

Verschaffel, L., Luwel, K., Torbeyns, J., & Van Dooren, W. (2009). Conceptualizing, investigating, and enhancing adaptive expertise in elementary mathematics education. *European Journal of Psychology of Education, 24*, 335–359. https://doi.org/10.1007/BF03174765

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University.

Wang, F., & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. *ETR&D, 53*, 5–23. https://doi.org/10.1007/BF02504682

Whitton, N. (2014). *Digital games and learning (1. publ. ed.)*. Routledge.

Chapter 12
The Iteration of Design and Assessment for a Digital Game to Support Reasoning in a College Algebra Course

Xun Ge, Scott N. Wilson, Jackie T. Mania Singer, William M. Thompson, Keri A. Kornelson, Jessica Lajos, Braden Roper, Javier Elizondo, Stacy L. Reeder, Leslie Williams, and Margaret L. Kleiser

12.1 Introduction

In higher education, particularly in the first two years of curriculum, many classes in Science, Technology, Engineering, and Mathematics (STEM) disciplines are dominated by large lecture-style classes due to financial considerations to save cost (Atkinson & Mayo, 2010). The STEM disciplines have also been known as challenging domains to many students. A learning environment that is dominated by lectures and note-taking and lack of opportunities for questions and answers during the class adds to learners' difficulty in understanding and acquiring the domain knowledge, increases their anxiety and decreases their motivation and self-efficacy. A myriad of the literature shows that lectures do not really help students acquire knowledge but rather lead to rote memorization and declarative knowledge, whereas a high level of interactivity leads to student engagement and academic achievement (Hake, 1998 as cited in Atkinson & Mayo, 2010). Through instructor–student and peer-to-peer interactions, students are actively engaged in the learning activities of question asking, providing explanations, and giving and receiving feedback that facilitate information processing, reasoning, elaboration, inquiry, argumentation, problem-solving, and reflection. These learning activities are beneficial for students to develop a deep understanding and acquire knowledge (Asikainen & Gijbels, 2017; Biggs, 1987; Ge & Land, 2003, 2004).

To address the issue of lack of interactivity typically found in lectures and help students overcome their learning challenges, educators and researchers have been

X. Ge (✉) · S. N. Wilson · J. T. Mania Singer · W. M. Thompson · K. A. Kornelson · J. Lajos
B. Roper · J. Elizondo · S. L. Reeder · L. Williams · M. L. Kleiser
The "Functions of the Machine" Research Team, K20 Center, The University of Oklahoma, Norman, OK, USA
e-mail: xge@ou.edu

C. Aprea, D. Ifenthaler (eds.), *Game-based Learning Across the Disciplines*, Advances in Game-Based Learning, https://doi.org/10.1007/978-3-030-75142-5_12

seeking alternative approaches and solutions to create learning environments to support student learning. Among a number of approaches (e.g., problem-based learning, inquiry-based learning), game-based learning (GBL) has been identified and recognized as a useful instructional approach that can be integrated into the existing curricula to create interactivities between students and content materials. According to Atkinson and Mayo's (2010) critical analysis of literature, students who studied in the STEM video game environment achieved better learning outcomes than students in the lecture environment because of the pedagogical features of games, such as adaptive learning pace, autonomy in choice, learning control, multiple representations, and just-in-time help or on-demand delivery. Specifically, at the higher education level, GBL has been shown to increase student motivation toward learning and encourage deeper learning and higher order thinking (Crocco et al., 2016; Nadolski et al., 2008).

12.2 Purpose of the Study

Despite the empirical evidence to support the benefits of digital games (including video and computer games) for learners in various aspects (e.g., cognitive, motivational, emotional, and social) across different disciplines, there are some confounding results about the effects of digital games and controversies about the impact of the games (Boot et al., 2011; Granic et al., 2014). Part of such controversies could be attributed to inconsistent assessment results from empirical studies and challenges of developing valid and reliable assessment instruments and methods due to the complex nature and contexts of GBL. We encountered two challenges with the research project on the "Functions of the Machine" game presented in this chapter. The first challenge was to fulfill the pedagogical goals, that is, developing an interactive game with technological scaffolds that were effective and supportive in engaging students in the reasoning and problem-solving process, pinpointing their difficulties, and providing timely help with prompts and feedback with clear instructions and directions. The second challenge was how to conduct an effective assessment to investigate the impact of GBL on the desirable learning outcomes and learners' motivation and engagement. Due to some practical issues for conducting assessment in the authentic university context and a natural classroom setting, such as recruiting participants, attrition, time limitation, and timing of the semester, we were challenged to seek ways to conduct assessments that were both scientific and feasible, which in turn helped us to improve the design features, functionality, and quality of a digital educational game.

The purpose of this research was to investigate (1) if a digital game environment helped college students achieve better learning outcomes on proportional, graphical, and covariational reasoning compared to a non-digital game environment, and (2) if students who played a digital mathematics game were more motivated and engaged compared to those who did not play the game. Another purpose of this research was to investigate if a digital game for educational purposes had advantages over other instructional methods in terms of mathematical understanding and student motivation. In addition, this study was also intended to examine the relationship between students' learning outcomes in mathematics, particularly in their understanding of functions and their motivation and engagement. The following research questions guided the assessment of the effectiveness of the "Functions of the Machine" game:

Question 1: Will the students in the game group perform better than the students in the non-game groups (the paper group and the control group) in performing mathematical tasks that involve graphical reasoning, proportional reasoning, and covariation reasoning as they work with functions?

Question 2: Will the students in the game group have better motivation scores for mathematical learning than the students in the non-game groups (the paper group and the control group)?

Given that *covariational* reasoning requires dynamic internal cognitive movement as indicated by Carlson's mental action framework (Carlson et al., 2010), it is hypothesized that the visually dynamic GBL environment may be better equipped at helping students develop *covariational* reasoning compared to static textbook exercises.

This chapter reports two iterations of the game design and assessment in a design-based research. Through this chapter, we hope to share our design-based research experience in educational digital game design and development, validating game assessment through the iterative cycles of designing and testing, and formulating a design, development, and assessment model for GBL.

12.3 Literature Review

Given the numerous advantages of GBL discussed earlier, we developed a serious game of mathematics named "Functions of the Machine" to support students in an undergraduate-level college algebra course and their transition to precalculus. The purpose was to motivate college students to learn mathematics through gameplay and scaffold their mathematics reasoning, critical thinking, and problem-solving in a way that is more visual, effective, and supportive. The college Algebra course includes the concepts of variable quantities and functions. Skills in this area can be built by gaining understanding in three important areas: graphical reasoning, proportional reasoning, and covariation reasoning. What motivated the development of this game was the prevailing learner difficulties in working with variables and their rudimentary understanding of mathematical functions, which prevent them from progressing to more complex mathematical concepts. Below we specifically explain learners' challenges in understanding functions and how the game design can scaffold their mathematical reasoning more dynamically and towards a more nuanced understanding of functions.

12.3.1 Student Difficulties in Algebra

It has been well established that college algebra level students' reasoning in relation to function concepts are rigid, primarily procedural, and indicative of an action view (Dubinsky & Harel, 1992; Oehrtman et al., 2008). Students with an action view have a limited interpretation of functions as a formula, symbols to manipulate, variables to replace with numbers, and something to perform arithmetic operations on. Moreover, students with an action view do not recognize symbolic manipulations of a function as a transformation, nor do they recognize one function as being a composition of other functions. They simply see a function as an object, that you plug in numbers for the variable letter, to get an answer. Students with an action view are ill-equipped to handle concepts like domain and range due to their visual nature. Even if precalculus students exhibit a process view of function, it is often a minimal interpretation of functions as a machine that processes input numbers one at time or as an algorithm that maps a discrete input to one output (Breidenbach et al., 1992, p. 258).

An action and minimal process view of functions is problematic and leads to a roadblock for calculus readiness for many students at the university level (Carlson et al., 2010). More specifically, these views block access to understanding concepts, such as average and instantaneous rate of change, concavity, limits, continuity, integration, and mastery of statistical concepts, such as correlation (Oehrtman et al., 2008; Zieffler & Garfield, 2009). The covariational approach to teaching the function concept was developed to encourage students to interpret functions as patterns of change in a variety of contexts and promote a more complex view beyond the minimal process or action view. Carlson et al. (2002) termed covariational reasoning as, "the cognitive activities involved in coordinating two varying quantities while attending to the ways in which they change in relation to each other" (p. 354). This type of reasoning has been documented to be difficult for even academically talented undergraduate students. Likewise, educators have found that this type of reasoning process is difficult to facilitate (Oehrtman et al., 2008). Some progress has been made to support students' covariational reasoning through the design of covariation tasks that utilize augmented reality and dynamic computer environments (DCE), such as MiniTool's software, which have shown to be useful (Cobb et al., 2003; Johnson, 2016; Swidan et al., 2019). However, more innovative approaches to covariation task design and evaluation are needed to better understand how different learning environments impact student's process reasoning of functions.

12.3.2 Game-based Learning Approach to Mathematics

Game-based learning (GBL) is a pedagogical approach to learning through games based on best practices in teaching and learning across educational settings (Amory, 2007; Gee, 2003; Sun et al., 2011). "Good" games (Gee, 2003) incorporate scaffolding, elements of constructivism, and acknowledge students' developmental stages (Amory, 2007; Sun et al., 2011). In GBL, learning is facilitated through play. As learners play the game, they engage not only with the educational content of the game but also the process of the game, which has been shown to have positive effects on learning (Cheng et al., 2020). GBL encourages risk-taking, customizes challenges based on individual progress, promotes agency and autonomy for learning, and encourages learners to solve problems less linearly and more laterally by exploring options and changing courses for improved outcomes (Hamari et al., 2016). Studies have also shown that GBL elicits not only cognitive involvement in learning but emotional involvement as well. Emotional involvement in the form of frustration and positive and negative emotions has been shown to have positive impacts on motivation, engagement, and learning retention (Cheng et al., 2020; Sabourin & Lester, 2014). Additional benefits of GBL include improved attitudes toward learning (Garneli et al., 2017; Ke, 2008), decreased test anxiety (Kiili & Ketamo, 2018), soft skills development, digital literacy, and improved collaboration (Anastasiadis et al., 2018). Meta-analyses of GBL have also found evidence of higher learning gains (Wouters et al., 2013) and academic performance (Clark et al., 2016) when compared to other test groups.

Some studies specifically investigated the effects of games in learning mathematics. For instance, Barros et al. (2020) developed a serious game *Tempoly* and examined how the game supported learners in the learning of the four arithmetic operations on polynomials among the eighth-grade middle school students. The results showed that the students who played the game significantly improved their test scores than those who did not play the game. In addition, the game also motivated the students to play more digital games and learn mathematics through gameplay. Similarly, the study conducted by Ku et al. (2014) revealed positive effects of digital games not only in mathematical achievement but also in efficiency and speed of learning. Jon-Chao and Chan's (2018) study confirmed that gameplay enhanced students' self-efficacy, interest, and metacognition, which were some variables negatively correlated with learning anxiety as commonly found in various disciplines of STEM education. In sum, research demonstrates the overall advantages of serious digital games in supporting learners in various aspects: cognition, metacognition, motivation, and emotion. It is important to note that existing literature on GBL and mathematics is focused mainly at the K–12 level, with few mathematics-specific studies at the higher education level, with (Lee et al., 2016) one exception. There is a need to address this gap in the literature. Based on the evidence of the positive effects of GBL on learning and motivation (Cheng et al., 2020; Hamari et al., 2016; Wouters et al., 2013) in higher education (Crocco et al., 2016; Nadolski et al., 2008) and in mathematics (Barros et al., 2020; Jon-Chao &

Chan, 2018; Ku et al., 2014), as well as the work of Hong et al. (2019) who found that in a GBL environment, metacognition was positively correlated with hedonic and utilitarian values, which are positively associated with gains in covariation performance. GBL environments may provide an additional platform for training covariational processes through interactive visualizations, which offer additional benefits and insights into cognitive-affective interplay that non-game methods do not provide.

12.3.3 Assessment of Game-based Learning

One of many challenges in GBL is to seek effective strategies and approaches that will lead to valid and reliable assessments of learning outcomes and processes affected by gameplay. A typical traditional assessment approach has been using external measures to assess learning, such as comparing pretest and posttest to gauge learners' progress and outcomes, which is referred to as the external assessment (Ifenthaler et al., 2012a, b). However, the external measures may not be effective to accurately assess what students have learned, where learners' difficulties lie, or what features of the game work or do not work. What happens between *before*, *during*, and *after* is often unknown to researchers, like a black box (Loh, 2012). The other type of assessment is the internal assessment, which is defined as assessment being part of the digital game environment and will not interrupt learners' gameplay or disrupt their engagement (Ifenthaler et al., 2012a, b). Examples of internal assessment include automatically tracking students' activities or behaviors as they are playing the game, such as clickstreams and log files (Ifenthaler et al., 2012a, b). Shute et al. (2016) called such an internal assessment stealth assessment. The main purpose of stealth assessment is to collect information that will enable researchers to make valid inferences about what learners know, what they are able to do, and to what degree they know or are able to do things, which Shute et al. (2016) referred to as competencies based on Mislevy, Almond & Lukas' (Mislevy et al., 2003) evidence-centered design assessment framework. Shute et al.'s (2016) study indicated that the learning outcomes generalized by the gameplay behavior data correlated with the external measures and could serve as evidence of learners' competence. This study (Shute et al., 2016) suggests that the stealth assessment is a valid assessment approach.

To sum up, stealth assessment can serve as an internal assessment that provides a wealth of data about players' or students' information through embedded gameplay behavior data (Ifenthaler et al., 2012a, b; Shute et al., 2016), which in turn provides insight into learners' performance, progress, and outcomes. The embedded gameplay data can help us to interpret external assessment results, which further informs us in our effort to refine and improve our assessment instruments to be robust, effective, and practical instruments through triangulating various types of data from various sources. By examining embedded gameplay data, researchers can better understand learners' behaviors, including the number of attempts and mistakes learners make in each of the interactions for each of the tasks within the digital game environment. The information gained from valid assessments is essential for developing a robust, valid, and impactful educational game (Ge & Ifenthaler, 2017).

12.3.4 Design-based Research

Design-based research is an emerging paradigm for the study of learning in the real educational context through systematic design and study of instructional strategies and tools. It is an educational research approach intended to overcome the limitation of laboratory experimental research that has little transferability to the rich and complex classroom setting (Brown, 1992). While "design-based research methods focus on designing and exploring the whole range of designated innovations: artifacts as well as less concrete aspects, such as activity structures, institutions, scaffolds, and curricula" (p. 5), it also aims at developing and contributing to theories of learning and instruction through implementing specific interventions or innovative pedagogical approaches (McKenney & Reeves, 2019; The Design-Based Research Collective, 2003). The primary goal of design-based research is to address educational needs, bring solutions to instructional problems, improve educational practice, and enhance students' learning experiences, which is different from traditional empirical research (McKenney & Reeves, 2019). An important value of design-based research is its attention to the sociocultural context and the complex system within the learning environments, which not only helps us gain a better understanding of the intervention but also leads to an improved theoretical account of learning and instruction.

In design-based research, intervention and context are intertwined. Because of the complex, flexible, and contextualized nature of everyday classroom settings, design-based research presents great challenges to researchers when carrying out research in situ, particularly in implementing and investigating the design of a technology-rich learning environment, in which technology is used both as a medium to support learning and a tool to collect data. Design-based educational researchers seek to conduct research in a complex sociocultural system of educational settings, where situations of learning are not fixed or immutable but rather open to redesign by the researchers. The researchers play the dual role of designer and researcher (Brown, 1992; Brown & Campione, 1996; Cobb, Confrey, et al., 2003).

In the design research, we report in this chapter, we started the digital game project with the primary purpose of addressing students' difficulties and challenges in learning algebra by providing scaffolds to students through the design of the mathematics educational game "Functions of the Machine." In the process of designing and research, we had to collect information about learners' characteristics, identify learning objectives and competences, and develop game features targeting students' difficult areas in reasoning. We also had to consider a variety of factors, specific contexts, and practicality issues as we implemented the game research among the students, such as when to implement the tests, what data to collect from students, length of time for implementation and assessment, and appropriate number test items. We worked as a research team that consisted of designers, game developers, educators, and researchers, although some of the team members played more than one role, such as educator and researcher or designer and researcher.

12.4 The Design of "Functions of the Machine" to Scaffold Student Reasoning in Algebra

To explore the efficacy of a GBL application to facilitate understanding of function concepts through *covariational* reasoning further, a university's Virtual Learning Experience Team affiliated with an educational research center developed a digital game titled *Functions of the Machine*. The game consisted of a series of interactive puzzles involving proportional, graphical, and covariational reasoning. The "Functions of the Machine" was deployed on Chromebook computers through WebGL.

Players were given an unlimited number of attempts to solve each puzzle, with adaptive, just-in-time feedback applied between each attempt. In the game, the student was asked to play the role of a scientist tasked with making a complex machine run. The student explored, tested, and fixed the machine's moving parts which consisted of gears, fluid tanks, and conveyor belt contraptions. Players were not allowed to move on to the next puzzle until completing the previous. One of the purposes of this game was to develop aspects that would give students a more dynamic experience to build their covariational reasoning. The goal was to use interactive scaffolded problems to build students' understanding of proportional relationships and functions from a graphical, and later, the more complex *covariational* perspective.

Many proportional reasoning puzzles involved gears to develop reasoning around proportions. In one gear problem, as shown in Fig. 12.1, students used the gear controls to set the direction of rotation for the inner 10-teeth gear A and number of rotations so that the three 15-teeth gears would each rotate 8 times in the clockwise direction. The student needed to determine that rotation of inner gear A corresponded to the opposite direction of rotation in the B gears. In addition, the student needed to determine a correspondence between the amount of rotation in gear A and the amount of rotation in B gears, for example, three rotations of gear A resulted in two rotations of the B gears. After setting up the gear controls, the student tested their decision by hitting calibrate to move the gears.

A graphical reasoning simulation, in Fig. 12.2, shows the position of a wheel crank graphically. The height of this crank was modeled as a sinusoidal function of rotation amount. In this puzzle, the student selected the rotation amount with a

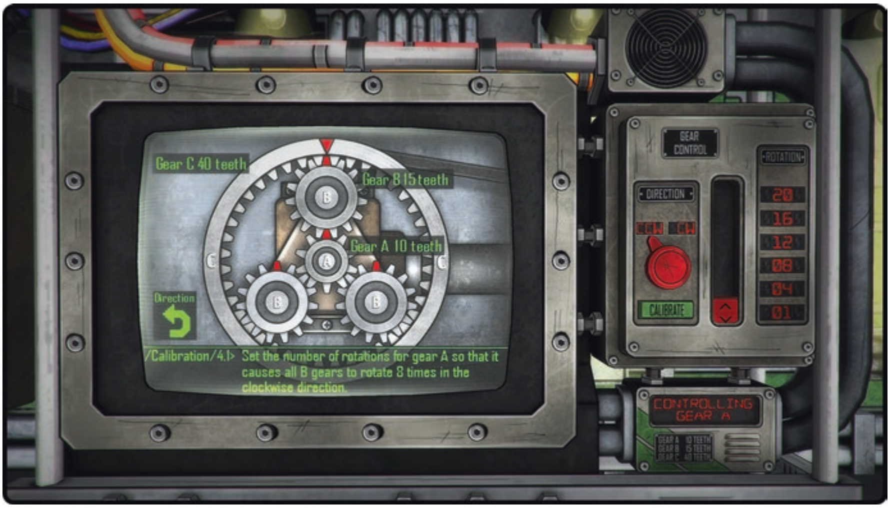


Fig. 12.1 Proportional reasoning gear puzzle

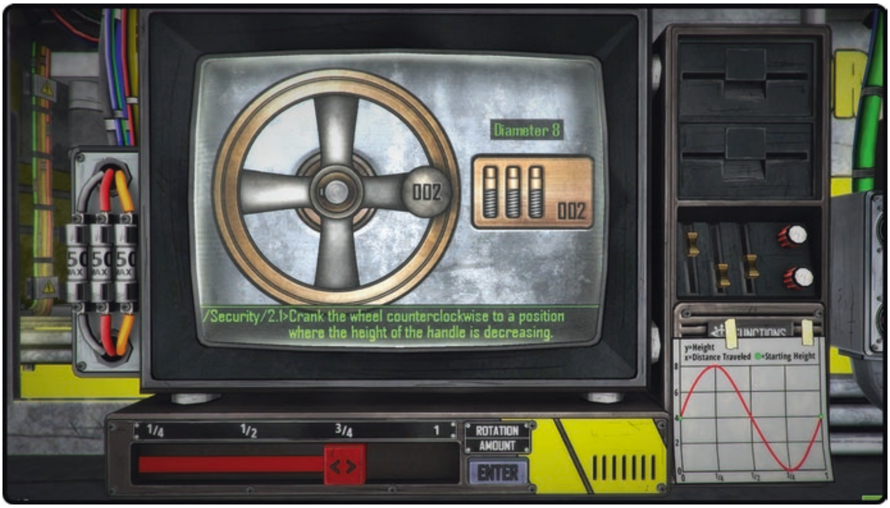


Fig. 12.2 Graphical reasoning puzzle

slider. The goal for the student was to rotate the wheel to a point where the height of the crank was decreasing.

The final levels of the game incorporated several covariational reasoning bottle problems. A bottle problem, shown in Fig 12.3, asked the student to use sliders to select graphs that represented the height of liquid in each cone as a function of time under the condition that the volume of liquid drained at a constant rate. To be successful in solving the bottle problem in Fig. 12.3, students had to move between

Fig. 12.3 Covariational reasoning bottle problem

multiple types of representations for the same functions, draining cones and their graphs, and combine reasoning types. The algebraic representation of the functions as a symbolic equation was intentionally not provided. If the algebraic equation was in hand, the move from the dynamic bottle representation to the graphical representation became algorithmic and discrete, a mere plugging in inputs to an equation and getting output and graphing the pairs of points. While an algebraic mediator paved a cognitively less demanding route from the bottle to graphical representation, it might disable the students' need to engage in covariational reasoning.

Embedded data regarding students' problem-solving in the game were collected using the Experience API (xAPI) framework. xAPI allows for secure, real-time collection of participants' in-game behaviors, formatted in a way that makes the data easily accessible. After the experiment, xAPI data were exported from the game database in the form of a comma-separated variable (CSV) file and analyzed in Microsoft Excel. Through xAPI, nearly every interaction a player made within the game was recorded. Relevant to the current research we collected overall playtime, time between attempts (mistakes), and individual choices made on each puzzle within the game.

12.5 Design-Based Research: The Evaluation of the Digital Game

A design-based research study was conducted in a public university in the southwest of the United States to investigate the effects of a digital game named "Functions of the Machine" in support of students' mathematical reasoning as well as their motivation and engagement in learning mathematics. As mentioned in the "Purpose" section, we went through two iterations of design and evaluation to improve the quality (e.g., functionality, interactivity, and clarity) of the game, students' experience, assessment instruments, techniques, and methods. After the first version of the game was developed, we conducted an experimental study to compare the game group with the nongame group and a control group, using the external assessment method to collect pretest and posttest data on mathematics reasoning and problem-solving as well as motivation and engagement. In addition, we also used the embedded assessment method and examined the log files (Ifenthaler et al., 2012a, b), including the tasks correctly performed, mistakes made, time intervals between attempts, and time for completion. The results from the first experimental study indicated that the students in the game group had higher motivational scores in several constructs than the nongame group and the control group, but they did not show significant differences between the game group and the nongame groups (the paper group and the control group) in mathematical reasoning and problem-solving in algebra. Based on the first round of iteration, revisions were made to the game, such as improving the clarity of instructions and making feedback more robust. Furthermore, the embedded data also helped us to interpret the external test results, which prompted us to improve test items and develop robust, effective, and reliable assessment for the second round of iteration. In the second iteration, the experimental results showed that the students in the GBL environments significantly outperformed the students in the nongame learning environments in most of the skill areas in algebra.

The development team consisted of a producer, an instructional game designer, a technology lead, an art director, and several students aiding in programming and quality assurance. Their work consisted of identifying game mechanics that would enable instruction, scaffolding, and practice; developing a concept that would result in engaging game activities; and finally using the Unity game engine to code all the designs into the actual game. The team used an agile method of development that facilitated the iterative design and therefore a very responsive improvement cycle. The game prototype was equipped with an event tracking system that provided in-game data to the research team but also allowed for design improvements. The subject matter experts on the team consisted of a professor in mathematics education from the Department of Instructional Leadership and Academic Curriculum, a professor, and a graduate student in mathematics from the Department of Mathematics. They helped to design the game that would help college students develop a deep understanding of functions and lay a solid foundation in College Algebra. The research team for the study of the second iteration consisted of the

Director of Research and Evaluation, a graduate student in psychology from the Department of Psychology, and a computer programmer and instructional designer from the K20 Center. They helped to design the pre-assessment and the post-assessment based on the items written by the SMEs and designed the research study. The research team also developed the facilitator guides for administering the pre-assessment and the post-assessment and conducted the statistical analysis.

12.5.1 The First Iteration Research

The first round of experimental study was conducted in Fall 2018 to (1) investigate the effects of the digital game on student learning of algebra, specifically in the skill areas of graphical reasoning, proportional reasoning, and covariation reasoning and (2) compare students' motivation and engagement between the game group and the other non-game groups. A total of 473 students from multiple sections of a college mathematics class at a public university in the southwest of the United States participated in the study. The participants were randomly assigned to one of the following three conditions or groups: the mathematics game condition (159 participants), the paper condition (158 participants), and the control condition (156 participants). The participants in the mathematics game group were asked to play a mathematics game, the participants in the alternative-approach condition (paper) had to complete a set of exercises integrated with scaffolding strategies, whereas the participants in the control group just read the texts. The participants completed a pretest and a posttest within a period of 2 h.

12.5.1.1 Instruments and Measures

The pretest consisted of demographic survey questions and a pretest of one mathematics problem to assess students' prior mathematics knowledge. The purpose of the mathematics pretest was to establish a baseline for comparison across the three conditions. The demographic data, such as the prerequisite courses they had taken and game playing experience, were collected to serve as a covariate with the mathematics test and engagement questionnaire. The posttest consisted of 25 items of motivation survey questions in eight subcategories (i.e., enjoyment, immersion, intrinsic motivation, pressure/tension, value, competence, behavioral engagement, and cognitive engagement) as well as 8 mathematics problems in three subcategories (i.e., graphical reasoning, propositional reasoning, and covariation reasoning). Two members of the research team, who were mathematics professors, developed and validated the problems for both pretest and posttest. The motivation and engagement questions were developed based on a variety of motivation instruments, including Intrinsic Motivation Inventory (IMI) (n.d.) (http://selfdeterminationtheory.org/intrinsic-motivation-inventory/), the attitudes toward mathematics inventory developed by Lim and Chapman (2013), and the engagement and flow survey items developed by Hamari et al. (2016), which all indicated good reliability with high Cronbach's alpha.

12.5.1.2 Data Analysis and Results from the First Iteration

Descriptive statistics were performed to examine the means and standard deviation of the posttest mathematics scores of the three groups. In the same way, descriptive statistics were performed to examine the means and standard deviation on the motivation measures among the three groups. In addition, one-way multivariate analysis of variables (MANOVA) was performed to determine if the mean differences of the three groups were significant. The MANOVA analysis was followed up by the one-way ANOVA in order to examine group differences on each dependent variable individually. The pretest mathematics score was used as a covariate for the analysis of the posttest mathematics scores. Further, the ANOVA results were followed up with Tukey's post hoc tests to explore between-group differences on those dependent variables that were significantly related to the grouping variable in the ANOVAs.

12.5.1.2.1 Results of Algebra Reasoning

The statistical analysis showed a significant difference in the subcategory of *graphical reasoning* between the three groups, and the game group ($M = 2.07$, $SD = 0.97$) performed significantly poorer compared to the paper group ($M = 2.37$, $SD = 0.93$) and the control group ($M = 2.43$, $SD = 1.03$). There were no significant differences between the paper and the control group. However, no conclusions could be reached from these results due to the low reliability of the mathematical items (Cronbach's $\alpha = 0.34$), although the means showed that the game condition performed the worst of all the three groups. In other words, further research was needed to assess the impact of the digital game on students' algebra reasoning.

12.5.1.2.2 Results of Motivation and Engagement

Statistically significant differences were found in the motivation and engagement between the three groups, Wilks' lambda = 0.829, $F(16,926) = 5.691$, $P < 0.001$; $\eta^2 = 0.09$ (medium effect). The one-way ANOVAs were performed in order to examine the group differences on each dependent variable individually. Significant group differences were observed on the following variables with size effect noted: *Engagement and Interest*, $F(2,470) = 10.242$, $P < 0.001$, $\eta^2 = 0.042$; *Pressure/Tension*, $F\ (2,470) = 14.717$, $P < 0.001$; $\eta^2 = 0.059$ (medium effect), *Competence*, $F(2,470) = 17.056$, $P < 0.001$, $\eta^2 = 0.068$ (medium effect), and *Behavioral Engagement*, $F(2,470) = 6.515$, $P = 0.002$, $\eta^2 = 0.027$.

The ANOVA results were followed up with Tukey's post hoc tests to explore between-group differences on those dependent variables that were significantly related to the grouping variable in the ANOVAs. Significant pairwise differences were found in the following areas: *Engagement and Interest*, *Pressure/Tension*, *Perceived Competence*, and *Behavioral Engagement*.

In *Engagement and Interest*, there was a significant difference between the game condition ($M = 3.56$; $SD = 1.23$) and the paper condition ($M = 3.24$; $SD = 1.21$), and between the game condition and the control condition ($M = 2.95$; $SD = 1.17$). However, no significant difference was observed between the paper and the control groups. This result showed that the participants in the game group enjoyed the math problem-solving tasks more than the participants in the other two groups.

In *Pressure/Tension* results, all pairwise group differences were statistically significant. Pairwise group differences were found between the game condition ($M = 3.17$; $SD = 1.31$) and the paper condition ($M = 3.57$; $SD = 1.41$), and between the game condition and the control condition ($M = 3.99$; $SD = 1.34$). However, no significant difference was found between the paper condition and the control condition. This result showed that the game group had the lowest pressure and tension, which was what was hypothesized.

With respect to *Perceived Competence*, significant differences were found between the game condition ($M = 3.88$; $SD = 1.15$) and the paper condition ($M = 3.41$; $SD = 1.16$), and between the game condition and the control condition ($M = 3.13$; $SD = 1.16$). However, there was no significant difference between the paper condition and the control condition. This result showed that the game group felt more competent than the paper group or the control group.

In *Behavioral Engagement*, we found a significant pairwise difference between the game condition ($M = 4.37$; $SD = 1.14$) and the control condition ($M = 4.84$; $SD = 1.19$). There were no other pairwise differences observed. This result showed that the control group exerted significantly more effort on math problems compared with the game group.

In summary, the analysis of motivation and engagement items showed that the participants in the game group (1) enjoyed the mathematics problem-solving tasks more than the participants in the other two groups; (2) had the lowest pressure or tension when solving the mathematics problems compared with the other two groups; (3) felt more competent than the other two groups; and (4) demonstrated significantly less effort on mathematics problems compared with the control group.

12.5.2 Analysis of Gameplay Behavior Data and Modification of Game Design

The results of the analysis of the first iteration led us to go back and revisit the design of game components (e.g., scaffolding, feedback, and clarity of instruction). We reexamined learner characteristics (e.g., prior knowledge, prior game experience), alignment of objectives and test items, validity and reliability of test items, and reviewed the implementation and administration process. Moreover, we also examined the embedded data that provided us insight into students' performance that was not captured by the external assessment data.

An item analysis was conducted. Each problem within the game was analyzed for level of difficulty, discrimination of items, and effectiveness of distractors. Game problems were flagged for adjustment or revision if they were identified as too easy (<70% of players answered correctly) or too difficult (>30% of players answered correctly, if a comparison of the top quartile of players and bottom quartile of players showed a disproportionate correct response rate (<25% discrimination index) or if negative discrimination was indicated. Multiple-choice responses for each problem were categorized as "retain," "revise," or "replace" based on the effectiveness of distractors. In cases where distractors functioned well, meaning distractors were chosen more by the bottom quartile of students than the top quartile of students, distractors were retained. Distractors that were not selected by any player or which were chosen more often by high-performing players were revised or replaced.

Based on the results of the item analysis, we modified the identified problems within the game to improve overall game quality. Specifically, the problem text was revised to clarify instructions, and the feedback display was edited to better inform players in their decision-making processes. Where necessary, explanatory text such as necessary mathematical formulas was added, and labels and game graphics were redesigned or repositioned. The revised version of the game was then used in the second iteration of the research that is described in the next section.

Furthermore, the embedded gameplay data from the first study helped us to interpret the external assessment results, which informed us to improve test items and develop robust, effective, and reliable assessment for the second round of iteration. The review of the first round of assessment scores and study design revealed that items from the first assessment were written to measure student knowledge of multiple mathematical concepts and included answers that could be partially correct or incorrect. The complexity of this question formatting proved challenging in the interpretation of results as student knowledge gain on assessed concepts could not be easily isolated. Additionally, more in-depth analysis showed that post-assessment items did not directly align with learning objectives of *Functions*, but rather, the more general concept of covariational reasoning, which is broad in scope. Therefore, students were being assessed on skills they did not encounter in the game or the alternative learning activities. Finally, it was found that the post-assessment was too lengthy, possibly leading to fatigue among students who both played the game and completed the post-assessment within the same time period. Students who participated in the two alternative learning activities finished much sooner than the game players.

12.5.3 The Second Iteration Research

Based on the first round of iteration, we conducted the second round of quasi-experimental study. This time, we only assessed students' performance in mathematical reasoning, specifically graphical reasoning, proportional reasoning, and covariational reasoning. We did not assess students' motivation and engagement since it was confirmed by the first study that students in the game group were significantly more motivated and engaged in several areas compared with the students in the other two non-game groups.

The participants were recruited from a university-level mathematics course and were randomized at the section level, with four sections (157 students) assigned to the control group and five sections (177 students) assigned to the game group. Each section was administered a preassessment at the beginning of Week 1 during regularly scheduled class meeting times. All sections received regular classroom instruction during Week 1. At the end of Week 1, the post-assessment was administered to the control group. In Week 2 of the study, both the control group and the experimental group were provided access to the game and instructed to play outside regular class time. In Week 3, the experimental group was administered the post-assessment as part of regularly scheduled class time. All the pretest and the posttest were administered on paper by the course instructors. The instructors submitted completed pre-assessment and post-assessment to a member of the research team who graded the assessments and entered them into an excel spreadsheet using unique randomized identifiers to match the pre-assessment and the post-assessment. De-identified data were provided to another member of the research team for analysis.

12.5.3.1 Revised Instrument for Measuring Mathematics Reasoning

For the second study, we revised pretest and posttest assessment instruments that were more explicitly aligned with the learning objectives of the game and included items that measured isolated mathematical concepts with single short answers or multiple-choice responses. Two of the team members were professors in mathematics and mathematics education, and they first developed 12–20 questions for each objective: covariational reasoning, graphical reasoning, and proportional reasoning. The questions were then screened by mathematics education graduate students who coded them to our learning objectives for the study and evaluated them for relevance. After this round of expert review, we finalized the instruments to 50 questions, including 18 covariational reasoning, 20 graphical reasoning, and 12 proportional reasoning. We then conducted a pilot study of the proposed assessment using participating students in an undergraduate level trigonometry/precalculus course. Reliability analysis was conducted for each of the outcome scales. For the items measuring covariational reasoning, the reliability analysis indicated adequate internal consistency for a classroom examination (Cronbach's $\alpha = 0.563$), and it also indicated that removal of Item 14 would result in increasing Cronbach's α to 0.600. Therefore, Item 14 was deleted. The reliability analysis of graphical reasoning items indicated adequate internal consistency (Cronbach's α = 0.691). We removed Item 4 from the assessment and increased internal consistency to α = 0.703. For proportional reasoning, the initial reliability analysis showed poor internal consistency (Cronbach's α = 0.442). Further inter-item analysis showed few items that correlated together at $r = 0.30$ or greater. Although removing Items 2, 3, and 8 did improve α to 0.513, the reliability of the instrument could not be improved to an adequate level. Therefore, the results of the proportional reasoning scales were not included in the final analysis for the second study. The resulting pre-assessment and the post-assessments were used in the second iteration of the study.

12.5.3.2 Data Analysis and Results from the Second Iteration

The analysis for the second round of the study was conducted using *SPSS version 25*. Participants were included in the analysis if they had both pretest and post-test scores. There were a total of 223 participants who met the criteria for inclusion: 94 participants in the control group and 129 participants in the experimental group.

For the analysis of overall assessment scores, we conducted independent t-tests of the pretest and posttest scores for each group. Results showed there were no significant differences in pretest scores, which suggests the students in the experimental and control groups were at approximately the same performance level at the start of the intervention. Results for posttest scores showed that the students in the control group scored lower on the posttest than the pretest, and students in the experimental group showed an increase in overall score at a significant level. Table 12.1 displays the results of the *t*-tests.

The independent *t*-tests were followed by a one-way ANOVA to examine between-group differences on overall assessment score. When looking at the difference between pre- and posttests for both groups, the control group had a negative difference, −0.5000, between tests, and the test group had a positive difference, 0.2481. The analysis did show the difference between pre- and posttest scores between the experimental group and the control group was significant ($F = 6.444$, $P = 0.012$). This result showed that the game group performed significantly better than the control group in overall scores.

Table 12.1 Overall assessment between the game (experimental) group and the control group

	Experimental M (SD)	Control M (SD)
Pretest	7.60 (2.00)	8.06 (1.93)
Posttest	7.85 (2.14)	7.56 (2.29)
Within-group difference between pre and post	**0.248** (**$t = -2.54$, $P < 0.012$**)	−0.500 ($t = -0.940$, $P > 0.05$)

Note: This table represents the overall scores of the pre- and post-tests from the control and experimental groups and the difference between the two test scores

Table 12.2 Covariational Reasoning

	Experimental *M* (*SD*)	Control *M* (*SD*)
Pretest	2.98 (1.52)	3.21 (1.49)
Posttest	3.40 (1.55)	2.81 (1.61)
Within-group difference between pre and post	**0.42)** ($t = -2.56$, $P < 0.012$)	−0.4 ($t = 2.42$, $P < 0.018$)

Note: This table shows the scores of the covariational reasoning portion of the tests and the difference between the two test scores of the two groups

Of particular interest to the researchers was how students performed on the covariational reasoning section of the examination. Paired *t*-test results demonstrated that the experimental group had a significant difference between pre- and posttest scores. Results also show that the control group scored lower on the posttest than the pre-test at a significant level (See Table 12.2). Further, a one-way ANOVA was conducted to compare the performance of the two groups. For the covariational reasoning portion of the assessment, there was a significant difference in the test score between the experimental and control groups ($F = 2.825$, $P = 0.038$). The post hoc tests indicated that the game group performed significantly better than the control group.

In summary, in the second iteration of the research, the statistical results showed that the students in the GBL environment significantly outperformed the students in the non-game learning environments in the overall test scores (consisting of graphical reasoning, propositional reasoning, and covariation reasoning) and the skill area of covariation reasoning.

12.5.4 Analysis of Gameplay Behavior Data

Finally, we wanted to compare the gameplay data from the first round of assessment to the second round. Of interest in both rounds was the average amount of mistakes made per question. To conduct this analysis, participants in the top quartile (top 23.3%, $N = 82$) were compared to students in the lower quartile (bottom 29.1%, $N = 65$). Quartiles were calculated by taking the frequencies of posttest scores, and then making cutoff points that were closest to the top 25% and the bottom 25%. When comparing the second assessment results to the first assessment results, we saw 5 questions go from negative differences in average mistakes to positive mistakes, meaning that the top quartile made fewer mistakes than the bottom quartile on average. Only one question went from positive in the first assessment to negative in the second assessment. The overall assessment of the gameplay behavior data suggested that the questions and adjustments made in the second assessment were positive changes, and the game was more reliable and valid in assessing student learning process and outcomes.

12.6 Discussion

This study confirmed the positive effects of the digital game in supporting student mathematical reasoning in college mathematics courses. The students who played the game outperformed the control group on covariational reasoning. This may be a positive indicator that through engaging and interactive mathematics lessons and curriculum, students in college-level mathematics can improve reasoning skills. However, the data failed to show the positive impact of the digital game in the first iteration of this study, which compelled us to revisit the design of the game and the assessment measures in the second iteration.

The goal of design-based research is to generate models of successful innovation, which we interpret as educational research models that can be adapted in various educational contexts, rather than limiting to simply artifacts, programs, or interventions (Brown & Campione, 1996; Mckenney & Reeves, 2019; The Design-Based Research Collective, 2003). This research has provided us with valuable insights that have led to the construction of a design and research model for developing educational digital games and GBL environments. We have gained rich experience through this iterative design-based research process, and we would like to share some of our reflections.

While we were engaged in the design-based research process for the digital game development, we were also engaged in the design-based research process for assessment development, such as developing valid and reliable measures, instruments, and assessment methods. It has become clear to us that the design-based research for the educational game evaluation informs the game development, which in turn helps to improve the quality of the game and vice versa. We have also learned that conducting game-based assessment in a situated context and complex system is a messy and ill-defined process, and we need to contextualize our research in the real context of a learning environment and create a practical and effective assessment model that does not compromise the rigor of research.

This research reveals important contextual information about our students, which reflects the value of design-based research. For example, while students who played the game outperformed students who did not play the game, the overall scores on the pre-test and posttest were surprisingly low for college-level mathematics students. This might reflect a gap in reasoning skills being developed in the high school grades or that traditional mathematics courses at the college level may not adequately develop reasoning skills. Such contextual information leads us to wonder if developing student reasoning skills at an earlier age will promote success in college as they take mathematics courses. It further validates the viability of design-based research which will help us to explore issues beyond the design of the intervention (the digital game) itself but other important variables and factors that need to take into consideration when designing and developing an innovative learning environment.

"Functions of the Machine" is a game that leverages video capabilities to help the learner visualize how functions work. In particular, it allows a student to encounter the idea of quantities that are related to each other and how a quantity changes in response to a change in the other. The target audience is students in secondary and post-secondary mathematics courses such as Algebra I, II, Precalculus, and Calculus. The facility with proportionality and the covariational viewpoint of a function has great impact in other disciplines and more advanced mathematics courses, so we see a potential for usage of "Functions of the Machine" in a broad range of math, science, social science, and business courses.

Beyond the domain of mathematical reasoning, the methods used in this study to evaluate and improve the game are highly adaptable to the design-based research of other serious games and interactive learning programs. By identifying in-game behavioral data that correlate with measures on the extremal assessment we were able to identify which areas of the game were most difficult or misleading for the players and thus needed revisions. This allowed us to target game development in areas that would be most crucial to players, which was a significant benefit since games tend to be expensive to produce. As is the nature of design-based research, every GBL program will have its own objective, game mechanics, and methods of evaluation. No single evaluation method will work for every game. However, the methods described here can serve as a framework or a starting point from which contextualized evaluation of other GBL programs can be adapted.

For future research, we need to investigate the questions on whether the effectiveness of gameplay will be sustained over time, or if continued use of engaging tutorials embedded in the game will lead to more improvement in reasoning. Future research could also integrate scaffolds of some type to introduce the concepts of reasoning and prepare students prior to the game in order to assess the impact of digital games on mathematics reasoning more accurately and effectively. As the embedded data from the game proved beneficial in improving game items and student performance on covariational reasoning in the second iteration, further exploration of internal game data generated by student gameplay as evidence-centered design (Mislevy et al., 2003) or its validity and reliability as stealth assessment (Shute et al., 2016) is warranted. Its viability as a stealth assessment could mitigate some of the challenges of pretest and posttest design identified in this study.

12.7 Conclusion

This chapter addresses the empirical issue of the design, development, and assessment in GBL in the domain of mathematics in higher education. Game-based learning brings about a new perspective of learning and instruction. It enriches students' experience through an alternative and innovative approach of learning. Therefore, it is important to design sound educational games and develop robust and reliable assessment over multiple iterations to demonstrate the effectiveness of GBL in various disciplines. We used a design-based research approach to develop an effective mathematics game over time through two iterations to scaffold students' reasoning in algebra learning. The stealth assessment used in the design-based research informed us of the game design because the embedded gameplay behavior data was consistently logged and captured over time. If we only relied on the external assessment instrument, we would not be able to gain a comprehensive and deeper understanding of students' performance, which area they did well and which area they were weak at, and why they did not do well in some test items. This research has provided us with valuable insights into the construction of a design-based research model for developing GBL environments in both the game and the assessments.

Acknowledgments The creation of Functions of the Machine was funded in part by the University of Oklahoma Provost's Office. We wish to thank Candace Andrews and Casey Haskins for their help and flexibility as we used their courses to validate the assessment questions and to assess the Functions of the Machine. We also wish to acknowledge the contributions of Emmett Mathews, the art director of the game development team.

References

Amory, A. (2007). Game object model version II: A theoretical framework for educational game development. *Educational Tech Research Development, 55*, 51–77.

Anastasiadis, T., Lampropoulos, G., & Siakas, K. (2018). Digital game-based learning and serious games in education. *International Journal of Advances in Scientific Research and Engineering, 4*(12), 139–144.

Asikainen, H., & Gijbels, D. (2017). Do students develop towards more deep approaches to learning during studies? A Systematic review on the development of students' deep and surface approaches to learning in higher education. *Educational Psychology Review, 29*, 205–234. https://doi.org/10.1007/s10648-017-9406-6

Atkinson, R. D., & Mayo, M. J. (2010). Refueling the US innovation economy: Fresh approaches to science, technology, engineering and mathematics (STEM) education. *The Information Technology & Innovation Foundation*. Retrieved from https://files.eric.ed.gov/fulltext/ED521735.pdf

Barros, C., Carvalho, A. A., & Salgueiro, A. (2020). The effect of the serious game Tempoly on learning arithmetic polynomial operations. *Education and Information Technologies, 25*, 1497–1509. https://doi.org/10.1007/s10639-019-09990-4

Biggs, J. (1987). *Student approaches to learning and studying*. Australian Council for Educational Research.

Boot, W. R., Blakely, D. P., & Simons, D. J. (2011). Do action video games improve perception and cognition? *Frontiers in Psychology, 2*, 1–5. https://doi.org/10.3389/fpsyg.2011.00226

Breidenbach, D., Dubinsky, E., Hawks, J., & Nichols, D. (1992). Development of the process conception of function. *Educational Studies in Mathematics, 23*(3), 247–285.

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of the Learning Sciences, 2*(2), 141–178.

Brown, A. L., & Campione, J. C. (1996). Psychological theory and the design of innovative learning environments: On procedures, principles, and systems. In L. Schauble & R. Glaser (Eds.), *Innovations in learning: New environments for education* (pp. 289–325). Lawrence Erlbaum Associates, Inc.

Carlson, M., Jacobs, S., Coe, E., Larsen, S., & Hsu, E. (2002). Applying covariational reasoning while modeling dynamic events: A framework and a study. *Journal for Research in Mathematics Education*, 352–378.

Carlson, M., Oehrtman, M., & Engelke, N. (2010). The precalculus concept assessment: A tool for assessing students' reasoning abilities and understandings. *Cognition and Instruction, 28*(2), 113–145.

Cheng, M., Huang, W., & Hsu, M. (2020). Does emotion matter? An investigation into the relationships between emotions and science learning outcomes in a game-based learning environment. *British Journal of Educational Technology, 51*(6), 2233–2251.

Clark, D. B., Tanner-Smith, E. E., & Killingsworth, S. S. (2016). Digital games, design, and learning: A systematic review and meta-analysis. *Review of Educational Research, 86*(1), 79–122.

Cobb, P., Confrey, J., di Sessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher, 32*(1), 9–13.

Cobb, P., McClain, K., & Gravemeijer, K. (2003). Learning about statistical covariation. *Cognition and Instruction, 21*(1), 1–78.

Crocco, F., Offenholley, K., & Hernandez, C. (2016). A proof-of-concept study of game-based learning in higher education. *Simulation & Gaming, 47*(4), 403–422.

Dubinsky, E., & Harel, G. (1992). The nature of the process conception of function. In G Harel & E. Dubinsky (Eds.), *The concept of function: Aspects of Epistemology and Pedagogy* (Vol. 25, pp. 85–106). MAA Notes.

Garneli, V., Giannakos, M., & Chorianopoulos, K. (2017). Serious games as a malleable learning medium: The effects of narrative, gameplay, and making on students' performance and attitudes. *British Journal of Educational Technology, 48*(3), 842–859.

Ge, X., & Land, S. (2003). Scaffolding students' problem-solving processes in an ill-structured task using question prompts and peer interactions. *Educational Technology Research and Development, 51*(1), 21–38. https://doi.org/10.1007/BF02504515

Ge, X., & Land, S. M. (2004). A conceptual framework for scaffolding III-structured problem-solving processes using question prompts and peer interactions. *Educational Technology Research and Development, 52*(2), 5–22. https://doi.org/10.1007/BF02504836

Ge, X., & Ifenthaler, D. (2017). Designing engaging educational games and assessing engagement in games. In R. Zheng & M. Gardner (Eds.), *Handbook of research on serious games for educational applications* (pp. 253–270). IGI Global.

Gee, J. P. (2003). What video games have to teach us about learning and literacy. *ACM Computers in Entertainment, 1*(1), 1–4.

Granic, I., Lobel, A., & Engels, R. C. M. E. (2014). The benefits of playing video games. *American Psychologist, 69*(1), 66–78. https://doi.org/10.1037/a0034857

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66*(1), 64–74.

Hamari, J., Shernoff, D. J., Rowe, E., Coller, B., Asbell-Clarke, J., & Edwards, T. (2016). Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning. *Computers in Human Behavior, 54*, 170–179.

Hong, J. C., Hwang, M. Y., Liu, M. C., Tsai, C. R., & Tai, K. H. (2019). Metacognition in covariation reasoning relevant to performance achievement mediated by experiential values in a simulation game. *Educational Technology Research & Development*, 1–20.

Ifenthaler, D., Eseryel, D., & Ge, X. (2012a). Assessment in game-based learning. In D. Ifenthaler, D. Eseryel, & X. Ge (Eds.), *Assessment in game-based learning: Foundations, innovations, and perspectives* (pp. 1–8). Springer.

Ifenthaler, D., Eseryel, D., & Ge, X. (Eds.). (2012b). *Assessment in game-based learning: Foundations, innovations, and perspectives*. Springer.

Loh, C. S. (2012). In formation trails: In-process assessment of game-based learning. In D. Ifenthaler, D. Eseryel, & X. Ge (Eds.), *(2012b) Assessment in game-based learning: Foundations, innovations, and perspectives* (pp. 123–144). Springer.

Intrinsic Motivation Inventory (IMI). (n.d.). Retrieved from http://selfdeterminationtheory.org/intrinsic-motivation-inventory/

Johnson, H. L. (2016). Designing technology-rich tasks to foster secondary students' covariational reasoning. In *Proceedings of the 13th International Congress on Mathematical Education*.

Jon-Chao, H., & Chan, C. H. (2018). Game performance in covariation reasoning: The correlates between gameplay self-efficacy, and metacognition reflected gameplay anxiety and gameplay interest. *Jiaoyu Kexue Yanjiu Qikan, 63*(3), 131.

Ke, F. (2008). Computer games application within alternative classroom goal structures: cognitive, metacognitive, and affective evaluation. *Educational Technology Research and Development, 56*(5), 539–556. https://doi.org/10.1007/s11423-008-9086-5

Kiili, K., & Ketamo, H. (2018). Evaluating cognitive and affective outcomes of a digital game-based math test. *IEEE Transactions on Learning Technologies, 11*(2), 255–263.

Ku, O., Chen, S.-Y., Wu, D.-H., Lao, A.-C.-C., & Chan, T.-W. (2014). The Effects of Game-Based Learning on Mathematical Confidence and Performance: High Ability vs. Low Ability. *Educational Technology & Society, 17*(3), 65–78.

Lee, Y.-H., Dunbar, N., Kornelson, K., Wilson, S., Ralston, R., Savic, M., Stewart, S., Lennox, E., Thompson, W., & Elizondo, J. (2016). Digital Game for Undergraduate Calculus Education: Promoting immersion, calculation, and conceptual understanding through game affordances. *International Journal of Gaming and Computer-Mediated Simulations, 8*(1), 13–27. https://doi.org/10.4018/IJGCMS.2016010102

Lim, S. Y., & Chapman, E. (2013). Development of a short form of the attitudes toward mathematics inventory. *Educational Studies in Mathematics, 82*(1), 145–164.

McKenney, S., & Reeves, T. C. (2019). *Conducting Educational Design Research* (3rd ed.). Routledge.

Mislevy, R. J., Almond, R. G., & Lukas, J. F. (2003). A brief introduction to evidence-centered design. *ETS Research Report Series, 2003*(1), i–29.

Nadolski, R. J., Hummel, H. G. K., van den Brink, H. J., Hoefakker, R. E., Slootmaker, A., Kurvers, H. J., & Storm, J. (2008). EMERGO: A methodology and toolkit for developing serious games in higher education. *Simulation & Gaming, 39*(3), 338–352.

Oehrtman, M., Carlson, M., & Thompson, P. W. (2008). Foundational reasoning abilities that promote coherence in students' function understanding. *Making the connection: Research and Teaching in Undergraduate Mathematics Education, 27*, 42.

Sabourin, J. L., & Lester, J. C. (2014). Affect and engagement in game-based learning environments. *IEEE Transactions on Affective Computing, 5*(1), 45–56.

Shute, V., Wang, L., Greiff, S., Zhao, W., & Moore, G. (2016). Measuring problem solving skills via stealth assessment in an engaging video game. *Computers in Human Behavior, 63*, 106–117.

Sun, C., Wang, D., & Chan, H. (2011). How digital scaffolds in games direct problem-solving behaviors. *Computers & Education, 57*(3), 2118–2125.

Swidan, O., Schacht, F., Sabena, C., Fried, M., El-Sana, J., & Arzarello, F. (2019). Engaging students in covariational reasoning within an augmented reality environment. In *Augmented Reality in Educational Settings* (pp. 147–167). Brill Sense.

The Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*(1), 5–8.

Wouters, P., Van Nimwegen, C., Van Oostendorp, H., & Van Der Spek, E. D. (2013). *A meta-analysis of the cognitive and motivational effects of serious games*. American Psychological Association.

Zieffler, A. S., & Garfield, J. B. (2009). Modeling the growth of students' covariational reasoning during an introductory statistics course. *Statistics Education Research Journal, 8*(1).

Part III
Substantiating Game-Based Learning

Chapter 13
Instructional Design for Digital Game-Based Learning

Jacqueline Schuldt and Helmut Niegemann

13.1 Introduction

Digital games for learning are expected to satisfy several demands. Concerning graphics, game mechanics, joy of use, and excitement, users hope for a level of quality they know from their computer games used for fun. Entertainment is surely a standard for all kinds of games. Those who are concerned with learning—teachers, trainers, parents, or self-regulated learners—may expect an increase in motivation to learn the subject matter and give top priority to the efficiency of learning, i.e., sustainable success of learning (durable change of personality traits) in appropriate time. By a psychological point of view, playing games is similarly complex as is learning. Depending on the respective perspective, various categories of games can be differentiated and also can learning be analyzed in different ways.

Hence, a learning game should combine a certain level of entertainment with a certain amount of learning efficiency. Obviously, it is not sufficient to combine both aspects additively. Typical for an additive form of combination are games containing a developing interactive scenario or a sequence of them which is interrupted for a learning scenario, often without any consequences of the learning process for the game scenario and vice versa. On the contrary, there are games where learning processes are intrinsically integrated into the game's flow.

The critical point is whether the outcome of the learning process has an impact on the further game flow and provides some gain for the player/learner (joy of play and experience of success). This kind of combination requires the learning game

J. Schuldt (✉)
Technische Universität Ilmenau, Ilmenau, Germany
e-mail: jacqueline.schuldt@tu-ilmenau.de

H. Niegemann
Universität des Saarlandes, Saarbrücken, Germany

C. Aprea, D. Ifenthaler (eds.), *Game-based Learning Across the Disciplines*, Advances in Game-Based Learning, https://doi.org/10.1007/978-3-030-75142-5_13

designers to analyze the domain-specific knowledge and task structures and their relationships inside the virtual world of the game as well as inside the real world. Well-designed and successful games for learning offer the chance to get alternative access to the subject matter, to approach a topic playfully, and to practice methods without the virtual world falling apart into the world of the game and the world of learning.

The focus of this contribution is on possibilities to intermesh domain-specific knowledge and task structures with suitable game scenarios and game mechanics using examples from different domains. Furthermore, we will discuss the respective design decisions based on the DO ID framework model (Decision Oriented Instructional Design Model).

13.2 Instructional Design (ID)

Learning by computer games is possible, and it may be more effective than learning by conventional instruction (Wouters et al., 2013). "Possible" and "maybe" refer to certain conditions: To be effective, a learning game must meet high demands resulting from our knowledge of cognitive and motivational processes. To make these demands available to teachers, trainers, and instructional (game) designers instructional design models have been developed delivering recommendations. The Decision Oriented Instructional Design (DO ID) model (Fig. 13.1) is a framework model developed over the last 12 years (Niegemann, 2020; Niegemann et al., 2008) to support instructional design by providing sound scientific information to make efficient ID decisions. As scientific research is always in progress, there are no eternal rules but instructional design patterns that recommend what aspects should be considered referring to the current state of instructional psychology and technology research. The DO ID model represents three areas of instructional design: (1) A goal perspective and measures to ensure an appropriate standard of quality (external shell); (2) suitable procedures to analyze the needs, the relevant conditions, and the context of the planned instructional programs (second shell); and (3) the fields of concrete decisions to be made by instructional designers.

The *general goal* is not a specific learning objective but a strategic one: What is the prospect of the company or the organization initiating the education or training measure? This is especially important from the pedagogical point of view to decide on the selection of elements of the subject matter to be included or excluded from the learning program.

Also, at this time, the *standards of quality* should be made clear and the *way to ensure the quality* should be launched: establishing project management and starting to develop evaluation tools and design an evaluation strategy including usability aspects.

The next level comprises the necessary *analyses:* Similar to a medical diagnosis and treatment is based on a detailed anamnesis, the design of education or training program must be based on information on the internal and external learning

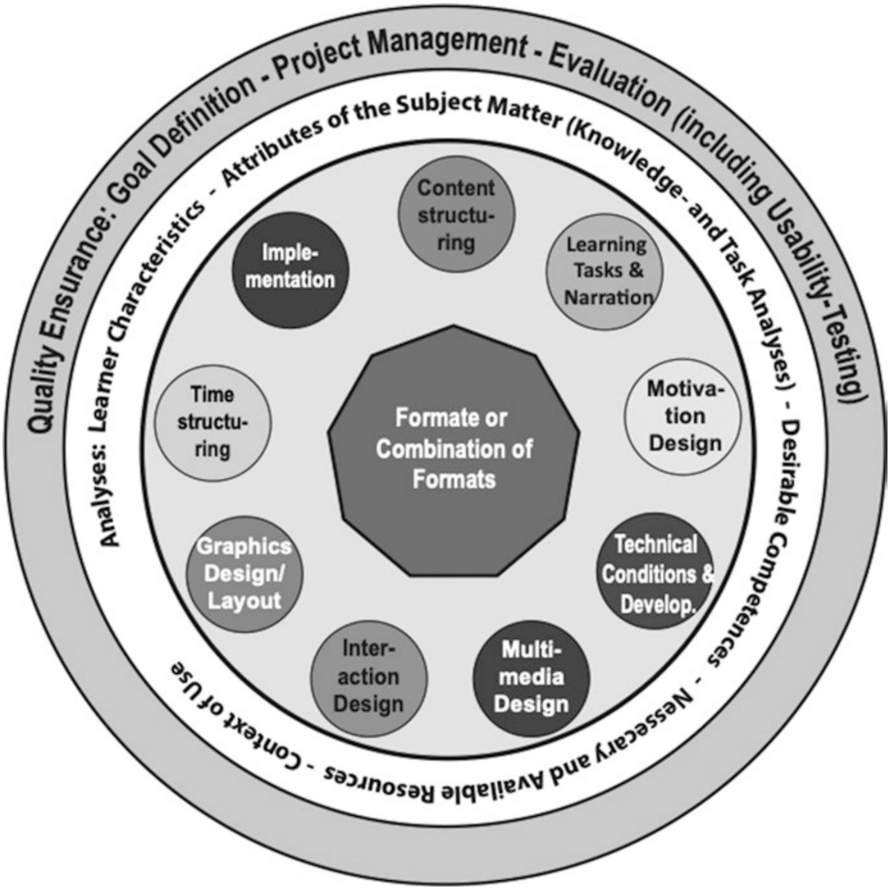


Fig. 13.1 Decision Oriented Instructional Design Model (Niegemann, 2020, p. 112)

conditions: relevant learner characteristics, attributes of the subject matter, the specific learning objectives or competencies, the available resources, and the context of the later use of the learning program. Questions to be answered are:

- What are the differences between the learners' prior knowledge and competencies and the desired competencies? Is there just a quantitative gap (missing knowledge or skills) or qualitative differences due to misconceptions (conceptual change)? To overcome misconceptions, it may be necessary to let the learners experience their original views are false. What about the presumable attitudes of the learners toward the subject matter? Are learners typically motivated to approach the subject matter? What emotions could be expected (boredom, interest, indifference, dislike,…)?
- What are the kinds of knowledge or the competences planned to convey by providing a learning program in detail? Task competencies are rather specific while

domain competences refer to a more holistic knowledge. Depending on the learner characteristics: what about the "depth" of the subject matter to be selected into a specific domain; e.g., due to the context of the later application: is it enough to convey physics knowledge on a Newton level or is a theoretically more "modern" level suitable? Games conveying task competencies will mostly include more exercise.

- Which elements of the subject matter (facts, concepts, relationships, principles, and theories) are relevant to be selected? Which are the criteria of relevance? Does the level of concept building refer to the context competencies should be applied in?
- What types of problems or tasks (from an instructional psychology point of view, e.g. Dörner, 1987; Jonassen, 2004) are typical in the relevant domain? Are there typical schemata of tasks (e.g., in math "amount-per-time," "distance-rate-time"; Mayer, 2008, p. 164 ff.) in the domain?

All that information provides the groundwork for any further decision.

While design decisions, in general, are not made following a specific sequence, the decision for the *format* should be made at first. Digital Game-Based Learning is one format with several *sub-formats*. A very popular sub-format is "learning adventures" (Egenfeldt-Nielsen, 2007, p. 70). A "learning adventure" game is based on an adventurous story, often with the main character (protagonist) who has to fulfill a task or to solve a problem in a more or less virtual world with sub-goals and virtually risky actions. Other subformats of game-based learning are jump-and-run games, memory games, shooter games (e.g., "Re-Mission 2"), strategy games (e.g., "Through the Darkest of Times", "Civilization"), sensomotoric training games (e.g., "Kinect Adventures!"), sports-simulation games (e.g. "FIFA", "AO Tennis 2"), hunting games (e.g., "Pokemon Go"), role-playing games (e.g., "Minecraft: Education Edition") social role-playing games (e.g., "The Sims"), and simulation games in a narrow sense (goal-based scenarios), etc.

Alexander Westphal (2009, p. 117) offers a classification of computer games from the point of view of interaction possibilities, whereby most games today, including educational games, have characteristics of several classes: skill games, adventure games, strategy games, simulations, and production games. Thus, the preferences of many players can be addressed.

Ratan and Ritterfeld (2009, p. 10) developed a classification system of serious games, which included four dimensions within which the games were categorized: primary educational content, primary learning principle, target age group, and platform.

In a wider sense, all games are in some way simulations (Tobias et al., 2011, pp. 129, 159), but not all simulations are games.

When the decision for a format and sub-format has been made, there are at least nine fields representing more or less evidence-based psychological principles to consider for further design decisions. These fields are not completely independent: Decisions made in one field may constraint or otherwise influence decisions concerning another field.

Content structuring demands decisions on the selection of elements or levels, the sequence, and the segmentation of the subject matter to be taught by the game. Based on the results of the analyses (learner characteristics, learning objectives, etc.) and external rules (e.g. school curriculum), design decisions concern the selection of knowledge pieces, the information density of the units, meaningful sequences of subject matter, etc.

The design of *learning tasks* is the main challenge of instructional design (van Merriënboer & Kirschner, 2018). A learning task should stimulate learners' mental operations in a way a desired cognitive structure is built up or strengthened. Learning tasks as the core of any instructional design project are always domain-specific, and they have to match game-specific challenges into the context of the narration. Question to be answered are:

- What about the complexity of the problems or tasks appropriate for the learners' abilities and the desired competencies?
- Does it make sense to differentiate hole tasks and part tasks (van Merriënboer & Kirschner, 2018) in more complex problems of the domain?
- Does the solution of problems or part tasks require specific knowledge the learners cannot be expected to have?
- How can transfer of learning be ensured from the world of the game to the world of work or everyday life or the world of a discipline in school or university? Is one complex problem with a series of part tasks sufficient or does transfer require a repetition (exercises) of tasks (e.g., different levels of a game)?

In practice, design decisions will not be processed in a clear sequence but more agile, so ideas concerning suitable plots will influence the decisions to select problem tasks.

In many sub-formats of games for learning the selection of learning, tasks are closely tied up with the *story (narration)* underlying the game. The tasks to be completed on the story level must match the structure of the learning tasks, which depends on the discipline.

- What types of cover stories are generally appropriate for the specific discipline or domain? Stories in general have typical deep structures depending on the culture in general and on the culture of a discipline ("story grammars", Thorndyke, 1977), and there are typical plot structures, which showed to be successful in the movie area (Tobias, 1993).
- Are there plots that can be modified to be used to integrate the sequence of domain-specific problems or tasks to a serious game?
- Are there any ethical aspects to be considered?

To be effective, the learning tasks have to be performed by the user (his/her character in the game), may be supported by other characters taking tutorial roles. To be effective for sustainable learning and transfer more than one task concerning, the same objective is necessary. Especially, in vocational education, the selection of the narration has to consider the context of utilization of the subject matter in real working life in the specific domain.

The fact that many people could be *motivated* by playing games does not mean they get automatically motivated to learn when engaged in playing a learning game. Learning and especially the transfer of learning have to be fostered specifically. Dedicated instructional design models like Keller's ARCS model could be applied fruitfully for learning games. But it should be clear that the motivation to play does not automatically transfer itself to a motivation to learn, especially stuff of a certain domain.

Design decisions on the *technical conditions* concern the devices used by learners. From an instructional design point of view, the different sizes of displays could be the main challenge for educational game design. While simple games for learning could be developed using e-learning authoring systems, more complex games are constructed using a dedicated engine. Decisions concerning the selection of the tools may constrain the use of the games on certain devices or display sizes.

As with the design of any instructional material containing more than one code (text, picture, and noise), the design of games for learning should consider the huge amount of experimental research on *multimedia learning* based on theories of cognitive load (e.g. Mayer, 2014, 2020). Even if not all "principles" are valid, under any circumstances, it seems highly recommendable to check the compatibility of the game design with applicable effects of multimedia learning research.

To foster *learning interactions* in a game (as in any other e-learning format), the realization should meet at least one of the "teaching functions" (Klauer, 1985): foster the motivation, providing information, ensure understanding, support remembering and recall, facilitate the transfer of knowledge, and/or organize or coordinate the instructional unit. Interactions, which do not fulfill a teaching task, could be superfluous or even hinder the learning process causing extraneous cognitive load. One of the most important categories of interactivity refers to feedback:

- What kind of feedback is possible and suitable after a learner tried a solution for a simple or a complex problem task? Immediate feedback to any part-task in order to enable a proper solution at the end of the learning unit or comprehensive feedback at the end of a complex problem to confront the learner with the "natural consequences" of his/her decisions?
- How much information (failure-related) should be provided as feedback (Narciss, 2008)?

Details of the *graphic design* decisions are mostly delegated to graphics design experts. From an instructional design perspective, aspects to be considered comprise: (a) the acceptance by the learners or other stakeholders (graphics style, 2D or 3D) which are mostly linked to the budget, (b) the accordance with the results of multimedia learning research (e.g., split-attention effect); *Split-attention* occurs when learners are required to split their attention between two or more mutually dependent sources of information (e.g., text and diagram), which have been separated either spatially or temporally. (Ayres & Cierniak, 2012).

Playing a learning game could take some time, and especially if the game should be used in the classroom, the designer has to consider typical time schedules in schools or other institutions. Also, the design of games to be used outside schools should consider *aspects of time*: breaks (should learners be able to suspend playing any time?), the typical length of a session (to be communicated in the beginning), and possible effects of cognitive depletion (depending on learner characteristics). The length of playing a learning game may also be judged by stakeholders concerning the opportunity cost of time: How much time does it take to successfully play a learning game and how much time is necessary to convey the same subject matter by another teaching method reaching the same results of learning?

Several ID experts see the implementation as an important part of the instructional design (Morrison et al., 2004). As with other formats of e-learning, the *implementation* of learning games in schools or organizations often needs an implementation strategy. The acceptance among stakeholders (in schools: principals, teachers, parents, students; in companies: chiefs, employee delegates, HR representatives, addressees) should be convinced of the advantages of the use of games for learning. Also, the availability of the technical equipment and support should be made sure in advance as well as the preparation of the addressees concerning the handling of the game software.

A specific problem of learning games is the "amount of invested mental effort" that was studied intensively by Salomon (1983, 1984) in the context of videos for learning. Salomon could show that the attitude toward the medium (comparing video and print) made a difference rather than the medium itself. Learners assume learning from videos will be much easier than learning from printed material performed worse under the video treatment due to investing less mental effort. Learning games could underlie the same effect, but Hawlitschek (2013) could not confirm this hypothesis for her game "1961" (history) comparing two versions.

We explain the game and domain-specific aspects of instructional design in three examples.

13.3 Examples for Domain-Specific Digital Games for Learning

In this section, we present examples of digital games for three different domains: History, STEM, and Ethics/Moral Development.

13.3.1 History: "1961" by A. Hawlitschek

The title "*1961*" of the game refers to the building of the Berlin Wall in 1961 by the East German Government (Fig. 13.2). The goal is initiating interest in the political events around the construction of the Berlin Wall and the consequences for the lives of people especially in East Berlin. Students should get a sense of the impact of the wall on everyday life. The prototype of the digital educational game "1961" was

Fig. 13.2 Screenshot of "1961" (http://www.1961.uni-halle.de/)

Fig. 13.3 Screenshot of "Serena Supergreen" (https://serena.thegoodevil.com/play/)

developed as part of a doctoral thesis and was accompanied by a research project at the University of Erfurt.

Learning with this educational game works and was evaluated within an empirical study at the University of Erfurt with more than 140 students from four grammar schools (Hawlitschek, 2013). A knowledge increase could be determined by playing the prototype of "1961," but what it couldn't accomplish is no deepening and structuring of the content, no answers to questions that arise for the students, and no questioning of the medium and the historical truthfulness of the game contents.

For this purpose, an e-learning application was developed to supplement the content and as a framework for integration in the classroom (www.1961.uni-halle.de/). "1961" consists of a digital learning game in the form of a point-and-click adventure and an associated e-learning application. Based on possible questions asked by the students, the e-learning application complements the learning game in terms of content and provides a framework for integration into the classroom. A variety of different materials are offered for this purpose. These are not only used to enrich the lessons but also to support the learning transfer of the students. Additional organizational and didactic hints are provided for the teachers.

The game is clearly not designed to substitute the teaching of the topic but to increase the learning motivation and to learn facts to ask questions.

This project was supported with funds from the "Bundesstiftung zur Aufarbeitung der SED-Diktatur," a Federal Foundation for coming to terms with the SED dictatorship.

The design of the game was part of research on the question, whether game-based learning would underlie an effect described by Salomon (1983, 1984): Learning requires an investment of mental effort, and results of learning will be poor if learners are convinced that the learning process will be easy and not mentally demanding (as is often in case of video-based learning compared to learning by printed material). Therefore, Hawlitschek designed originally two versions of the game, one with the explicit instruction to concentrate on the learning aspect. Contrary to the hypothesis learning this version was not better (Table 13.1).

13.3.2 STEM: "Serena Supergreen" funded by the German Federal Ministry of Education and Research and "Experimento Game" by Siemens Stiftung

Science, technology, engineering, and mathematics (STEM) is a term used to group together these academic disciplines. For this special domain, we would like to present two different digital games for learning.

The digital game "*Serena Supergreen and the broken wing*" was created as part of a research project "Serena" funded by the German Federal Ministry of Education and Research (2015–2019) and shows you jobs in renewable energies. The project Serena aimed at developing and evaluating a serious game providing individualized feedback to female adolescents (13–15 years) regarding their vocational competencies in the innovative field of renewable energy technologies. The serious game uses a point and click adventure to provide the girls with opportunities to explore the exciting working areas of technological vocations, and in doing so, to master typical challenges technicians are faced with when working in the renewable energy sector. The serious game is expected to contribute to (a) the acquisition of knowledge and competencies regarding technological vocations, in particular their typical tasks and challenges, (b) the development of interest in this vocational field, and (c) the increase of confidence in their abilities. Serious games can be particularly helpful for career orientation in areas where girls are underrepresented, such as science and technology. Girls playfully test job-related technical tasks and can experience that

Table 13.1 Game-specific aspects of the instructional design of the educational game "1961" in the discipline of history

Game-specific aspects of instructional design	"1961"
Knowledge-/Task-Analyses	"1961" is not only a memorable year, it is also the title of a multimedia learning environment for history teaching. It consists of two components: the digital educational game "1961", a Point and Click Adventure, and an e-learning application in which the game is embedded. The unit comprises two school hours including an introduction by a teacher and a discussion after the game is over. The game fits into the curriculum of eight to ten graders in Germany Learning goals: The students will … • know reasons for the construction of the Berlin Wall • trace the concrete events of August 13, 1961 • understand consequences of the construction of the Wall for the everyday lives of the people affected • experience a historical situation • become curious and motivated to ask questions about history An e-learning application complements and enriches the learning game "1961" It offers the students: • further information on various questions from the game • work and exercises • worksheets for dealing with the subject matter in the class
Narration/Story	A young boy owning a time machine lands on August 13, 1961 in East Berlin. As the battery of the machine is down, to go back he needs to get a new one, which is only available in West Berlin. But it is just the day the Berlin wall is erected. So he has to try ways to reach West Berlin, learning why this is difficult, what happens and why the wall is under construction, etc.
Motivation	The motivational design of "1961" is aimed at stimulating curiosity and exploratory behavior. After the start of the game, players go on a time travel into the past. The players are confronted with the problem, having to get batteries on the day the wall is built. This fatal situation of being caught in East Berlin and the seek for a possibility to overcome the just closing borders to get a battery, outlines a game situation that is not only novel and uncertain but is also characterized by the experience of incongruence The evaluation of "1961" showed that the greater the intrinsic motivation of the players, the more points they score in the retention and comprehension tests. The postulated connection between motivation and attention can also be proven. The greater the intrinsic motivation of the students, the more attention they pay to the content of the game
Interactivity	The game is a point-and-click adventure, where the player has to ask people or read documents to advance in the story and to experience different perspectives on the construction of the Berlin Wall. In each scene of the game, there are different objects with which the player can interact. Each object was assigned a specific function in the conception. In order to ensure the integration of game content and learning content, each learning-relevant object has both a function in the game or for the further course of the game and a didactic function. The didactic function of the objects is based on the learning objectives
Time	Duration: approx. 60–70 min; The mean length of the game is adapted to the 45′ schema of German school lessons. It should be used during a double unit of 90′
Technical aspects	The game "1961" requires: one computer per student and Internet access (operating system: Microsoft Windows, browser: Mozilla Firefox from version 24.0; Internet Explorer from version 10)

they succeed in mastering these tasks. These master experiences as well as the feedback strategies integrated into the game help to strengthen their ability concept for technical tasks. The point-and-click adventure aims to promote girls' self-concept and interest in technology-related tasks, focusing on entertainment and a strong connection between the player and game characters (models) that lead to an increase in learning (Spangenberger et al., 2019). The technical skills self-concept of girls is a factor that has a significant influence on whether girls even consider a technical profession.

The confrontation of the young people with the technical activities in the game and the successful completion of the tasks lead to the fact that the subject of technology is positively occupied after the game experience. This first step in the career orientation process aims to achieve openness to technology and to oppose a fundamentally negative attitude. Building on this, a practical connection to the game content and experience is created through practical experimentation. The students put technical activities from the game into practice, for example by soldering solar cells together. In the next step, the technical activities are evaluated using an online tool and assigned to specific occupations from the renewable energies division. Finally, the pupils use a guided Internet search to find out about a training occupation in the field of renewable energies that correspond to their interests (Table 13.2).

Another example for the domain STEM is presented subsequently.

The "*Experimento Game*" was developed in 2018 for STEM teaching in subjects Biology, Chemistry, Physics, and Technology by the Siemens Stiftung in cooperation with the Fraunhofer Institute for Digital Media Technology IDMT for the target group of students ages 11 to 13 in all types of schools. The game was developed for Experimento, an international education program that is directly related to the everyday lives of children and young people. The program focuses on independent experimentation, exploration, and comprehension of natural phenomena and technological developments that address the environment, energy, and health. Experimento emphasizes up-to-date materials pertaining to global challenges, such as the greenhouse effect, the use of renewable energy, or water filtration (https://medienportal.siemens-stiftung.org/en/experimento-matrix).

The "Experimento Game" is a point-and-click adventure (Fig. 13.4). It unfolds as a linear plot made up of two successive stories and integrates puzzles, search tasks, and combinatorial tasks:

- Story 1: We produce drinking water—methods of purifying water;
- Story 2: Waste incineration/waste separation.

The game starts with a tutorial phase that illustrates the controls in the game in an entertaining way (making a fire, setting up a tent, collecting items in a backpack, etc.). The players don't just watch how a figure experiences the story; they actively participate and control the figure. The story in the "Experimento Game" depends on the players' decisions in short dilemma situations and their success in the puzzle and skills exercises (Schuldt et al., 2018). The players go through a defined storyline, and they can choose one of three characters at the beginning of the game:

Table 13.2 Game-specific aspects of the instructional design of the educational game "Serena Supergreen" in the discipline of STEM

Game-specific aspects of instructional design	"Serena Supergreen"
Knowledge-Task-analyses	The game comes with a teaching unit that can also be carried out in extracurricular education. The unit comprises four school hours and is aimed at the 9/10 grade. The curricular integration of the game ensures that results and experience gained in the game also flow into the students' in-depth career choice Learning goals: The students will … • Analyze technical activities from the game, relate them to professional situations, and evaluate them in a way that is based on interests • Recognize and discuss sustainability references in game actions • Describe the qualification requirements of selected professions in the field of renewable energies and compare them with personal interests and skills • Reflect and evaluate professional perspectives in the industry • Develop professional goals, analyze personal motivational factors • Independently access, summarize and present professional information on web portals and audio-visual media
Narration/Story	In a fictional game world, players have to cope with technical tasks that are relevant in training professions in the fields of metal, electrical engineering, mechanical engineering, sanitary, heating and air conditioning technology, computer science, automotive technology, or chemical engineering. This is done without emphasizing the technical requirements
Motivation	The social component of technology and the integration of technical requirements into a sustainability context are also important in the game. The game builds on the motivation of young people to get involved in climate and environmental protection
Interactivity	By taking an active role in the game, which is a point-and-click adventure, the success of the action is attributed to your own abilities. Feedback strategies integrated in the story also helpless technically savvy young people to successfully complete the tasks. Such master experiences contribute to the strengthening of the own technical ability concept, an important step in the career orientation process
Time	The students play the point and click adventure "Serena Supergreen" in 3–5 h at school or home on their smartphone, tablet or PC. It is possible to save the game progress.
Technical aspects	The game "Serena Supergreen and the broken wing" is provided as a program for computers with Windows and OSX operating systems and as apps for iOS and Android devices (smartphones and tablets) There are three options to purchase the game: a. Download the game b. Mail delivery USB stick c. Appstore and Google Playstore

Fig. 13.4 Screenshot of "Experimento Game" (https://medienportal.siemens-stiftung.org/en/experimento-game)

Sappho, Dante, or Mokobe. In addition, the players can select a language: German, English, or Spanish.

The goal of the "Experimento Game" together with the associated teaching methods is to increase the students' awareness of the complexity of environment-related judgments, point out to them the necessary conditions for making a fair judgment, and create an understanding for others' judgments. They should become aware of their own interests and be able to analyze them. The digital game opens up new possibilities because the players are put in a dual role: First, they enter into the game world and the events taking place within it; second, they actively intervene in the events, therefore embracing them as their own.

Playing involves forms of learning. It thus helps in the acquisition of competences, knowledge, and experiences and simultaneously in experimentation and discovery. Learning occurs best when it describes an active process, when it is goal-oriented, contextualized, and interesting.

What value does game-based learning within "Experimento Game" add, compared to a real learning situation, especially in STEM contexts?

- It spurs motivation through immediate feedback (points).
- It creates opportunities to talk and makes room for discussion and reflection.
- The game can be used in a wide range of applications. It can be used to prepare for new learning material, to reinforce existing knowledge during class, or to summarize and review as a follow-up to the lesson.

What is the "Experimento Game" designed to accomplish?

- Generate intrinsic motivation in students to examine the topic of waste and water contamination.
- Pique students' interest in the topics of environmental awareness and sustainability and sensitize them to environmental issues.

- Create space and opportunities to speak for reflection: A reflection phase guided by the teacher following the serious game is crucial to value formation.
- Enable students to make decisions in a protected space without having to fear “real” consequences.
- Give students the opportunity to reflect on their behavior in the game and become aware of the reasons for their decisions (Table 13.3).

13.3.3 Ethics/Moral Development: “Catch 22” by J. Schuldt née Krebs

Digital games and their numerous decision-making situations can have an inestimable educational value. By acting morally in games, the player receives practical experience with morally correct decisions or maybe acting on immoral decisions by the consequences experienced (Wimmer, 2014, p. 277). The gaming experience meets the intellectual and emotional attitudes of the players. The players are forced to interact with the game-specific rules and ethics (Pohl, 2009, p. 279).

A moral dilemma can be a powerful source of conflict within digital games. Moral dilemmas are situations where players must weigh the consequences of their choices carefully because there are at least two or more values battling for the “pole position,” and there is no ideal answer (Krebs, 2013, p. 233). Moral dilemmas, intentionally or not, provoke the violation of the learned value system or have no happy ending. For players, virtual worlds thus represent worlds for self-construction, identity testing, and community experience. They are to be understood as a kind of social laboratory beyond physical resistance and real-world obstacles. So the morality of digital games is not only in what they say but in how they say it (Wimmer, 2014, p. 275). Moral dilemmas in digital games can thus make the player sensitize for real-world moral dilemmas and thus promote ethical reflection. An ideal scenario for a moral dilemma is one with the potential for good and bad decisions, with significant consequences for the course of the game.

“*Catch 22*” is an example of a digital game that was developed in 2013, at the Fraunhofer IDMT in Erfurt, to promote critical thinking and to educate moral reasoning through moral dilemmas (Krebs, 2013). Therefore, Kohlberg’s dilemma-discussion approach (Kohlberg, 1995) and its further development through Georg Lind (Lind, 2009) was combined with Haidt’s Social Intuitionist Model (Haidt, 2001) and implemented in a serious game called “Catch 22” (Krebs & Jantke, 2014). For this purpose, six dilemma situations referencing to Haidt’s moral foundations (Haidt, 2001) were designed:

- Harm/care
- Fairness/cheating (reciprocity)
- Loyalty/betrayal (ingroup)
- Authority/subversion (respect)
- Sanctity/degradation (purity)

Table 13.3 Game-specific aspects of the instructional design of the educational game "Experiment Game" in the discipline of STEM

Game-specific aspects of instructional design	"Experimento Game"
Knowledge Task Analyses	The game is closely related thematically to several experiments from Experimento|8+ and Experimento|10+ and can be used in the course of conducting these experiments. Main issue: Environmental pollution and destruction • Water contamination—water purification • Environmental pollution due to waste—waste disposal and waste separation (recycling) The students will… ● Understand the process of filtering water through a simple filter system ● Be able to reflect on the causes of water contamination ● Realize that not all pollutants and substances that are harmful to health can be identified with the naked eye ● Understand the filtering properties of the individual filter components ● Analyze their own practical experiences and opinions of waste separation ● Learn how to use resources responsibly
Narration/Story	Each dilemma story also includes a mini-game that offers the player the opportunity to collect points In a puzzle and skills exercise in connection with dilemma story 1, the player makes a water filter that is used in the course of the game to make the dirty stream water drinkable In a skills exercise in connection with dilemma story 2, the player separates waste
Motivation	During the "Experimento Game" the students collect points, which spurs motivation through immediate feedback. At the end of the game, the players receive a summary report on their decisions and the points they scored in the game
Interactivity	In these mini-games, the students learn on the one hand how to build a water filter and to determine the sequence of the individual components, and on the other hand how to separate waste. The students learn furthermore, especially in connection with the additional hands-on experiments and worksheets … ● To process and generate information by playing the game ● To use a new digital medium (computer game) in a reflective manner ● To approach problem-solving ● To give feedback ● To discuss and reason
Time	The game can be integrated into a regular lesson, playable in about 15 min
Technical aspects	The game can be started online or downloaded as a ZIP file for playing it offline. The users only need an up-to-date desktop browser to run the game Operating system: Windows, Mac, Linux

- Liberty/oppression

The player wanders around in a 3D world, has to solve quests, and deals thereby with various virtual people who involve the player in moral dilemmas (Fig. 13.5). The decision-making process follows ad hoc to the exposition and experience of the dilemma. Target of the game is to enhance critical thinking skills and to raise awareness of the complexity of moral reasoning. For this purpose, the reasons and objections, which count for the chosen position, are structured and arranged in argument maps (van Gelder, 2013, Figs. 13.6 and 13.7). As a design methodology storyboarding was deployed (Jantke & Knauf, 2005; Krebs & Jantke, 2014).

13.4 Discussion: Domain-Specific Aspects of Game Design

We don't know whether and how many learning games are designed systematically following an instructional design plan. So, we listed the above main questions to be answered from a joint instructional psychology, pedagogy (of the disciplines), and instructional design approach:

- In any case, a thorough analysis of the knowledge and task structure of the specific part of the subject matter as well as of the learner characteristics is indispensable. These analyses provide the information necessary to make rational design decisions. Games for learning science (e.g. "Experimento Game") will typically focus on *explanations* of physical, chemical, or biological phenomena, showing that specific observations could be explained by subsuming them under natural laws and their consequences. Activities will comprise thorough experimentation, observation, analyses, and inferences based on clear con-

Fig. 13.5 Screenshot of the exposition, confrontation, and decision of moral dilemmas in "Catch 22," example of harm/care

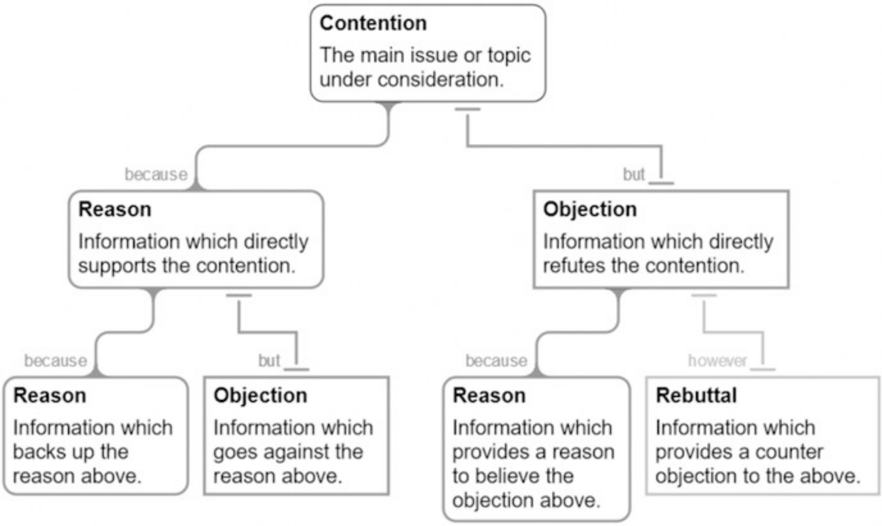


Fig. 13.6 Basic structure of an argument map (according to van Gelder, 2013)

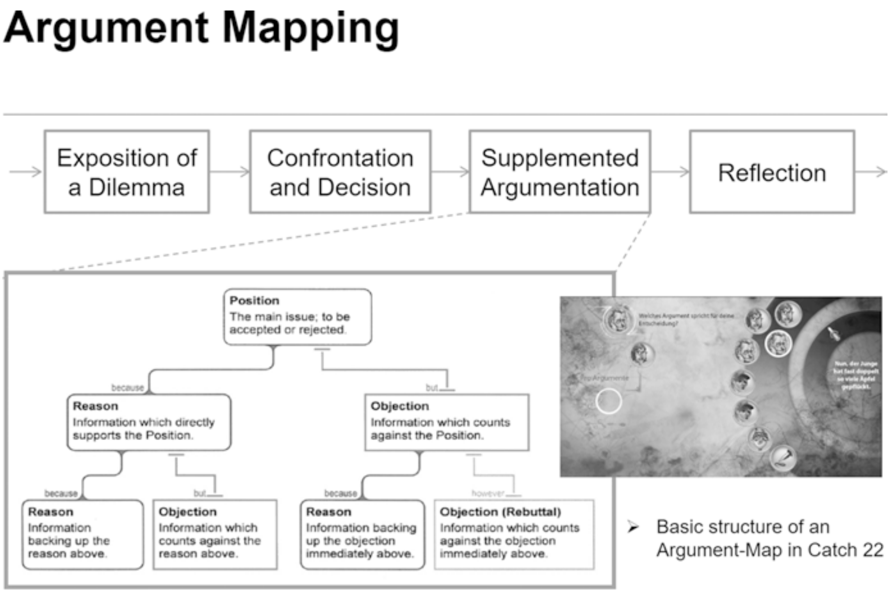


Fig. 13.7 Visualization of an argument map in "Catch 22." To create an argument map, the player chooses from different arguments (pros and cons) that speak for the decision made in the game (position). The player also has the possibility to write his own arguments. The resulting argument map can be printed out for further discussion in class (Table 13.4).

Table 13.4 Game-specific aspects of the instructional design of the educational game "Catch 22" in the discipline of Ethics/Moral

Game-specific aspects of instructional design	"Catch 22″
Knowledge–task–analyses	"Catch 22" intermeshes the altercation with dilemmas and gameplay, so players are involved in an adventure focusing on critical thinking, change of perspectives, and self-reflection. The game is using argument maps to illustrate the individual position and makes moral reasoning obvious. The game comes with a teaching unit and further dilemmas to discuss Learning goals: The students will … • evolve critical thinking • enhance moral reasoning
Narration/story	Within an adventurous story, six dilemma situations referencing to Haidt's moral foundations were designed. Using argument mapping within the game, the first step is to identify the players' main position in a dilemma situation. The game visualizes this, in a single, simple, and general sentence and pictures the available reasons and objections the player has gathered
Interactivity	Not uncommon in everyday life, different values compete with each other. Moral reasoning is an important factor for the sustainability of teaching values. Players make decisions within "Catch 22" in dilemma situations (moral dilemmas/conflict of values) and back up these decisions with arguments. They should critically question their own position. The dilemma discussions in the game actively stimulate a change of perspective, role assumption, and reflection
Motivation	Dealing with dilemma situations not only helps to learn which principles exist and which are most important for the respective individual, but rather values and norms are questioned and their consequences in everyday life are examined and reflected upon. A mystical story with 6 different moral dilemmas in 6 levels (following the MFT of Jonathan Haidt) can be played either with a male or female character, Andri or Elin The construction of "Argumentation Maps" is an innovative gameplay element (see Fig. 13.7). This kind of visualization can help our minds cope with the complexity of dilemmas in everyday life
Time	The students play the browser game "Catch 22" in 1–2 h at school or at home on PC
Technical aspects	The game "Catch 22" is a single-player adventure. The Browser game was created with Unity 3D

cepts and relationships. Games for history typically focus on the *understanding* of historical situations from a specific or from different perspectives (e.g. "1961"). Game activities will include conversations, asking questions, and making experiences to better reflect and understand factors influencing historical changes. Games for learning philosophical matters like basics of ethical or moral discourses will focus on the structure of argumentations, possible practical outcomes or consequences, always considering different values and value conflicts.

- Most games need a story. Subject matter should be integrated intrinsically (not additively) into the story which must fit the mentioned different objectives in different domains.
- Learners should have opportunities to make experiences and to observe the consequences. The consequences of learners' decisions and actions should be salient to provide sustainable feedback.
- Learning tasks should represent core elements of the domain-specific curriculum: learning by games takes a lot of time compared to conventional instruction; therefore, topics to be conveyed via games should be selected thoroughly by game developers and teachers.
- Interactions should contribute to at least one of the "teaching functions" (Klauer, 1985): motivate, provide information, ensure understanding, foster remembering and recall, foster transfer, or organize and coordinate the learning process. This includes considering the domain-specific prerequisites, contexts, and consequences of the particular actions of the learners to be enabled by interaction design.
- The level of graphics quality is less important than the structuring of the subject matter.
- Learning game design should consider aspects of time structuring (e.g., matching school lesson schemata).

13.5 Conclusions and Open Research Questions

Digital games have been divided in the literature into a number of subsidiary categories, including computer games, learning games, serious games, and instructional games (Tobias et al., 2011, p. 128). Over the years, educators, trainers, and researchers have recognized that using digital games in general, and serious games in particular, entails a number of very elementary problems. Those typically mentioned first relate to the constraints within an educational setting, e.g., installation, costs, short lessons, teacher preparation time, physical space, playing and learning falls apart, and variations in game competence among students.

Tobias et al., 2011 presented a comprehensive review on computer games and state that it had become clear "from reading the game literature that there is considerably more enthusiasm for describing the affordance of games and their motivating properties than for conducting research to demonstrate that these affordances are used to attain instructional aims, or to resolve problems found in prior research." In recent years, more studies and evaluations of educational games have been carried out as the examples presented show.

The DO ID model shows the most important decisions in instructional design and provides hints and possible design patterns that instructional designers can use to intermesh domain-specific knowledge and task structures with suitable game scenarios and game mechanics.

If a digital game for learning becomes boring, even the most careful attention to content and content structuring can be nullified by player and learner indifference, thereby negating one of the major advantages of games for use in instruction. Instructional Design for digital games for learning must incorporate motivational considerations dealing with whatever is needed, including entertainment, to engage players and learners.

Managing the trade-off between entertainment and instruction is likely to remain more of an art than a science, but instructional design for game-based learning and evaluations on digital games for learning will help to understand and solve this problem. We propose a holistic approach within an iterative design process, whether it comes to the evaluation or optimization of a digital game or eventually the redesign. Good usability and user experience are important for the acceptance of digital game-based learning approaches. Whereby good usability is usually not even noticed, in contrast to poor usability.

Regarding the conditions of efficient game-based learning in general, there are several open questions. Concerning the domain specificity, e.g.:

- Are there preferences of game genres to specific disciplines?
- Are there affinities of some categories of story schemas to domain-specific content structures?
- What are the conditions to avoid the effects Salomon (1984) found in learning with video compared to print learning material (reduced investment of mental effort) in the case of games?
- Does game-based learning—independent of the learning results in a special game—enhance the interest in a discipline? Under what conditions?

References

Ayres, P., & Cierniak, G. (2012). Split-attention effect. In N. M. Seel (Ed.), *Encyclopedia of the sciences of learning*. Springer.

Dörner, D. (1987). *Problemlösen als Informationsverarbeitung* (3rd ed.). Kohlhammer.

Egenfeldt-Nielsen, S. (2007). *Educational potential of computer games*. Continuum.

Haidt, J. (2001). The emotional dog and its rational tail: A social intuitionist approach to moral judgement. *Psychological Review, 108*, 814–834.

Hawlitschek, A. (2013). *Spielend lernen. Didaktisches Design digitaler Lernspiele zwischen Spielmotivation und Cognitive Load*. Logos.

Jantke, K. P. & Knauf, R. (2005). Didactic design through storyboarding: Standard concepts for standard tools. In Baltes, B. R., Edwards, L., & Galindo, F. (Eds.) (2005). *Proc. 4th Int. Symposium on Information and Communication Technologies*, Cape Town, South Africa, January 3–6, 2005, pp. 20–25. Trinity College Dublin, Ireland: Computer Science Press.

Jonassen, D. H. (2004). *Learning to solve problems. An instructional design guide*. Pfeiffer.

Klauer, K. J. (1985). Framework for a theory of teaching. *Teaching & Teacher Education, 1*(1), 5–17.

Kohlberg, L. (1995). *Die Psychologie der Moralentwicklung*. Suhrkamp Verlag.

Krebs, J. (2013). Moral Dilemmas in Serious Games. In *Proceedings of the 2013 International Conference on Advanced ICT* (pp. 232–236). Atlantis Press.

Krebs, J. & Jantke, K. P. (2014). Methods and technologies for wrapping - educational theory into serious games. In S. Zvacek (Ed.), *Proceedings of the 6th International Conference on Computer Supported Education*, Barcelona, Spain, 1–3 April, 2014 (p. 497–502). S.l.: SCITEPRESS.

Lind, G. (2009). *Moral ist lehrbar: Handbuch zur Theorie und Praxis moralischer und demokratischer Bildung* (2nd ed.). Oldenbourg Verlag.

Mayer, R. E. (2008). *Learning and Instruction* (2nd ed.). Pearson.

Mayer, R. E. (2014). Cognitive theory of multimedia learning. In R. E. Mayer (Ed.), *Cambridge handbooks in psychology. The Cambridge handbook of multimedia learning* (pp. 43–71). Cambridge University Press.

Mayer, R. (2020). *Multimedia learning* (3rd ed.). Cambridge University Press.

Morrison, G. R., Ross, S. M., & Kemp, J. E. (2004). *Designing effective instruction* (4th ed.). Wiley.

Narciss, S. (2008). Feedback strategies for interactive learning tasks. In J. M. Spector, M. D. Merrill, J. van Merriënboer, & M. P. Driscoll (Eds.), *Handbook of research on educational communications and technology* (3rd ed., pp. 125–143). L. Erlbaum Associates.

Niegemann, H. M., Domagk, S., Hessel, S., Hein, A., Hupfer, M., & Zobel, A. (2008). *Kompendium multimediales Lernen*. X.media.press, Springer.

Niegemann, H. (2020). *Instructional Design*. (S. 95-151). In H. Niegemann & A. Weinberger, A. (Hrsg.). Handbuch Bildungstechnologie. Berlin: Springer (https://doi.org/10.1007/978-3-662-54368-9_7)

Pohl, K. (2009). Just a game? Simulating moral issues. In S. Baumbach, H. Grabes, & A. Nünning (Eds.), *Literature and values. Literature as a medium for representing, disseminating and constructing norms and values* (pp. 279–292). WVT.

Ratan, R., & Ritterfeld, U. (2009). Classifying Serious Games. In M. J. Cody, P. Vorderer, & U. Ritterfeld (Eds.), *Serious games. Mechanisms and effects* (pp. S.10–S.24). Routledge.

Salomon, G. (1983). The differential investment of mental effort in learning from different sources. *Educational Psychologist, 18*, 42–50.

Salomon, G. (1984). Television is "easy" and print is "though": The differential investment of mental effort in learning as a function of perceptions and attributions. *Journal of Educational Psychology, 76*(4), 647–658.

Schuldt, J., Sachse, S., Hetsch, V., & Moss, K. J. (2018). The Experimento Game: enhancing a players' learning experience by embedding moral dilemmas in serious gaming modules. In M. Auer & D. Zutin (Eds.), *Online engineering & internet of things. Lecture notes in networks and systems* (Vol. 22). Springer.

Spangenberger, P., Kruse, L., & Kapp, F. (2019). Serious games as innovative approach to address gender differences in career choice. In M. Gentile, M. Allegra, & H. Söbke (Eds.), *Games and learning alliance. GALA 2018* (Lecture notes in computer science) (Vol. 11385). Springer.

Thorndyke, P. W. (1977). Cognitive studies in comprehension and memory of narrative discourse. *Cognitive Psychology, 9*, 77–100.

Tobias, R. B. (1993). *20 Master Plots (and how to build them)*. F&W Publications.

Tobias, S., Fletcher, J. D., Dai, D. Y., & Wind, A. P. (2011). Review of research on computer games. In S. Tobias & J. D. Fletcher (Eds.), *Computer games and instruction* (pp. 127–221). New Age Publishers.

van Gelder, T. (2013). Argument mapping. In H. Pashler (Ed.), *Encyclopedia of the Mind*. Sage.

van Merriënboer, J. J. G., & Kirschner, P. A. (2018). Ten steps to complex learning. In *A systematic approach to four-component instructional design* (3th ed.). Routledge Taylor & Francis.

Westphal, A. (2009). Die Einbettung von Lerninhalten in Serious Games. In J. Sieck & M. A. Herzog (Eds.), *Kultur und Informatik. Serious Games. (Game studies, Als Typoskript gedr)*. vwh Hülsbusch.

Wimmer, J. (2014). Moralische Dilemmata in digitalen Spielen. Wie Computergames die ethische Reflexion fördern können. *ComSoc Communicatio Socialis, 47*(3), 274–282.

Wouters, P., van Nijmwegen, C., van Oostendorp, H., & van der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games. *Journal of Educational Psychology, 105*(2), 249–265. https://doi.org/10.1037/a0031311

Chapter 14
Play Attention: Thinking Like a Game Designer with Online Instructional Design

Christopher Lindberg and Meghan Naxer

14.1 Introduction

While much has been written about games and learning, a deeper understanding of what using games as learning tools can mean, as well as how games can look in learning environments, has historically been neglected by practitioners and instructional designers. Additionally, early research in gamification and Game-based learning (GBL) studies did not focus on motivational changes, such as extrinsic and intrinsic motivating factors, instead favoring student performance and time-based engagement as metrics (e.g., Landers & Landers, 2014). Often, game elements are simply pasted into learning modules as a fun, but optional, way to learn or practice some material. However, recent trends are showing an increased interest in measuring the motivation of student learning (Antonaci et al., 2019).

While it is nice and can be helpful, for educators to include games "on the side" of course content, we argue that games and game mechanics can more effectively be used to enhance students' motivation if they are incorporated into course design at inception, discussed as a systems-level approach. This approach is recommended because games have the potential to utilize elements of motivation in a way that is distinct from other instructional techniques (Fullerton, 2014; Juul, 2013; Rigby & Ryan, 2011).

In this chapter, we will provide a rationale for why game-based learning can be impactful and describe a strategy for thinking like a pedagogue and a game designer simultaneously. While these strategies have been effective in our work, based on student and instructor feedback, future research is needed to gather more definitive evidence. By building off of research from various fields, including game-based

C. Lindberg (✉) · M. Naxer
Oregon State University, Corvallis, OR, USA
e-mail: lindbech@oregonstate.edu; meghan.naxer@oregonstate.edu

C. Aprea, D. Ifenthaler (eds.), *Game-based Learning Across the Disciplines*, Advances in Game-Based Learning, https://doi.org/10.1007/978-3-030-75142-5_14

learning, Self-Determination Theory, and game design research, this theoretical review provides practical applications in the form of examples from our own work that can start a conversation about combining game design and instructional design practices. We will describe how principles of game design can be incorporated into online educational contexts to transform students' motivation by satisfying their psychological needs for autonomy, competence, and relatedness (Ryan & Deci, 2017). The theoretical background of Self-Determination Theory (SDT) provides a foundation for the interrelationship between game design, instructional design, and motivation. Then, we will focus on the principles of game mechanics and gameplay as applied to online higher education, and review how these game elements are currently being implemented in educational contexts. Finally, we will propose a way for educators to use motivational and pedagogical theory, as well as the principles of game mechanics and gameplay, to enhance student motivation. We will discuss these two game elements, gameplay, and game mechanics, as the means to bring GBL into the design at a systems level, incorporating it into conventional instructional design processes. This chapter ends with how we have successfully implemented these ideas into online courses across diverse disciplines and looking ahead to future possibilities.

14.2 Self-Determination Theory

Self-Determination Theory (SDT) has often been cited as a theoretical basis for gamification and GBL (e.g., Rigby & Ryan, 2011; Ryan & Rigby, 2019), and can be used to explain how and why GBL can be a compelling method for increasing students' motivation. In the "self-determination continuum," Gagné and Deci (2005) posit that individuals can be motivated to complete a task due to either intrinsic or extrinsic origins. Extrinsic motivation describes behavior that is accomplished because the individual perceives some sort of reward separate from the task. Extrinsic "rewards" can be conceptualized on a continuum, with rewards and punishments for task completion or incompletion ("external regulation") being the most "removed" from the individual. In an educational context, an example of external regulation could be a student learning material because they perceive that they need to pass the course to obtain employment after graduation. In this example, a diploma would be the perceived reward for learning. A slightly less "removed" form of motivation includes ego-involvement and self-worth contingencies ("introjected regulation"), such as a student studying so that they can feel "smart." Other forms of extrinsic motivation that are less "removed" from the individual include "identified regulation" and "integrated regulation," which describes task completion because the task fits in with the individual's goals, values, and regulations. While these four forms of motivation may look, and be conceptualized, differently, they all fall under the broader category of "extrinsic motivation" because they describe motivation as derived from a source that is separate from the task itself. In contrast, intrinsic motivation describes behavior that is accomplished because the individual enjoys, or derives satisfaction, from the task itself (Gagné & Deci, 2005). Intrinsic motivation brings people closer to well-being through needs satisfaction. It puts them on that pathway to engaging experiences, improving “people’s motivation to persist” (Ryan & Rigby, 2019, p. 158), as already mentioned.

While instructors may hope that students are intrinsically motivated during their courses, there are numerous reasons why that may or may not be the case. However, by acknowledging a range of types of motivation, we can consider ways of designing that will encourage and aid students in moving closer toward intrinsic motivation. When implementing GBL designs, our goal for this implementation is to shift motivation across the spectrum, from extrinsic to identified and integrated regulation then, if possible, to intrinsic motivation.

When conceptualizing extrinsic and intrinsic motivation, work by Deci and Ryan (e.g., Deci & Ryan, 2000; Ryan & Deci, 2000; Ryan & Deci, 2017) suggests that humans need three psychological components to achieve well-being. The first need, autonomy, describes the need for individuals to consider their own values, and self-regulate their behaviors and experiences accordingly. The second need, competence, describes the need for individuals to feel effective at what they do. The third need, relatedness, describes the need for individuals to feel connected to and valued by other individuals, and to feel belongingness in their communities. If these three psychological needs are not met, individuals will have trouble achieving optimal motivation, in educational contexts, as well as in other areas.

Social environments can play a large role in whether the needs for autonomy, competence, and relatedness are met (e.g., Deci & Ryan, 2000; Ryan & Deci, 2000; Ryan & Deci, 2017). For example, demanding or controlling environments can threaten individuals’ need for autonomy. Discouraging environments, or environments devoid of positive feedback for quality work, can threaten individuals’ need for competence. Impersonal environments, or environments that reject certain groups of people, can threaten individuals’ need for relatedness. Therefore, when considering student motivation in educational contexts, it is important to consider what may or may not meet learners’ needs.

Several elements of design can promote optimal student motivation (Naxer, 2019). For example, students’ need for autonomy can be enhanced if students are given enough resources to make course content personal to them. To accomplish this, some educators may provide additional reading material for students interested in certain content, allow students to come up with their own examples that illustrate concepts or allow students to make meaningful decisions about how they will go about completing course objectives. Students’ need for competence can be enhanced as educators set realistic expectations, provide clear objectives, scaffold course content, and provide positive feedback. Lastly, students’ need for relatedness can be enhanced as educators interact with their students, encourage students to interact and collaborate with each other, and implement inclusive practices in course design and teaching.

Not only does SDT outline the needs and supports of learners in an educational context, but it also outlines how these needs can be met in virtual worlds and video games. “Simply put, basic need satisfaction was found to be the pathway to both enjoyable and engaging game experiences and to people's motivation to persist in them" (Ryan & Rigby, 2019, p. 158). To go a step further, there is even more overlap between potential SDT applications in online education by considering that the online environment has the potential to be a "virtual world" that can provide or simulate experiences that may not be possible in face-to-face environments (Thomas et al., 2019). Therefore, effective techniques in other forms of virtual worlds, such as the worlds created in video games, can inform the usage of gaming in education.

14.2.1 Examples of Self-Determination Theory in Gaming Contexts

Salen and Zimmerman (2003) have identified four traits, or capacities, of digital games: immediate but narrow interactivity, information manipulation, automated complex systems, and networked communication. These four traits are defined and described below, followed by commentary about how each of these traits can support learners' needs as identified by SDT. This information can be used to explore how autonomy, competence, and relatedness can be supported within online gaming environments (Tables 14.1, 14.2, 14.3, and 14.4).

Online course designs can often benefit from some of the same traits of digital games outlined earlier. Therefore, educators such as instructors, faculty, and instructional designers can implement competence-, autonomy-, and relatedness-supportive design structures into the GBL systems they create. While including any one of these supportive designs can impact motivation, implementing two or all three of these elements can strengthen the motivational pull for students by fulfilling more needs. In addition to understanding how SDT can be applied to enhance motivation, as well as understanding how games can provide psychological need fulfillment for autonomy, competence, and relatedness, it is important to understand two key game elements, game mechanics and gameplay, to successfully integrate game-based learning.

Table 14.1 Immediate but Narrow Interactivity (Salen & Zimmerman, 2003; p. 87)

Description of trait	How each trait supports autonomy, competence, and relatedness
Many digital games are able to offer immediate feedback to players. For example, the game can provide feedback to the player about their performance, letting the player know if they have succeeded or not succeeded in the task. While this feedback can be helpful, it is often limited, especially if the player has not yet "succeeded," as the games often provide hints toward the correct answer, but not the correct answer. Although limited, much of this kind of feedback tends to be positive and varied in type. For example, different games can provide granular, sustained, and cumulative feedback at different times (Ryan & Deci, 2017, p. 514)	*Competence*: Behaviors such as positive feedback and scaffolding can fulfill individuals' need for competence. Therefore, the interactivity and feedback within digital games have the potential to enhance players' competence

Table 14.2 Information Manipulation (Salen & Zimmerman, 2003 p. 88)

Description of trait	How each trait supports autonomy, competence, and relatedness
Games can store vast amounts of data, including graphics, audio, and text. This digital data can be manipulated in numerous ways, from gradually introducing rules as the game is played, to withholding information from players when creating moments of uncertainty	*Autonomy and Competence*: Individuals' need for competence can be satisfied if goals are clearly outlined, and their need for autonomy can be satisfied when given choices on how to proceed with their goals. The informational manipulation trait can satisfy both of these needs. Games can communicate goals in numerous ways, through both text and visual cues, and can even obscure goals through a lack of information to encourage free exploration, as well as adjust the game's difficulty. Games that offer players choices over what to do and strategies to pursue are also autonomy-supportive, especially when players can control the amounts and types of information they receive and interact with *Competence*: The information manipulation feature of digital games can also enhance the game's interface in regards to smoothness, intuitiveness, and accessibility. This intuitiveness allows players to quickly grasp the interface of games, allowing them to focus more on the game's goals. As confirmed by Ryan and Deci (2017), "The more intuitive the controls, the less the players are aware of them, and the more effectiveness and mastery they feel in their engagement" (p. 515)

Table 14.3 Automated Complex Systems (Salen & Zimmerman, 2003, p. 88)

Description of trait	How each trait supports autonomy, competence, and relatedness
Digital games can automate complex systems, or game procedures, within the game, such as the process of moving a player up or down a level. This feature can be used to make the game either easier or more difficult, depending on the player's past and current performance. In other words, these complicated procedures can be automated to facilitate playability, but can also be used to obscure rules and mechanics	*Competence*: Leveling systems within games, or processes that determine whether a player progresses to more or less difficult versions of the game, are often automated based on players' past performance (the player's "stats") and progression. If a player achieves a certain level of performance, as defined by the game designers, then the player is automatically moved to a higher level, or more difficult version, in the game. These leveling systems can also be a form of scaffolding, as the players are slowly introduced to new objectives, and more difficult versions, of the same kinds of tasks

14.3 Game Mechanics and Gameplay

Some interesting schools of thought have emerged that begin to clarify how game elements can be used effectively in learning, particularly to improve the motivation of learners (e.g., Eseryel et al., 2014; Plass et al., 2020). Now that we have described SDT in the context of digital games, it is important to note here that the satisfaction of SDT's psychological needs for autonomy, competence, and relatedness comes not from the superficial game content and thematic settings, but the mechanics under the hood—game systems and game design. To better discuss these game

Table 14.4 Networked Communication (Salen & Zimmerman, 2003, p. 89)

Description of trait	How each trait supports autonomy, competence, and relatedness
Digital games can facilitate communication between players in a way that is varied and integrated into the design. For example, games can provide text or audio messaging abilities so that players can communicate with other people who are also playing the game, allowing players to team up with, or compete with, each other. Games can also provide means of communication for players to communicate with non-playable characters (NPCs), or characters that exist within the game that are not controlled by other players. These forms of networked communication can turn games into their own form of social communication	*Autonomy*: Some games provide players with the option of choosing or creating a "within-game character" that represents the player. Players can use this character to interact with the game interface, NPCs, as well as other players within the game. When individuals are allowed to create their own character, that process can satisfy individuals' need for autonomy because they are allowed to create a "virtual self" and make meaningful decisions about how they will exist within the game. In other words, these games allow players to make choices in how to represent themselves as they communicate with others within the game *Relatedness*: Some games reward cooperative play and teamwork by designing tasks that are easier with cooperation between multiple players of the game. These games can further fulfill players' need for relatedness, as they encourage players to collaborate with, as opposed to compete with each other *Relatedness*: Non-playable characters (NPCs) within games can provide additional interaction possibilities for players within the game. Many games design NPCs that are interactive and reactive to the player. This feature can further simulate social environments within the game, which can further fulfill players' need for relatedness

elements, we would like to take a moment to consider the smaller building blocks of games: gameplay and mechanics, which are important concepts to understand when considering game-based learning.

Gameplay includes the rules, world logic, objectives, and challenges set by a game for its players, but also the experience a player gains when interacting with these elements. Game Mechanics are the specific methods given to a player to interact with these rules. They are the tools given to a player to interact with the logic of a game to meet the objectives and challenges. These same principles can easily fit into an instructional design setting, as courses and online environments also set up the rules, logic, objectives, and challenges for students. In turn, students are given avenues for interacting with those rules, systems, and content to meet objectives and challenges to gain a particular experience (Deterding et al., 2011; Sicart, 2008).

In chess, capturing the opponent's king, or checkmate, is an element of the gameplay. The rules about how a Knight or the Queen move are also part of gameplay. These are the challenges and rules set by the game. A player's strategy for achieving a checkmate is also part of the experience included in the gameplay. The chess pieces themselves, the checkered 8 × 8 chessboard, and turn-based moves are the mechanics. These are the tools by which each player interacts with the rules of the game.

It has been observed that "successful video games are highly motivating and can foster both deep and long-term engagement" (Ryan & Rigby, 2019, p. 158). Therefore, gameplay and game mechanics are of interest to educators because they are the basic tools used by game designers, and available to educational designers, in creating these motivating experiences. For example, many video games can be difficult and demanding; however, many people choose to play these games during their free time! In narrative-rich roleplaying games that are particularly autonomy-supportive, we have spent hundreds of hours exploring both our characters' relationship with non-playable characters (NPCs) and the effect of our choices on the game world, sometimes resulting in playing the same game numerous times with different characters. We can also attest to spending hours wandering around a dangerous dinosaur-laden world "grinding" through the collection of resources to put together a recipe for building a personal spyglass (so as to be able to examine dinosaurs from a safe distance).

So, what are the game mechanics and gameplay found in digital games? The following is a list, adapted from Plass et al. (2015), of some of the more common components, though not all games will incorporate all of these. This list is curated to include the gameplay and game mechanics that might be of greatest interest in designing learning activities (Table 14.5).

Game Mechanics
- Visual aesthetics
- Narrative
- Clear player interface
- Incentive structures built into games (leveling up, unlocking abilities)
- Feedback mechanisms (story changes, NPC dialogue interaction, unlocking levels)
- Inventory systems for resource management

Other Elements Found in or connected to Modern Games
- Game Wikis, game communities, YouTube, live streams, and let's plays (Twitch)

Educators can seek to leverage the intrinsic motivation observed in gameplay and game mechanics in their learning environments, as shown in this list of curated game elements. It is important to remember that "Mechanics alone are insufficient to turn a boring experience into a game-like engaging experience, but they are crucial building blocks used during the gamification process" (Kapp, 2012, p. 11). To be successful, game mechanics and gameplay should be used with intent—used as tools to access inherent motivation and needs satisfaction through the lens of Self-Determination Theory. Therefore, educators who wish to optimally incorporate game elements into their coursework can use game mechanics and gameplay to intentionally satisfy learners' needs for autonomy, competence, and relatedness, thereby providing an ideal environment for student motivation.

We have identified two strategies that educators are currently using to incorporate game elements into learning, namely, gamification and game-based learning.

Table 14.5 Gameplay

Gameplay element	Pedagogical examples	SDT examples
There is logic or set of rules that are understood, or discoverable, by the player.	Rubrics Activity instructions Syllabus	Competence Autonomy
The rules, logic, or goals of the game are challenging, but this does not necessarily mean conflict is involved.	Bloom's Taxonomy (Anderson & Krathwohl, 2001) Cognitive levels of analysis	Competence
The game logic builds a world, or community, in which the player participates; sometimes known as world building.	Experiential learning Simulations	Relatedness
Flow Theory, which is balancing difficulty and player ability in an upward trajectory over time, (Csikszentmihalyi & Csikszentmihalyi, 1992) often plateaus at important moments in the narrative culminating in a climax or boss encounter.	Scaffolded activities Learning objectives Exams	Competence
Players can make choices in this world and interact with Non-Player Characters (NPCs). These choices have an effect. The world of the game is responsive to player actions; world building and world inhabiting.	Active learning	Autonomy
Actions by the player have quantifiable outcomes. Success or failure is measurable and observable.	Course learning outcomes	Competence
Progress in the game world is cumulative in some way. Progress is made and observable.	Scaffolded activities Cumulative assessments	Competence
Players are given autonomy support to interact with the world, thus motivating them to engage in that world.	Feedback Peer reviews	Autonomy
Integration of social elements—NPCs or other players.	Peer reviews Discussions	Relatedness

Each of these strategies has strengths and weaknesses, as well as opportunities for improvement in their execution. We review and contrast these strategies below in terms of their implementation. Our emphasis is that while gamification is often implemented at a surface level, game-based learning is more effective because it is implemented at a systems level. After we review these strategies, we elaborate on how we have utilized gameplay and game mechanics, as well as SDT, to incorporate game elements at a systems level into learning modules.

14.3.1 Reviewing the Use of Gamification in Education

Gamification as a term has been in use since the early 2010s, with definitions and techniques focusing on the implementation of game elements for non-game contexts. Deterding et al. (2011) first defined gamification as "the use of game design elements in non-game contexts" (p. 10). Specifically, in education, Kapp (2012) elaborated that gamification is "using game-based mechanics, aesthetics and game thinking to engage people, motivate action, promote learning, and solve problems" (p. 23). Plass et al. (2015) added further insight and clarity to these definitions by noting that these game elements are added to an existing nongame activity, rather than incorporated as part of the systems-level design. We agree with Seaborn and Fels (2015), who further explained that "the inconsistent use of the term 'gamification' serves to impede attempts to define it but also exposes its multiplicity. This raises questions about the real differences between gamification and games and complicates how to draw the line between systems that incorporate some aspects of games and systems that are or use fully-fledged games" (p. 18). In short, while gamification has a broad definition, its common usage often equates to any element of gaming, games, or game design used for educational purposes, making it a catch-all term that has led to widespread misconceptions and misunderstandings from its initial definitions.

We argue that adding game elements to course design at a systems level, rather than on a surface level, can more effectively enhance students' motivation to learn. Where outcomes and goals drive the design process, a systems-level approach is incorporating games and game design into the process at the outset, instead of on a surface level, which would only apply those elements near the conclusion of the design process. This strategy allows educational designers to think in a game context and is the same process game designers use. Although the end product may not appear like a game, adding game mechanics at the systems level is essentially turning the learning activity into a game by using the online learning environment's built-in tools (i.e., learning management systems). Ryan and Rigby (2019) further explain that "if learning material is not in that (SDT) satisfaction loop, it will not benefit from being loosely juxtaposed near game content. In this circumstance, game content becomes a competitor for attention and engagement rather than a conduit for deeper learning" (p. 159). In this context, the (SDT) satisfaction loop is parallel to positive reinforcement loops as described by behaviorism, but differs in that rewards are internal and associated with autonomy, competence, and relatedness needs instead of external rewards.

Plass et al. (2019) have defined game-based learning (GBL) as educational learning activities that have been redesigned to include the full range of game mechanics and design in a gaming context. This results in a learning game or a game with specific learning objectives. Here, the idea emerges of the learning material being designed as a game at its roots. The game-based learning approach tries to balance learning outcomes with game mechanics, resulting in learning activities and materials that are more relevant and interesting (Plass et al., 2019). In other words, game-based learning does not add game elements on top of an existing learning component, the learning component is designed from the ground up, at a systems level, using game mechanics and game thinking in the pedagogical design. Using a systems-level approach gives a designer an opportunity to set learning goals and outcomes, select appropriate gameplay and game mechanics, and also consider the psychological needs of SDT from the start of the process. An educational designer can achieve an effective design with an understanding of pedagogies to reach the educational outcomes with an understanding of gameplay and game mechanics to achieve motivational goals.

The Systems-Level approach entails wearing two different hats: a game designer and an instructional designer. While the goals and intentionality of games and learning seem very different, there are many similarities. Both talk about creating intentional environments. Both benefit from user motivation. Many aspects of designing a game and designing an educational experience are not that different. As Salen and Zimmerman (2003) define, "game design is the process by which a game designer creates a game, to be encountered by a player, from which meaningful play emerges" (p. 80). The "meaningful play" aspect can be summarized as the relationship that forms between the actions of the player and the outcomes in the game, which should be both observable and integrated into the context of the game. Likewise, designing a learning activity using GBL is the process by which an instructional designer creates an educational experience, to be encountered by a learner, from which "meaningful play" emerges. Therefore, a learning component is designed using game mechanics and game thinking in the pedagogical design.

14.4 Thinking Like a Designer

As evidenced earlier, the application and act of design for games and GBL are not dissimilar. In fact, Hunicke et al. (2004) outline the MDA (Mechanics, Dynamics, Aesthetics) framework for game design that "formalizes the consumption of games by breaking them down into their distinct components and establishing their design counterparts" (p. 2). This framework also mirrors the work in education on backward design (Wiggins & McTighe, 2005), which advocates designing courses and curriculums first by considering learning outcomes and cognitive level (rules/mechanics), then activity and assessment alignment (system/dynamics), and finally to content (fun/aesthetics). This mapping between backward design and Hunicke et al.'s (2004) MDA Framework is not exactly a 1:1 match, but the concept of designing an experience in reverse of the player/learner experience is the goal in juxtaposing these two frameworks, as seen in Fig. 14.1. One additional step during this phase would be to consider player/learner motivation and designing these three pillars with SDT in mind.

While taking all of these theories into practical application, it may seem like a daunting task. However, small changes can lead to big results. Even when making changes or additions at a systems level, those changes don't need to be extensive or complicated.

1. *Think about outcomes.* What is the goal of the activity? What do students gain and experience from this activity? What rules need to be established so those outcomes can be met by all students?

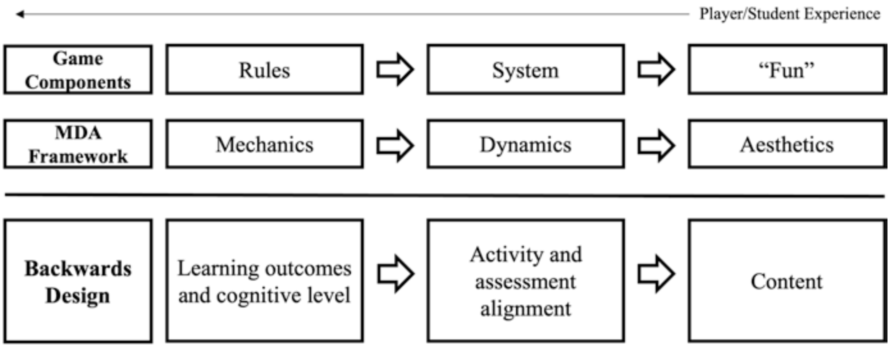


Fig. 14.1 Game components and MDA Framework as described by Hunicke et al. (2004) and Backwards Design (Wiggins & McTighe, 2005) shown in tandem

(a) What cognitive level is intended by these outcomes and rules? (e.g., critical analysis, peer teaching, active learning, etc.)
(b) At this stage, try to think big enough to keep content-specific considerations for a later step. Outside of discipline-specific goals, what is the big picture?

2. *Consider the three components of SDT (competence, autonomy, and relatedness).* How will one or more of these needs be satisfied to attain the desired cognitive level? The desired motivation? What need might students be lacking most during the activity while attempting to reach the desired outcomes? Confidence in their own abilities? Their ability to make meaningful and volitional choices? Connection to their peers?
3. *What mechanics, activity type, and assessment/feedback are needed to realize the first two steps?* These might be more game-like in nature (e.g., world-building, character creation, role-playing, etc.) or more pedagogical in nature (e.g., discussions, peer reviews, online interactive, etc.).
4. *Finally, how is content woven into these mechanics?* Is a psychological needs-satisfaction loop present after incorporating content?

Working through these steps may begin in an ordered and linear fashion, but as different elements change during the creative design process, it may be necessary to revisit earlier steps or consider later ones that are implicated in the change. If a mechanic changes, you might need to alter the SDT support, which might also necessitate revisiting outcomes. Like both backward design and the MDA Framework, these steps are more meant as a guide for creative design. Additionally, by placing content as the last step instead of a first step, this process is inherently valuable to multiple disciplines. Part of the systems-level approach and early steps require a designer to consider the task and design at a more abstract level before inserting discipline-specific content and idiosyncrasies.

Another distinction to consider during this design process is how the resulting design will look and feel. Landers (2019) explains that due "to construct confusion among both scholars and practitioners regarding the relationships between the term "gamified" and other game-related terms … gamification may or may not result in the creation of a game" (p. 137). While it is generally understood that game-based learning techniques will result in the creation of a game (Plass et al., 2019), we would like to argue that due to the close connection of design techniques in both pedagogy and games, the resulting design does not necessarily need to look and/or feel like a gaming experience to have an effect on student motivation. In fact, because some game mechanics and visual game cues might make students aware that they are in a "game-based" or "gamified" environment, especially when using points, badges, and leaderboards, students may respond apprehensively toward these applications (Hanus & Fox, 2015). In some situations, a more traditional game presence around an activity might not enhance the learning outcomes or motivational goals of SDT. In other words, ask yourself whether there is a pedagogical reason for adding additional game-like effects.

14.4.1 Examples from Online Higher Education

How do we apply thinking like a designer and systems-level design to existing learning content? The following examples will show how this approach has worked for us. Sometimes, only a few small changes are needed. Each example below will provide some context for the course, an outline of the design process, and the outcome of the design's implementation. All of the following examples come from fully online courses that were part of a 20-week development cycle at the Oregon State University Ecampus where a faculty course developer collaborates closely with an instructional designer.

14.4.1.1 Small-Scale Example: MRKT 396, Fundamentals of Marketing Research (by Meghan Naxer)

Fundamentals of Marketing Research is an undergraduate business course focused on understanding marketing research and relevant decisions in that process. When I began working on this course with the faculty developer, the course had already undergone an initial online development and was returning to Ecampus for redevelopment. As we assessed the strengths and weaknesses of the initial course design, we highlighted a quiz on US Census and American Community Survey (ACS) data that we wanted to be more motivating, engaging, and thought-provoking for students.

The original design included a quiz asking students to find specific data from the US Census and ACS, and enter that data into a quiz, thus assessing student competence in accessing and searching for that data. The initial inspiration for this activity was a scavenger hunt, so we sought a game-based redesign. The first step in the design process was to evaluate the learning outcomes—in this case, the outcomes for this specific week of the course that aligned with the activity, which included:

(1) compare the US Census to the ACS, and (2) use the US Census Bureau data to find answers about demographics in the US.

For this first step, a specific outcome was created for the new activity: “The goal of this assignment is to help you become familiar with and adept at using the U.S. Census and American Community Survey (ACS).”

The next two steps during the design included thinking about SDT and what needs we wanted to fulfill with this activity, as well as what actual mechanics and elements would be used. Since this was an individual activity, we focused on competence-supportive and autonomy-supportive designs. For competence support, we decided to give students multiple attempts at the activity (i.e., “You can submit this assignment up to three times in order to improve your score.”) with immediate feedback (correct/incorrect) and answers revealed only after their final attempt. For autonomy support, we wanted to create an environment for students where they would be able to identify and/or integrate the rationale for the activity. For this aspect, we turned to world-building and narrative approaches and created a scenario for students to imagine as they embarked upon the activity:

> You work for a real estate developer from the East Coast who wants to build an apartment complex and is considering Oregon as a potential location. You have been asked to gather data about the population and demographics in Oregon that will be used to determine if Oregon would be a good location, but you have a tiny research budget. You remember from your marketing research class that the U.S. Census is a credible source of free information. Luckily, your firm has a template for this kind of research and the questions of interest have already been created. All you need to do is fill in the blanks. As you answer each question, think about how this information might be relevant to your firm.

By providing students a character role (working for a real estate developer), there was a clear personal rationale and context for their need to participate in the activity. There was also a clear goal, gathering data, which supported both autonomy and competence. As an added bonus, this also asked students to think critically about how the data they’re gathering could be useful in this scenario. This activity was designed and implemented in an online environment in OSU’s learning management system (LMS) and formatted as a quiz to aid in delivering immediate feedback and mimicking a form a developer might use to fill out their firm’s template. As a final step, the instructor crafted relevant questions about various demographics and population information as it pertained to the scenario, based on fulfilling the learning outcome.

In sum, while this activity was redesigned with GBL in mind, much of the changes and implementation of the activity were dependent on the language and context provided by the scenario. This design necessitated returning to the drawing board to examine a small system for creating this game-based activity. While this design has not been formally reviewed empirically, it has been informally reviewed by the instructor. Overall, this activity was well received by students, with the instructor commenting that “students appreciated the … variety of assignments and application of the content to real world problems” (N. A. Brown, personal communication, December 19, 2019).

14.4.1.2 Large-Scale Example: NMC 470, Media Law (by Christopher Lindberg)

The steps we've laid out under thinking like a designer can also be considered when building larger-scale learning content. This approach was used in designing the course Media Law, an upper division course for the New Media Communications department at OSU. This course was redesigned as part of the move from face-to-face instruction to a fully online environment, as the face-to-face course included activities that did not easily transfer to an online environment.

14.4.1.3 Background

When redesigning NMC 470, we identified two learning outcomes: (1) students would be able to assess justifications for the regulation of media, and (2) students would learn how the regulatory legal structure works around the media and learn strategies to operate within that system to initiate change. It was also important that students should be able to appraise the role of copyright, patents, and trademarks in the media culture as these topics were covered throughout the 10-week course.

The activities previously used in the face-to-face version of the course included a series of mock trials held in the classroom. The expectations for cognitive level with these activities were high. Students were expected to go beyond reading and understanding high-level court cases in the U.S. The hope was to engage students to apply U.S. court cases to theoretical legal situations, implement their knowledge of these cases within a simulation of the existing regulatory system, and create arguments that would initiate change to that system.

The instructor found these mock trials to be engaging for students in the face-to-face courses and thought they met many of the cognitive criteria mentioned. But how would this translate to the online environment? As we discussed our options, we looked for advantages held in the online environment. Online learning is asynchronous. There was an opportunity to give students more time to come up with thoughtful arguments and responses. Holding these trials online could alleviate the performance anxiety many students had during the live trials, and build a different kind of environment. With these outcomes and advantages of the online environment in mind, we talked about how we could motivate students to engage in these trials.

14.4.1.4 Structure of the Activities

While I am hoping to model the backward design aspect of course building in this section, I think it is important to take a moment to describe the structure of the debate activities we designed to emphasize the intention behind that structure.

Each debate was set to span a 2-week period, recurring four more times through the course. The debates were held in an online discussion format with three students

Table 14.6 Debate Schedule

	Monday	Tuesday	Wednesday	Thursday	Friday
Week 1	Plaintiff opening statements		Defense opening	Judge's questions	Responses to Judge's questions
Week 2	Plaintiff statement 2	Defense statement 2	Judge's questions	Responses to Judge's questions	Plaintiff and Defense-closing arguments
Week 3	Judge's verdict				

in each discussion playing the roles of the plaintiff, defendant, and judge. These roles would switch with each new debate. The instructor monitored each of these trials as 'Chief Justice' to make sure arguments stayed on task or to make recommendations to the student judge in charge. Students were expected to post as per the following schedule (Table 14.6).

14.4.1.5 Motivation

These trials weren't going to work if students did not engage with them, so the concepts of motivation we've discussed in this chapter were essential to the design. Competence was supported by giving students search tools and supporting access to the entirety of the Supreme Court record regarding media cases. They were taught how to use these tools, then given low-stakes practice with them before each mock trial began. These "practice" searches included many of the court cases relevant to the mock trial for that 2-week block. To be successful in the mock trials, students would need to do their own research to support their cases, and be comfortable finding resources through the tools provided. Instructor and peer feedback also contributed to competence. Other historical regulations and background history were covered as needed for each week.

While the basic arguments for each case were set for the plaintiffs and defense (e.g., "The State of Missouri is suing the FDA over ..."), students were given autonomy to find case precedents to support the argument for the side they were assigned to. The interpretation and strategy for winning or defeating the argument were up to each student. They were also free to interpret the meaning of the decisions they chose for their cases in any manner that might support their argument, and there were consequences for the choices made. A student could win or lose a case based on their preparedness and the interpretations they chose.

Another intent was to build relatedness with the larger regulatory legal system. Within each trial, a community would be created as each student played the role of judge, plaintiff, or defendant. These were small, focused communities that built further on relatedness as each student played their role, referring to each other as judge, or counselor.

There was also a psychological needs-satisfaction loop built-in. With each round of Judge questions and the instructor's strategic recommendations, students received peer-reviewed feedback that built on both competence and relatedness.

14.4.1.6 Game Mechanics and Gameplay

As part of the instructions to students, the instructor included the following statement, "... These assignments and turns are intended to induce a high level of metacognition. This course works because you are asked to think about how complex systems function, not to memorize details." That also set the tone that the rules of this game were meant to mirror a real-world system and students were invited to participate. But it also emphasized that students would be engaging in world-building, building a world that is loosely based in reality, but something of their own creation too.

Obviously, role-playing was an important consideration in this world-building. But importantly, this world changes based on the choices a player makes, which is important for fulfilling autonomy needs-satisfaction. Also, in his role as Chief Justice, the instructor acted as a non-player character.

Another important consideration in this design was that this activity was turn-based. Unlike the face-to-face version (and reality) these court cases would not be live. Students were able to pause to come up with well-considered solutions to the problems they were given. This mechanic also allowed us to take advantage of the asynchronous nature of online learning.

A brief look at some of the instructors' feedback on this project provides some insight into why this game-based activity was successful. "At the heart of debates and success are three factors: extensive external backgrounding (these are policy debates not spar or parliamentary debates which feature comedic improv), goal direction (the game has a clear win condition that maps a real activity), turn taking. When translated into hybrid and online spaces, the debates also map with the three kinds of interaction: Student-Content, Student-Instructor, and Student-Student." This also maps with the SDT criteria of Autonomy, Competence, and Relatedness.

The instructor also sheds some insight into the instructor preparation process and consideration of cognitive level, "In 470 I have five activities total for the quarter. The most intense part, aside from subbing into Trials, is getting the mock-trial preps properly tuned. The proposed cases need to be difficult enough to require real backgrounding, but not so difficult that students shut down." (D. Faltesek, personal communication, December 14, 2020).

14.5 Conclusion

We have highlighted the strengths of the systems-level approach to instructional design over a surface-level approach through implementing frameworks from both SDT and GBL. The systems-level approaches that we have examined and explored point to much more strategic ways to incorporate elements of GBL that fulfill student needs, setting them up for more meaningful and effective learning experiences. As we have shown, game mechanics and gameplay concepts can be applied at a systems-level by choosing specific game mechanics and gameplay that are appropriate for the learning outcomes and cognitive level sought.

Implications for this strategy are that designers can weave game elements into learning with pedagogical intent and to improve student motivation by using game elements that support psychological needs, no matter the course's discipline. We believe that these design considerations are an essential part of creating effective learning. As an instructor or instructional designer, incorporating game design into the backward design process should be a natural step. Just as learning outcomes play a critical role in the development of activities, gameplay, and mechanics, if used at the systems level, can be used to enhance motivation while attaining these outcomes. While there may be an allure to adding game-based learning to improve the fun factor of a course or activity, we would caution against using fun as the motivating factor for inclusion in a course design. Instead, identifying the activities or aspects of a course design where improvement can be made to the learning environment, to foster a change in student motivation, is the ideal goal for any endeavor in game-based learning design. We hope that this chapter has both highlighted the background research on Self-Determination Theory and game design practices for instructors and instructional designers, while also providing some strategies and examples for how to implement our systems-level approach to game-based learning.

In our current work, we primarily receive feedback on the effectiveness of designs from teaching faculty and instructors. Oftentimes that feedback includes an instructor's own observations from teaching the course for the first time after a redevelopment period. Sometimes that feedback also incorporates student comments both solicited and unsolicited at various points of the term. Most commonly, this feedback speaks to increased student enthusiasm, but importantly, a broader understanding of the purpose of course content and how it affects students personally and professionally. While this feedback is invaluable to our work as instructional designers, further research is needed to gather more formal evidence about the motivational impact and psychological need satisfaction of these designs. That research may involve a multistage redevelopment of an entire course or even an investigation of a single activity. Future research and design work should examine multiple disciplines, including STEM, liberal arts, and a variety of other professional courses in fields like business and public health. We hope to continue this research in the future and also look forward to the continued work of GBL, SDT, and instructional design colleagues and communities.

Acknowledgments We would like to acknowledge our Ecampus colleagues who have immensely helped us through this research project. First, thank you to the Ecampus Research Unit, including Mary Ellen Dello Stritto, and especially Rebecca Thomas, without whom this chapter would not have been possible. Second, to our colleagues in the Ecampus Course Development and Training Team, including Laurie Kirkner, Katherine McAlvage, and Cyndie McCarley, for their support and insightful feedback. Finally, to instructors Nikki Brown and Daniel Faltesek, for their collaboration and trust while developing the courses featured in this chapter.

References

Anderson, L. W., & Krathwohl, D. R. (2001). A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives, complete edition. New York: Longman.

Antonaci, A., Klemke, R., & Specht, M. (2019). The effects of gamification in online learning environments: A systematic literature review. *Informatics, 6*(3), 1–22. https://doi.org/10.3390/informatics6030032

Csikszentmihalyi, M., & Csikszentmihalyi, I. S. (1992). *Optimal experience: Psychological studies of flow in consciousness*. Cambridge University Press.

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry, 11*(4), 227–268. https://doi.org/10.1207/S15327965PLI1104_01

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: Defining "gamification." *Proceedings of the 15th International Academic MindTrek Conference:* Envisioning Future Media Environments*,* Finland, 9–15. https://doi.org/10.1145/2181037.2181040

Eseryel, D., Law, V., Ifenthaler, D., Ge, X., & Miller, R. (2014). An investigation of the interrelationships between motivation, engagement, and complex problem solving in game-based learning. *Educational Technology & Society, 17*(1), 42–53.

Fullerton, T. (2014). *Game design workshop: A playcentric approach to creating innovative games*. CRC Press.

Gagné, M., & Deci, E. L. (2005). Self-determination theory and work motivation. *Journal of Organizational Behavior, 26*(4), 331–362. https://doi.org/10.1002/job.322

Hanus, M. D., & Fox, J. (2015). Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance. *Computers & Education, 80*, 152–161.

Hunicke, R., LeBlanc, M., & Zubek, R. (2004). MDA: A formal approach to game design and game research. *Proceedings of the AAAI Workshop on Challenges in Game*, USA, 4(1).

Juul, J. (2013). *The art of failure: An essay on the pain of playing video games*. MIT Press.

Kapp, K. M. (2012). *The gamification of learning and instruction: Game-based methods and strategies for training and education*. John Wiley & Sons.

Landers, R. N. (2019). Gamification misunderstood: How badly executed and rhetorical gamification obscures its transformative potential. *Journal of Management Inquiry, 28*(2), 137–140.

Landers, R. N., & Landers, A. K. (2014). An empirical test of the theory of gamified learning: The effect of leaderboards on time-on-task and academic performance. *Simulation & Gaming, 45*(6), 769–785.

Naxer, M. (2019, June 10). Self-determination theory and online education: A primer. *Ecampus Course Development & Training Blog*. http://blogs.oregonstate.edu/inspire/2019/06/10/self-determination-theory-and-online-education-a-primer/

Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of game-based learning. *Educational Psychologist, 50*(4), 258–283. https://doi.org/10.1080/00461520.2015.1122533

Plass, J. L., Homer, B. D., Mayer, R. E., & Kinzer, C. K. (2019). Theoretical foundations of game-based and playful learning. In J. L. Plass, R. E. Mayer, & B. D. Homer (Eds.), *Handbook of Game-Based Learning* (pp. 3–24). MIT Press.

Plass, J. L., Mayer, R. E., & Homer, B. D. (Eds.). (2020). *Handbook of game-based learning*. MIT Press.

Rigby, S., & Ryan, R. M. (2011). Glued to games: How video games draw us in and hold us spellbound. New Directions in Media. https://search.library.oregonstate.edu/permalink/f/ueodtl/CP51230824680001451

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology, 25*, 54–67. https://doi.org/10.1006/ceps.1999.1020

Ryan, R. M., & Deci, E. L. (2017). *Self-determination theory: Basic psychological needs in motivation, development and wellness*. Guilford Press.

Ryan, R. M., & Rigby, S. (2019). Motivational foundations of game-based learning. In J. L. Plass, R. E. Mayer, & B. D. Homer (Eds.), *Handbook of Game-Based Learning* (pp. 153–176). MIT Press.

Salen, K., & Zimmerman, E. (2003). *Rules of play: Game design fundamentals*. MIT Press.

Seaborn, K., & Fels, D. I. (2015). Gamification in theory and action: A survey. *International Journal of Human - Computer Studies, 74*(C), 14–31. https://doi.org/10.1016/j.ijhcs.2014.09.006

Sicart, M. (2008). Defining game mechanics. *Game Studies, 8*(2). Retrieved from http://gamestudies.org/0802/articles/sicart

Thomas, R. A., Linder, K. E., Harper, N., Blyth, W., & Yee, V. (2019). Current and Future Uses of Augmented Reality in Higher Education. *IDEA Paper#81*. IDEA Center, Inc. Retrieved from https://www.ideaedu.org/idea_papers/current-and-future-uses-of-augmented-reality-in-higher-education

Wiggins, G., & McTighe, J. (2005). *Understanding by design* (2nd ed.). Association for Supervision and Curriculum Development.

Chapter 15
The Teacher-Centered Perspective on Digital Game-Based Learning

Quantitative and Qualitative Evaluation Methods from Diverse Disciplines

Thea Nieland, Anna Fehrenbach, Maximilian Marowsky, and Miriam Burfeind

15.1 Introduction

Games meet the fundamental needs of learning, as they are active, fun, social, experiential, situated, problem based, and provide immediate feedback (Boyle et al., 2011; de Freitas, 2018; Prensky, 2001). Combining games with novel technologies and education has led to a promising learning method that balances subject content with gameplay and helps to apply the learned matter to the real world (Cojocariu & Boghian, 2014). Digital game-based learning (DGBL) brings together serious learning and interactive entertainment (Prensky, 2001) and has been shown to improve student motivation, stimulate creative thinking, and provide a challenging and meaningful context for learners (Egenfeldt-Nielsen, 2007; Gee, 2003; Shaffer, 2007). Despite the positive effects on learning outcomes, it has been shown that teachers[1]—especially the less experienced ones—still hesitate to adopt DGBL applications (Razak & Connolly, 2013). Despite the increasing digitalization of the last few years, 61% of European students never or almost never use digital learning

[1] In the following, we will refer to teachers in general, i.e., teachers from primary, secondary, and higher education.

T. Nieland (✉) · M. Burfeind
Osnabrueck University, Osnabrueck, Germany
e-mail: thea.nieland@uni-osnabrueck.de

A. Fehrenbach · M. Marowsky
Pearprogramming GmbH, Osnabrueck University, Osnabrueck, Germany

C. Aprea, D. Ifenthaler (eds.), *Game-based Learning Across the Disciplines*, Advances in Game-Based Learning, https://doi.org/10.1007/978-3-030-75142-5_15

games in the classroom, and only 9% of the students use DGBL on a regular basis (European Commission, 2019). The question of how to increase the teachers' acceptance of DGBL is therefore a timely one.

To date, educational game designers and the DGBL literature have mainly focused on students as users (Hwang & Wu, 2012; Šumak et al., 2011), centering the motivational and learning outcomes of DGBL as their primary research interest (Connolly et al., 2012). Ultimately, however, teachers play the most crucial role in DGBL, as they decide for or against the use of DGBL in the classroom. In order to address teachers' concerns, and hence increase the teacher's acceptance of DGBL, a shift in focus is necessary. Teachers' needs regarding DGBL must be identified and systematically evaluated before DGBL applications can be adapted accordingly to ensure high acceptance. Several studies investigated the factors that influence teachers' attitudes toward DGBL and its actual integration in the classroom (e.g., Baek, 2008; De Grove et al., 2012; Hamari & Nousiainen, 2015). However, previous research has shown high variability in results, depending on the investigation approach and the context in which DGBL is used.

Thus, the question arises: *how can DGBL applications be assessed from the perspective of teachers in different settings?* This chapter aims to elaborate on this research question by first identifying *what* factors are important to teachers in regard to DGBL. We will briefly summarize research findings and propose key criteria that can be considered when developing DGBL applications. Second, we will provide an overview of quantitative and qualitative evaluation methods to illustrate *how* exactly the teachers' perspectives can be captured and analyzed. Finally, we will map key criteria and exemplary studies to different development stages, in order to provide an evaluation framework that indicates *when* researchers can meaningfully assess the key criteria. In addition to the framework, we briefly introduce first-hand experiences to illustrate how evaluation procedures can be practically integrated into different development phases.

Overall, this chapter brings together insights from various disciplines to advance the understanding of teachers' needs and perspectives on DGBL in educational research. More specifically, psychological theories and empirical findings from the field of information systems (IS) and human–computer interaction (HCI) are integrated with the results from educational research. By moving the focus onto the teacher and providing an evaluation guideline, this chapter aims to facilitate a systematic, teacher-centered development of DGBL applications that are more accepted and hence more often employed in the classroom.

15.2 Understanding Teachers' Acceptance of DGBL

We will begin by integrating theories from IS and psychological research with empirical findings from educational research to understand the factors that drive teachers' acceptance of DGBL. In IS research, many scholars have tried to explain which features and perceptions promote an individual's intention to use technology—as well as the resulting actual use—based on basic psychological theories to predict behavior (e.g., Sharma & Mishra, 2014). Here, we apply these models to teachers, presenting DGBL applications as the technology in question. Next, we combine adoption factors from IS research with factors, identified in the field of educational research, which hinder teachers' use of DGBL in practice. Then, to sum up the findings, we propose key criteria that reflect the relevant factors promoting teachers' acceptance of DGBL. In the sense of an iterative development process, these criteria can help to evaluate DGBL applications from a teacher-centered perspective.

15.2.1 Models of Technology Acceptance

To explain teachers' individual acceptance of DGBL, one can build on the extensive literature on general technology acceptance. The most prominent and widely used models are the Technology acceptance model (TAM, Davis, 1985) and the Unified theory of acceptance and use of technology (UTAUT, Venkatesh et al., 2003), which have been adapted to multiple contexts and extended in various studies (e.g., Tseng et al., 2019). Both models share the basic assumption that the intention to use a technology precedes its actual use. Briefly summarized, the intention to use technology depends on the perception of the technology and resulting beliefs about its characteristics (e.g., how useful it is). Knowing which beliefs effectively predict the use of technology, and knowing how to promote them, may inform the design process of technology. By considering influential factors throughout the design process, a product can be created that is actually used by the users as intended. Thus, theoretical models of technology acceptance can guide the development and evaluation of DGBL by providing a set of relevant beliefs and factors that influence the use of DGBL technology. Figure 15.1 illustrates beliefs included in the TAM and UTAUT(2).

The Technology acceptance model (TAM). Davis (1985) considered two main beliefs affecting the intention to use technology[2]: *perceived usefulness* and *perceived ease of use*. Perceived usefulness refers to "the degree to which an individual believes that using a particular system would enhance his or her job performance" and perceived ease of use describes "the degree to which an individual believes that using a particular system would be free of physical and mental effort" (Davis, 1985, p. 26). In the context of DGBL, various external factors that shape teachers' perceptions have been investigated (Blume, 2020; Bourgonjon et al., 2013; De Grove et al., 2012; Dele-Ajayi et al., 2019). In each of these studies, the TAM overall has proven useful to explain instructors' general acceptance of DGBL.

[2] In fact, in between the two main beliefs and the intention to use a technology, Davis added an additional step in the model: an overall attitude that is based on the beliefs and preceding the intention (Davis, 1985). For the sake of brevity, this step is neither shown in Fig. 15.1 nor discussed in the text.

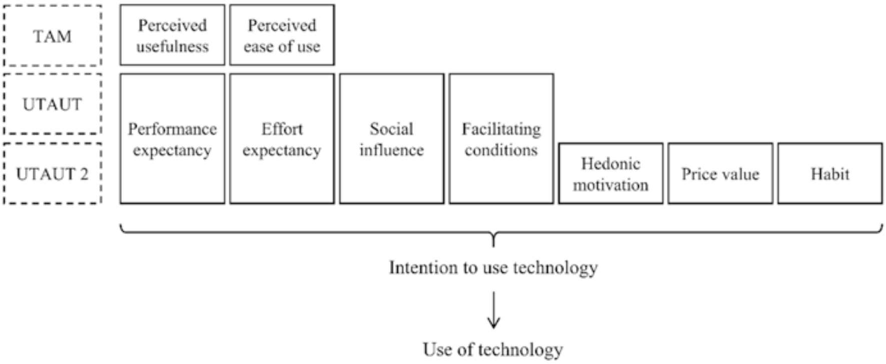


Fig. 15.1 Simplified illustration of beliefs represented in the TAM, UTAUT, and UTAUT2 to predict the intention to use a technology

The Unified theory of acceptance and use of technology (UTAUT). Building on the TAM and an extensive literature review of other approaches to explain technology acceptance, the UTAUT was established as an attempt to integrate preexisting theories into one model (Venkatesh et al., 2003). In their synthesis, Venkatesh et al. (2003) identified four main factors preceding the intention to use technology. Analogous to perceived usefulness in the TAM, *performance expectancy* describes the extent to which the technology is expected to enhance one's performance of the relevant task. In addition, *effort expectancy* reflects the perceived ease of using technology, comparable to perceived ease of use in the TAM. Beyond that, perceptions of the context of use are added to the model: *social influence*, as the extent to which one perceives that "important others believe he or she should use the system" (Venkatesh et al., 2003, p. 451) and *facilitating conditions,* describing the "degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system" (p. 453). Moreover, it is assumed that these four factors do not universally predict the intention to use technology but that their relevance depends on gender, age, previous experience, and the degree to which technology use is voluntary or mandatory. For instance, individuals with little previous experience might particularly value a technology that is easy to use. In the context of DGBL, the consideration of general conditions (facilitating conditions and voluntariness) and the social environment (social influence) seems particularly appropriate, as previous research highlighted the role of contextual factors for teachers' acceptance of DGBL (e.g., Burfeind et al., 2020).

A recent extension of the UTAUT, the UTAUT2, further addresses the *habit* of using technology, its perceived *price value,* and *hedonic motivation*, which describes the perceived enjoyment when using a technology (Venkatesh et al., 2012). Since it includes derived fun and pleasure as an explanatory factor for technology use, UTAUT2 is often used for evaluation in the context of game-based applications (e.g., Tseng et al., 2019). However, hedonic motivation is mostly (but not exclusively) relevant from the students' perspective, as enjoyment is intended mainly for the students' sake.

A recent overview of these theories concludes that the UTAUT and UTAUT2 largely receive empirical support (Tseng et al., 2019) and thereby prove to be useful frameworks for predicting the use of technology. Across all included studies, performance expectancy (or the belief that technology is useful) was identified as a key driver, while the relative importance of other factors varies depending on the specific context of the studies and technologies at hand (Tseng et al., 2019).

Taken together, models of general technology acceptance contain several important elements that should be considered to successfully develop and implement DGBL. In practice, these models are mostly used to predict teachers' overall acceptance of DGBL and do not focus on the evaluation of a specific DGBL application. Due to this broader approach, some factors included concern implementation issues rather than features of the DGBL itself (e.g., social influences). Findings regarding these context factors can guide implementation strategies (e.g., identifying driving teachers in an institution, building teams around them, and enabling networks) but are not in the scope of this chapter. Overall, however, the models provide a basic set of well-defined beliefs and skills that can be used to evaluate DGBL.

15.2.2 Determining Barriers for Teachers in DGBL

The models described above show that acceptance is strongly influenced by individual beliefs and perceptions. Some studies investigated external factors that promote the perception of usefulness and ease of use or contribute to acceptance beyond the described models (e.g., Bourgonjon et al., 2013; Dele-Ajayi et al., 2019). In this section, we give a short overview of the literature, classify the determining factors, and combine the theoretical models with findings from educational practice. For this purpose, we focus on barriers that hinder teachers from using DGBL in order to identify what needs to be overcome for a high acceptance of DGBL applications.

Concerning the acceptance of e-learning in general, some scholars have already summarized common barriers for teachers. For instance, Ertmer (1999) was one of the first to distinguish first- and second-order barriers, a distinction still referred to today. First-order barriers include all external factors, such as limited resources or technical aspects. Second-order barriers, on the other hand, are internal and include self-perceived abilities or attitudes. A more recent approach further identifies *personal* and *professional* factors as internal barriers and *institutional* and *contextual* factors as external ones (Mercader & Gairín, 2020). This typology serves as a basis for this section and is partly adapted to the context of DGBL. The studies presented involve teachers from higher education (e.g., Hsu et al., 2014), primary education (e.g., Cojocariu & Boghian, 2014; Kamişli, 2019), and secondary education (e.g., Jong, 2016).

Internal barriers. A major barrier for teachers in the use of a DGBL application is their self-perceived professional skills. Only a few teachers already possess game-specific skills; however, it is crucial that they have some general familiarity with such formats. Studies show that familiarity leads to less uncertainty (Cojocariu &

Boghian, 2014) and more acceptance and competence with DGBL formats (De Grove et al., 2012), no matter if teachers' experiences are with specific game-based learning formats or with video games in general (Schrader et al., 2006). Becker (2007) states that "expecting teachers to use games without having played games is similar to expecting teachers to use novels and other books without them ever having read one" (p. 486). In the terms of acceptance models, this finding can be reinforced by the central role of *experience* as an important moderator variable (Venkatesh et al., 2003).

Furthermore, the technical skills of teachers are crucial to the use of DGBL (Cuhadar, 2018). Technical skills include basics such as installing, controlling, or storing the application, or even knowledge of copy protection functions (Sandford et al., 2006). Teachers must also be able to combine the technical aspect with didactic strategies. They need pedagogical knowledge of games and must discern how best to use the game-based digital functions and features (Hsu et al., 2014; Loperfido et al., 2019). Thus, it is crucial to offer teachers technical training in these areas (Egenfeldt-Nielsen, 2004; Kamişli, 2019). In summary, it can be stated that "teachers need to be confident in their ability to properly use technology before they will consider using digital games" (Dele-Ajayi et al., 2019, p. 5).

Other internal barriers for teachers are individual aspects that are not linked to their profession but instead to their individual values, beliefs, characteristics, or attitudes. The more teachers are interested in DGBL teaching approaches, the more they are willing to use them (Schrader et al., 2006; Selwyn, 2007). Even more important is whether teachers consider DGBL to be pedagogically useful in offering learning opportunities to students (Dele-Ajayi et al., 2019; Loperfido et al., 2019). Teachers' belief in the potential and positive learning outcomes of game-based applications can be categorized in the terms of technology acceptance models as a belief of perceived usefulness (Davis, 1985) and performance expectancy (Venkatesh et al., 2003).

Teachers tend to be skeptical of game-based learning (Gaudelli & Taylor, 2011; Gerber & Price, 2013) because they associate games with playfulness rather than with learning and education. Other doubts arise from natural anxiety and discomfort with new media in general (Rice, 2007) or specifically with DGBL (Chee et al., 2015; Cojocariu & Boghian, 2014; Kamişli, 2019; Loperfido et al., 2019).

External barriers. The determining external factors include all organizational and technical challenges connected with the application but not with the skills of the teachers (Becker & Jacobsen, 2005). Technical accessibility is often determined by simplicity of use, comprehensible design, and supportive material within the application (Urh et al., 2015). In the models of general technology acceptance, this is associated with the perceived ease of use or effort expectancy (Davis, 1985; Venkatesh et al., 2003).

Furthermore, general technical infrastructures such as the administration system or learning management system can be challenging to grasp or not visible and available to teachers (Gerber & Price, 2013; Urh et al., 2015). Teachers are often concerned about the infrastructure and equipment of their educational institutions for providing DGB lessons (Jong, 2016; Sandford et al., 2006). How responsive and efficient is the technical assistance with DGBL when problems occur? Well-functioning systems should provide the support that teachers perceive as important (Baek, 2008). Another major obstacle to the use of DGBL is teachers' concern about limited resources (Iosup & Epema, 2014), such as time (Becker & Jacobsen, 2005) and finances (Baek, 2008). In the UTAUT model, all these factors are identified as facilitating conditions (Venkatesh et al., 2003).

Context factors include aspects that do not relate to specific applications but rather to how the technology is embedded in existing teaching structures and educational institutions. Teachers often express concerns about the institutional fit and integration of DGBL (Chukwunonso & Oguike, 2013; Jong, 2016; Mercader, 2019). In particular, consistency and congruence with curricula and framework course programs are the most frequently mentioned concerns (Baek, 2008; De Grove et al., 2012; Takeuchi & Vaala, 2014).

In sum, the aforementioned barriers regarding teachers' usage of DGBL provide guidance as to which factors must be considered in the development and implementation of DGBL. It should, however, be noted that this approach of analyzing negative barriers can be enriched by identifying positive adoption factors that promote the integration of DGBL in the classroom (Kebritchi, 2010). Generally speaking, studies with this positive focus yield similar results but with some important additions. For example, Kebritchi (2010) emphasizes the relevance of access to a trial version of the DGBL application, as well as the option to adjust game difficulties, showing that teachers should be able to influence the content of DGBL applications for the best result.

15.2.3 Key Criteria for Teacher-Centered Evaluation

The presented models of general technology acceptance, as well as the research findings, highlight factors that must be taken into account when developing and implementing DGBL to promote its acceptance and usage. In an attempt to condense the previously summarized factors, we selected those that relate to modifiable aspects of DGBL and its context of use. We set aside factors that cannot be influenced by people in charge of the development (e.g., personal traits of users such as openness to new technology) in favor of factors that can be adjusted (e.g., the usability of the application or usefulness of the provided training). We then clustered the factors derived from different theoretical models and researchers by similarity, resulting in 13 key criteria divided into three clusters (see Fig. 15.2). The first cluster relates to the *usefulness* of a DGBL application and the extent to which it enables and facilitates teaching. The second cluster integrates aspects of the *user experience* and how teachers feel while navigating and using the application. The third cluster encompasses the *context factors*, which relate to teachers' perceptions of whether they have all the necessary resources (time, support, material, etc.) available to employ DGBL in teaching.

Fig. 15.2 Overview of the key criteria for teacher evaluation

The identified list of key criteria is intended to provide a rough framework for evaluation. It goes beyond existing reviews of evaluation criteria (e.g., Tahir & Wang, 2017), as it focuses explicitly on teachers as users of DGBL. This framework can be adapted depending on the specific context of use for which the DGBL is developed (see also Burfeind et al., 2020). For example, the teacher's role within the DGBL environment may vary across diverse contexts (Hanghøj & Brund, 2010; Kangas et al., 2016). Hanghøj and Brund (2010) distinguish four possible roles based on empirical studies of teachers' game-based practices: instructor, game maker, guide, and explorer. According to the role and hence the actions that teachers usually take in the application of DGBL, certain key criteria acquire more or less importance (e.g., hedonic motivation is more important when teachers take part in the game as game makers or explorers themselves). Similarly, the relevance of certain key criteria may depend on teachers' levels of education and previous experiences with DGBL and educational technologies in general.

15.3 Teacher-Centered Evaluation

Having identified key criteria for DGBL evaluation from a teacher's point of view, we now turn to the question of *how* to assess the respective criteria and conduct systematic evaluations. Various DGBL applications, each with individual metrics, have been developed in different domains (primary education, secondary education, and higher education) and subjects (natural sciences, social sciences, languages, etc.). The lack of uniformity makes a standardized evaluation procedure difficult. In response, we discuss different strategies to enable a more effective and teacher-centered evaluation. Using an overview of relevant studies related to teacher-centered evaluation of DGBL, we link the key criteria to relevant evaluation methods in order to help guide the selection of evaluation methods appropriate to individual cases.

15.3.1 Evaluation Methods and Strategies in DGBL

The overall purpose of an evaluation dictates whether a *formative* or a *summative* approach is chosen. In formative evaluation, applications are evaluated during their development to generate early insights and modify the application accordingly. Once the development is completed, summative evaluation takes place, providing a final assessment of the fully developed application. Formative evaluation is intended to influence the development process, while the summative evaluation identifies whether the application leads to the desired outcome (Bortz & Döring, 2006). The appropriate type of evaluation is therefore determined by the stage of development. This chapter aims to improve the development of DGBL applications in their early stages and therefore increase their acceptance by introducing a teacher-centered development and evaluation process. Thus, the following guidance focuses on formative rather than summative evaluation.

First, a clear research objective is crucial for the evaluation of DGBL applications. Once researchers break down the objective into research questions, they need to choose the right research design to address these questions appropriately. Depending on variables such as resources, time, and sample size, the design and approach of the study could favor quantitative methods, qualitative methods, or a combination of the two. Quantitative research collects data in numerical form and uses statistics to confirm or reject a hypothesis (Bortz & Döring, 2006), while qualitative research takes a more interpretive approach by exploring the experiences of individuals and thus focusing on the qualities of data (Howitt & Cramer, 2007). Although quantitative designs seem to enjoy greater popularity in the evaluation of DGBL (Connolly et al., 2012), the advantages of the qualitative approach for teacher-centered evaluations should not be overlooked, particularly in light of the practical limitations and subjective nature of small sample size data. In teacher-centered DGBL evaluations, research instruments range from quantitative methods

Table 15.1 Instruments for DGBL teacher evaluation

Instrument	Advantages (+) and disadvantages (−)	Illustrative research question
Questionnaire	+ Collection of objective and subjective data + High standardization and comparability + Anonymity + Resource-efficient, allows to efficiently collect data from large samples − Uncontrollable collection of data − Accessible to manipulation and bias effects	Did the user experience improve compared to the last prototype?
Experiments/ Testing	+ Comparison between design alternatives − High effort and expenses (time resources of teachers are scarce, expensive equipment)	Based on the eye-tracking results which part of the application captures the teacher's attention the most?
Observation	+ Allows a neutral, unobtrusive detection + Requires few resources from the teacher − No coverage of opinions and attitudes − Possible observer effect (behavior is influenced by the presence of the observer) − Willingness to be observed might be low	How is the application used in the everyday routine of the teacher? Which features of the application are used most of all?
Interviews/ Focus groups	+ High flexibility + Possibility for more detailed inquiry + Clarification of misunderstandings − High effort and expenses − A certain amount of participants needed for comparability − No anonymity − Low comparability	Which features support successful/efficient/etc. teaching?

Note. Instruments and related (dis-)advantages adapted from Bortz and Döring (2006)

such as questionnaires and experiments to more qualitative methods like interviews and observations. The most frequently used instruments (Bortz & Döring, 2006) are presented below in Table 15.1 with an emphasis on their DGBL evaluation potentials and possible research questions.

In the context of DGBL evaluation, questionnaires can be used at the beginning of a development process as a cost-effective method for collecting data from large samples of teachers and identifying key features of the technology that teachers believe are important. Questionnaires are also used to quantify target achievement during iterative development, e.g., if a second prototype is more user-friendly than the first prototype. Moreover, experimental tests or psychophysiological measures can deliver quantitative and generalizable findings by examining variables empirically. Particularly promising in this context might be eye-tracking (Mussgnug et al., 2015), which has been used to investigate the effect of DGBL design features and monitor students' attention (Rosengrant et al., 2012). However, due to the high effort and expense involved, to our knowledge, eye-tracking has not yet been used in practice to evaluate DGBL from a teachers' perspective. A less resource-intensive method of data collection is systematic observation; in the DGBL evaluation context, a researcher could observe how DGBL is integrated into teachers' daily routines and assess the challenges that teachers face when using the application. Interviews and focus groups can also explore teachers' individual needs in regard to DGBL and possibly identify missing features that they require, thereby uncovering the reasons behind perceptions of the DGBL, e.g., *why* an application is perceived as useful or not.

15.3.2 Combining Key Criteria and Methods for a Teacher-Centered Evaluation

In the following section, we provide an overview of specific methods that can be used to evaluate DGBL from a teacher's perspective (see Table 15.2), combining the key criteria and methods described above. Additionally, we provide examples of different procedures for *how* to assess the key criteria (*what*). To facilitate orientation, the key criteria are sorted according to *when* they can be meaningfully assessed for the first time in the development process. We therefore distinguish four stages adapted from a framework for new product development (Sommer et al., 2015).

First, based on the needs of the target group (teachers), a rough concept is designed. A set of *features and functions* derives from the initial requirements. Furthermore, in this concept stage, it is important to analyze the need for and availability of resources. At the early development stage, the prototyping of the application takes place to analyze whether the identified requirements and *usability* standards are met. At this stage, it makes sense to evaluate the application's *ease of use*, *usefulness,* and the degree to which the teachers perceive the application as a helpful *learning opportunity* for their students. Identified problems lead to modifications of the application or even the concept. In contrast, at the late development stage, a functional version of the application is available, and the focus therefore lies on its *user experience* and *design*. For the first time, the whole software functionality can be tested and its *(price) value* determined. At the implementation stage, the fully developed application is integrated into the educational setting. This stage is crucial for the success of the application. Therefore, criteria such as *perceived support*, *training,* and *infrastructure* should be met. Most importantly, the *institutional integration* must be guaranteed, as this is often teachers' biggest concern (Baek, 2008; De Grove et al., 2012; Takeuchi & Vaala, 2014).

When the product development process is completed, a summative evaluation usually takes place. The summative evaluation assesses whether the resulting DGBL application leads to the desired outcome.

Although the key criteria have been sorted by stages, they all should be kept in mind from the start even if they cannot yet be meaningfully evaluated at a certain stage. For example, the fit of the application into existing infrastructure should be targeted immediately but can only be tested once the application is finalized and

Table 15.2 Overview of the formative teacher evaluation of a DGBL application development

Stage (*When?*)	Criterion (*What?*)	Evaluation method (*How?*)
Concept	Required features and functions	Q: Bourgonjon et al. (2010), I: Alt et al. (2016)[a], Burfeind et al. (2020)
	Resources (time, costs, devices)	Q: Buchanan et al. (2013), Venkatesh et al. (2003),[a] Q/O: Jong (2016)
Early development	Usability	Q: Liu (2015), I: Kebritchi (2010), O/I: Rubin and Chisnell (2008, Chap. 8)[a]
	Perceived ease of use and effort expectancy	Q: De Grove et al. (2012), Venkatesh et al. (2003)[a]
	Perceived usefulness and performance expectancy	Q: Buchanan et al., 2013, De Grove et al. (2012), Hamari and Nousiainen (2015), Hsu et al. (2013), Venkatesh et al. (2003)[a], I: Seaborn et al. (2017)
	Learning opportunities	Q: De Grove et al. (2012), Hamari and Nousiainen (2015), Hsu et al. (2013), Schmitz et al. (2015), Q/O: Jong (2016)
Late development	Design	Q: Laugwitz et al. (2008)[a], I: Kebritchi (2010)
	Hedonic motivation	Q: Venkatesh et al. (2012)[a]
	Price value	Q: Venkatesh et al. (2012)[a]
Implementation	Perceived support and material	Q: Buchanan et al. (2013), Hamari and Nousiainen (2015), Venkatesh et al. (2003)[a]
	Infrastructure	Q: Buchanan et al. (2013), Dele-Ajayi et al. (2017)
	Institutional integration	Q: De Grove et al. (2012), Takeuchi and Vaala (2014), Q/O: Jong (2016)
	Training	Q: Kamişli (2019)

Note. Q: questionnaire I: interview O: observation
[a]References related to descriptions of general methods to evaluate the criteria, not applications in the context of DGBL

integrated into the infrastructure. Importantly, this overview (Table 15.2) is intended as a guideline—not a regulation—for planning and conducting DGBL evaluations from a teacher's perspective. The indicated evaluation methods (questionnaire, interview, and observation) can be transformed into one another and are not meant to be strictly separated categories (e.g., Saleem et al., 2016).

Table 15.2 shows that some key criteria have been examined more often than others in teacher-centered DGBL evaluations. In particular, usefulness and perceived learning opportunities offered by DGBL applications have been evaluated in various ways and several studies so far. This is in line with the finding that the usefulness of technology is a key driver of its acceptance (Tseng et al., 2019). In contrast, up to now hedonic motivation, price value, and quality and amount of DGBL training for teachers have not played a major role in teacher-centered evaluations of DGBL applications. To assess the first two criteria, questionnaires based on the UTAUT2 (Venkatesh et al., 2012) can be applied to the context of DGBL; the third criterion could be investigated by referring to basic literature on training evaluation (e.g., Kirkpatrick & Kirkpatrick, 2006).

15.4 Experiences With Teacher-Centered Evaluation: Two Cases

In order to gain practical insights into DGBL evaluation, we present first-hand experiences from two German projects, one in secondary education and one in higher education. The projects are at different stages of development, target different groups, and pursue different objectives. They also emerged from various disciplines, including neuroscience, computer science, education, and psychology. However, they share a common goal: to integrate game-based elements into teaching and learning, thus increasing the students' commitment, retention, and motivation to learn. During the development of these two projects, the applications were iteratively evaluated. They are here presented as illustrations to the previously introduced evaluation framework in order to provide insight into how evaluation practices can be integrated into development phases.

15.4.1 DGBL Evaluation in yUOShi and Pearprogramming

The yUOShi application. yUOShi[3] is an e-learning application with gamification elements for first-year students in higher education in vocational training and education study programs, specifically for use in didactic and educational psychology courses. The main idea of the application is that students play the role of a vocational teacher in a virtual school and solve simulated situations by applying the basics of educational psychology. The yUOShi application is administered by the teachers of the course program, who therefore assume the role of an instructor (Hanghøj & Brund, 2010). Instructors can edit the application, add content, and view rankings, performance assessments, and the results of internal surveys in order to prepare for face-to-face meetings following a blended learning approach. The teachers will access the application via the university's learning management system, which provides them with supporting materials and a teacher's guide.

Currently, a first functional prototype is available and has been tested in the field. As the teacher's view is still in an early stage of development, so far qualitative and exploratory methods have mainly been used for evaluation. In the beginning of the development, an analysis of requirements was carried out to identify specific factors affecting teachers' acceptance of DGBL in higher education (Burfeind et al., 2020). First, we identified their basic needs regarding DGBL with three semi-structured interviews. Next, to elaborate and specify requirements, a focus group with eight teachers was conducted. The results highlighted the importance of supporting contextual conditions, congruence with the curriculum, the ability to influence the

[3] Full project name: Digital didactic formats in teacher training in higher education—implementation of a gamification strategy in the teaching of vocational education (for further information, see www.yuoshi.uni-osnabrueck.de)

content and design, a possibility to assess learning analytics, and high levels of usability.

In the first prototype of the teacher's view of the application, attempts were made to meet these requirements. To ensure high usability, a *cognitive walkthrough*[4] was initiated. Six so-called activity streams were tested, describing the actions teachers usually need to perform to effectively prepare their classes (e.g., adding a task, editing texts, tracking students' learning progress, etc.). The identified usability problems were prioritized according to their severity. The results were used to improve the user experience and form the basis for further development of the application.

The PearUp application. Pearprogramming,[5] an edtech-startup that aims to improve the teaching of computer science in secondary education, is currently developing PearUp, a DGBL application in open beta phase. PearUp is designed to teach students in secondary education the basics of computer science with a focus on programming through integrating learning material into a business game. The game's premise is that a pair of students must found a virtual IT start-up, which they then must lead to success by solving computer-science-related tasks (Pasternak, 2019, p. 382). The application has been specifically designed to address the lack of computer science teachers in Germany by providing pre-built content and enabling teachers to teach computer science without deeper knowledge of the subject itself. After logging in as a teacher, the application allows the user to keep track of all classes and their groups, select or create tasks, provide direct or indirect assistance, and monitor the performance and working style of each student. In PearUp, the teacher fulfills the role of a guide, supporting the students to reach their learning goals while simultaneously evaluating the students' experience and progress (Hanghøj & Brund, 2010).

The development of PearUp's concept was influenced by scientific findings from various disciplines. During the iterative development process, the team's primary goal was to improve the perceived usefulness for teachers and the learning opportunities for students. To ensure the desired user experience for teachers, the development team pursued a quantitative approach to evaluation by conducting the *User Experience Questionnaire* (Laugwitz et al., 2008). Since the sample size was not satisfyingly high ($N = 8$), they complemented the quantitative approach with open questions, e.g., how they experienced the use of the application and what should be improved, what they liked, and what was left to be desired.

The evaluation revealed that it is crucial to properly address the teachers' needs. Thus, the development team decided to explicitly structure their development culture in a teacher-centered way. To better understand the teachers' needs, qualitative telephone interviews were conducted. During these semi-structured interviews ($N = 4$), the teachers were asked about positive and negative experiences with digital applications (DGBL or learning management systems), their needs for successful

[4] Cognitive walkthrough: a usability inspection method focusing on the cognitive user activities. "The evaluator uses the interface to perform tasks that a typical interface user will need to accomplish" (Mahatody et al. 2010, p. 742).

[5] For further information, see www.pearprogramming.eu

teaching with and without DGBL, ideas for useful features of DGBL applications, and their thoughts on the future of DGBL. Based on these insights, a follow-up survey ($N = 54$) was conducted. With this survey, the pearprogramming team intended to assess and quantify the opinions of the interviewed teachers. The survey results presented an overview of teachers' use of digital media, as well as specific topics such as what resources teachers need in order to prepare and evaluate lessons, how much money they spend on teaching material, and how much they are willing to spend on a digital assistant. These evaluations henceforth form the basis of developing and implementing new features in PearUp.

15.4.2 Evaluation Experiences and Suggestions

Although yUOShi and PearUp come from different domains and address different target groups, certain similarities emerged while evaluating these DGBL applications from a teacher-centered perspective.

Experience 1: Unique ecosystems. Each school and university is a unique ecosystem with its own curricula, regulations, privacy policies, operating systems, computer programs, learning management systems, browser versions, and more. The various obstacles involved in evaluating DGBL applications in such ecosystems can be roughly divided into two categories: administrative and technical. While evaluating PearUp, which is used in secondary schools, we have mainly encountered technical challenges such as non-functional or outdated computers, restricted installation rights, and almost always poor internet connection. In fact, poor internet connection made collecting reliable evaluation results difficult, as PearUp relies on internet connectivity in order to function.

In the university setting, we mainly faced administrative challenges. The yUOShi application needed to be integrated into the existing learning management system, which inevitably led to a dependency on that system. For instance, software updates of the overall learning management system occasionally caused unpredictable problems such as visual bugs or malfunction within the newly developed yUOShi application.

To overcome administrative or technical challenges within the educational environment, we recommend that researchers first identify the unique characteristics of their ecosystem, then choose, and adapt their evaluation methods accordingly to ensure that they remain sensitive to changes in the ecosystem. In other words, researchers must be very flexible, adaptive, and evaluate iteratively.

Experience 2: The "no additional work" mentality. During the analysis of teachers' needs in the yUOShi project, the most frequently mentioned requirement was that the future DGBL application should lead to no additional work (Burfeind et al., 2020). As we have already seen, concern for teachers' resources is a frequent and enduring barrier in both evaluation and implementation of DGBL applications (Sect. 15.2.2). This is not surprising: due to their tight schedules and the different roles and demands placed on them, teachers often experience high levels of stress

(Kyriacou, 2010). Integrating and also evaluating DGBL applications is perceived as additional work and thus can lead to more stress. The "cost[s] of gamification" (Iosup & Epema, 2014, p. 31) are already demanding, and fear of a higher workload even causes preliminary evaluations to be viewed with suspicion. As a result, teachers often avoid participating in evaluations, leading to small sample sizes within these evaluations.

As we cannot change the structures that lead to the workload, we must concentrate on motivating teachers. Based on the experiences in the case of yUOShi and PearUp, successful acquisition often requires personal contact with teachers through which personal appreciation is expressed. Furthermore, to motivate teachers to take part in an evaluation, it can be beneficial to explain the vision of the DGBL application and its intention to reduce teachers' workloads.

Experience 3: Pragmatism. The literature on user experience differentiates between hedonic and pragmatic qualities (Laugwitz et al., 2008). Students tend to be most aware of hedonic qualities; for example, students want the DGBL application to be fun, entertaining, and nicely designed. However, we discovered that teachers are relatively undemanding in terms of hedonic qualities. Instead, they focus on pragmatic qualities such as ease of use and efficiency of applications. Before using a DGBL application in class, teachers tend to evaluate its pragmatic qualities to ensure a smooth implementation and beneficial learning outcome.

During the PearUp evaluation, we found that pragmatic qualities were particularly important for teachers with backgrounds in subjects other than computer science. We concluded that the teachers who were not familiar with the subject of computer science had fewer resources and thus needed more support from our application. We have therefore placed special emphasis on pragmatic qualities such as usability in the development process.

The silver lining. Evaluating DGBL from a teacher-centered perspective is a young research topic and still faces some challenges; however, the task is worth the effort. We have had many positive experiences with dedicated teachers who were highly motivated and pleased to support the development of our applications even in their free time. These teachers often reported that they want to teach actively, instead of being passive users, and appreciated being asked for their opinion and expertise. We therefore highly recommend collaboration with teachers before and during the development of a DGBL application.

15.5 Conclusion

In this chapter, we have identified and examined the principles of DGBL teacher-centered evaluation. We have highlighted the importance of focusing on the teachers' needs regarding DGBL, as considering and integrating their requirements in the development process can lead to a higher acceptance rate.

First, we identified *what* teachers consider as key factors in order to integrate a DGBL application in their lessons. Summarizing existing literature from the field of

IS, HCI, psychology, and educational research on general technology acceptance and the teachers' view of DGBL, we clustered key criteria into the categories of usefulness, user experience, and context factors. This framework goes beyond existing reviews of evaluation criteria (e.g., Tahir & Wang, 2017), as it explicitly focuses on teachers as users. Next, we illustrated *how* exactly the teachers' perspectives can be evaluated to optimize the development process of a DGBL application. To this end, we provided an overview of quantitative and qualitative evaluation methods with their advantages and disadvantages. Then, to facilitate future research and development, we sorted the previously identified key criteria into the four stages of product development (adapted from Sommer et al., 2015). Our overview proposes which key criteria might be meaningfully evaluated at each stage of development and refers to studies with appropriate evaluation examples. Finally, we reported first-hand experiences from two cases of DGBL projects to illustrate how they integrated evaluation procedures in the development process. Based on these examples, we suggested that evaluation methods should be selected according to the characteristics of the specific ecosystem for which the DGBL application is developed. Furthermore, to increase teachers' acceptance, DGBL applications should be developed in a way that minimizes the additional workload for teachers, since they value pragmatism and high success in learning outcomes.

As in any other research work, there are some limitations to consider. First of all, we do not claim that our research is comprehensive. We did not find much DGBL literature focusing on teachers, as most research in the field investigates students as main users. Consequently, once more research is conducted, the key criteria and associated evaluation methods can benefit from extension, prioritization, and refinement. For instance, future studies could work toward an evidence-based prioritization of criteria by investigating whether certain key criteria are more effective than others in enabling teachers' acceptance of DGBL applications. We have also pointed out that previous studies have addressed some of the key criteria more than others (see Sect. 15.3.2). Further research should make sure to include the somewhat neglected criteria of price value, hedonic motivation, and quality and amount of provided training. Although we found that most teachers especially value pragmatic aspects, the effect of perceived enjoyment in teaching via DGBL applications should not be underestimated, particularly when teachers take part in the game as game makers or explorers themselves.

Another limitation lies in our broad definition of "teacher," which encompasses teachers in primary, secondary, and higher education. By doing so, we combine findings from different contexts to reduce complexity and give an overall picture of the state of the art in teacher-centered DGBL evaluations. Yet, as described above (see Sect. 15.2.3), it is likely that the relative importance of key criteria differs across contexts, depending on the role that teachers play in the DGBL application. Therefore, an interesting line of research could be to explicitly examine contextual effects on teachers' acceptance of DGBL. The overview of key criteria and evaluation methods provided in this chapter facilitates orientation and could serve as a basis for further research.

Finally, it must be noted that the illustrative experiences we shared are obviously subjective in nature and stem from two specific contexts. However, they illustrate important aspects to consider when conducting teacher-centered evaluation of DGBL applications in line with previous relevant findings (see Sect. 15.2).

Overall, the approach of integrating theories from IS, HCI, and psychology research with empirical findings from educational research has proven helpful in systematically examining teachers' perspectives on DGBL. Therefore, we highly encourage basing further DGBL research on the fundamental research literature of related disciplines (IS, psychology, education, etc.). Transferring the more technical perspective of IS development to education could be one way to overcome barriers to the use of DGBL. Likewise, a focus on technology acceptance can be valuable for the development of DGBL applications across disciplines.

Despite certain challenges, involving teachers in the development of DGBL applications by systematically evaluating and adapting them to teachers' needs seems to be crucial for the diffusion of DGBL in the classroom setting. While previous research has focused on students and their experiences with DGBL, we propose to emphasize teachers' perspectives in the development and implementation (Alexander et al., 2019). With this work, we hope to make a valuable contribution to advance research on innovative teaching approaches by summarizing evaluation criteria and methods for digital game-based teaching and thereby promoting a more teacher-centered development of DGBL applications.

Acknowledgments We thank the pearprogramming and the yUOShi project team for providing data and experiences for this chapter.

References

Alexander, B., Ashford-Rowe, K., Barajas-Murphy, N., Dobbin, G., Knott, J., McCormack, M., & Weber, N. (2019). *EDUCAUSE horizon report: 2019 Higher Education Edition*. Louisville, CO: EDUCAUSE. Retrieved from https://library.educause.edu/resources/2019/4/2019-horizon-report

Alt, R., Hamborg, K.-C., Metzger, F., Straatmann, T., & Hofmann, A. (2016). Systematischer Einsatz von Playful Prototyping und Gamification im Requirements Engineering. In V. Nisse, D. Stelzer, S. Straßburger, & D. Fischer (Eds.), *Multikonferenz Wirtschaftsinformatik (MKWI) 2016* (pp. S.1–S.7). Universitätsverlag Ilmenau.

Baek, Y. K. (2008). What hinders teachers in using computer and video games in the classroom? Exploring factors inhibiting the uptake of computer and video games. *Cyberpsychology & Behavior, 11*(6), 665–671. https://doi.org/10.1089/cpb.2008.0127

Becker, K. (2007). Digital game-based learning once removed: Teaching teachers. *British Journal of Educational Technology, 38*(3), 478–488. https://doi.org/10.1111/j.1467-8535.2007.00711.x

Becker, K., & Jacobsen, D. M. (2005). *Games for learning: Are schools ready for what's to come*. Paper presented at the DiGRA 2005 Conference: Changing Views – Worlds in Play. Vancouver. https://doi.org/10.11575/PRISM/30340

Blume, C. (2020). Games people (don't) play: An analysis of pre-service EFL teachers' behaviors and beliefs regarding digital game-based language learning. *Computer Assisted Language Learning, 33*(1–2), 109–132. https://doi.org/10.1080/09588221.2018.1552599

Bortz, J., & Döring, N. (2006). *Forschungsmethoden und Evaluation für Human- und Sozialwissenschaftler*. Springer.

Bourgonjon, J., De Grove, F., De Smet, C., Van Looy, J., Soetaert, R., & Valcke, M. (2013). Acceptance of game-based learning by secondary school teachers. *Computers & Education, 67*, 21–35. https://doi.org/10.1016/j.compedu.2013.02.010

Bourgonjon, J., Valcke, M., Soetaert, R., & Schellens, T. (2010). Students' perceptions about the use of video games in the classroom. *Computers & Education, 54*(4), 1145–1156. https://doi.org/10.1016/j.compedu.2009.10.022

Boyle, E. A., Connolly, T. M., & Hainey, T. (2011). The role of psychology in understanding the impact of computer games. *Entertainment Computing, 2*(2), 69–74. https://doi.org/10.1016/j.entcom.2010.12.002

Buchanan, T., Sainter, P., & Saunders, G. (2013). Factors affecting faculty use of learning technologies: Implications for models of technology adoption. *Journal of Computing in Higher Education, 25*(1), 1–11. https://doi.org/10.1007/s12528-013-9066-6

Burfeind, M., Nieland, T., & Hamborg, K.-C. (2020). Nutzerzentrierte Entwicklung einer spielerischen E-Learning Anwendung für Studierende und Lehrende. *Zeitschrift für Hochschulentwicklung, 15*(1), 127–146. https://doi.org/10.3217/zfhe-15-01/07

Chee, Y. S., Mehrotra, S., & Ong, J. C. (2015). Authentic game-based learning and teachers' dilemmas in reconstructing professional practice. *Learning, Media and Technology, 40*(4), 514–535. https://doi.org/10.1080/17439884.2014.953958

Chukwunonso, F., & Oguike, M. C. (2013). An evaluation framework for new ICTs adoption in architectural education. *International Journal of Informatics and Communication Technology (IJ-ICT), 2*(3), 183–189. https://doi.org/10.11591/ij-ict.v2i3.5285

Cojocariu, M. V., & Boghian, I. (2014). Teaching the relevance of game-based learning to preschool and primary teachers. *Procedia - Social and Behavioral Sciences, 142*, 640–646.

Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education, 59*(2), 661–686. https://doi.org/10.1016/j.compedu.2012.03.004

Cuhadar, C. (2018). Investigation of pre-service teachers' levels of readiness to technology integration in education. *Contemporary Educational Technology, 9*(1), 61–75. https://doi.org/10.30935/cedtech/6211

Davis, F. D. (1985). *A technology acceptance model for empirically testing new end-user information systems: Theory and results* (Doctoral dissertation, Massachusetts Institute of Technology). Retrieved from https://dspace.mit.edu/bitstream/handle/1721.1/15192/14927137-MIT.pdf

de Freitas, S. (2018). Are games effective learning tools? A review of educational games. *Journal of Educational Technology & Society, 21*(2), 74–84. Retrieved from https://psycnet.apa.org/record/2018-18436-006

De Grove, F., Bourgonjon, J., & Van Looy, J. (2012). Digital games in the classroom? A contextual approach to teachers' adoption intention of digital games in formal education. *Computers in Human Behavior, 28*(6), 2023–2033. https://doi.org/10.1016/j.chb.2012.05.021

Dele-Ajayi, O., Strachan, R., Anderson, E. V., & Victor, A. M. (2019). Technology-enhanced teaching: A technology acceptance model to study teachers' intentions to use digital games in the classroom. *2019 IEEE Frontiers in Education Conference (FIE)*, 1–8. https://doi.org/10.1109/FIE43999.2019.9028527

Dele-Ajayi, O., Strachan, R., Sanderson, J., & Pickard, A. (2017). A modified TAM for predicting acceptance of digital educational games by teachers. *IEEE Global Engineering Education Conference (EDUCON)* (pp. 961–968). Athens: IEEE. https://doi.org/10.1109/EDUCON.2017.7942965 . https://doi.org/10.1016/j.sbspro.2014.07.679

Egenfeldt-Nielsen, S. (2004). Practical barriers in using educational computer games. *On the Horizon, 12*(1), 18–21. https://doi.org/10.1108/10748120410540454

Egenfeldt-Nielsen, S. (2007). *Educational potential of computer games*. Continuum Press.

Ertmer, P. A. (1999). Addressing first- and second-order barriers to change: Strategies for technology integration. *Educational Technology Research and Development, 47*, 47–61. https://doi.org/10.1007/BF02299597

European Commission. (2019). *2nd Survey of schools: ICT in education: Objective 1: Benchmark progress in ICT in schools*. European Commission. https://doi.org/10.2759/23401

Gaudelli, W., & Taylor, A. (2011). Modding the global classroom? Serious video games and teacher reflection. *Contemporary Issues in Technology and Teacher Education, 11*(1), 70–91. Retrieved from https://www.learntechlib.org/p/35439/

Gee, J. P. (2003). *What video games have to teach us about learning and literacy*. Palgrave Macmillan.

Gerber, H. R., & Price, D. P. (2013). Fighting baddies and collecting bananas: Teachers' perceptions of games-based literacy learning. *Educational Media International, 50*(1), 51–62. https://doi.org/10.1080/09523987.2013.777182

Hamari, J., & Nousiainen, T. (2015). Why do teachers use game-based learning technologies? The role of individual and institutional ICT readiness. *Proceedings of the 48th Hawaii International Conference on System Sciences*, 682–691. IEEE Computer Society. https://doi.org/10.1109/HICSS.2015.88

Hanghøj, T., & Brund, C. E. (2010). Teacher roles and positionings in relation to educational games. In B. Meyer (Ed.), *Proceedings of the 4th European Conference of Games Based Learning* (pp. 116–122). Academic Publishing Limited.

Howitt, D., & Cramer, D. (2007). *Introduction to research methods in psychology*. Pearson Education.

Hsu, C.-Y., Liang, J.-C., Chai, C.-S., & Tsai, C.-C. (2013). Exploring preschool teachers' technological pedagogical content knowledge of educational games. *Journal of Educational Computing Research, 49*(4), 461–479. https://doi.org/10.2190/EC.49.4.c

Hsu, C.-Y., Liang, J.-C., & Su, Y.-C. (2014). The role of the TPACK in game-based teaching: Does instructional sequence matter? *The Asia-Pacific Education Researcher, 24*(3), 463–470. https://doi.org/10.1007/s40299-014-0221-2

Hwang, G. J., & Wu, P. H. (2012). Advancements and trends in digital game-based learning research: A review of publications in selected journals from 2001 to 2010. *British Journal of Educational Technology., 43*(l), E6–E10. https://doi.org/10.1111/j.14678535.2011.01242.x

Iosup, A., & Epema, D. (2014). An experience report on using gamification in technical higher education. *Proceedings of the 45th ACM Technical Symposium on Computer Science Education – SIGCSE'14*, pp. 27–32. https://doi.org/10.1145/2538862.2538899

Jong, M. S. (2016). Teachers' concerns about adopting constructivist online game-based learning in formal curriculum teaching: The VISOLE experience. *British Journal of Educational Technology, 47*(4), 601–617. https://doi.org/10.1111/bjet.12247

Kamişli, H. (2019). On primary school teachers' training needs in relation to game-based learning. *International Journal of Curriculum and Instruction, 11*(2), 285–296. Retrieved from https://eric.ed.gov/?id=EJ1232773

Kangas, M., Koskinen, A., & Krokfors, L. (2016). A qualitative literature review of educational games in the classroom: The teacher's pedagogical activities. *Teachers and Teaching, 23*(4), 451–470. https://doi.org/10.1080/13540602.2016.1206523

Kebritchi, M. (2010). Factors affecting teachers' adoption of educational computer games: A case study. *British Journal of Educational Technology, 41*(2), 256–270. https://doi.org/10.1111/j.1467-8535.2008.00921.x

Kirkpatrick, D., & Kirkpatrick, J. (2006). *Evaluating training programs: The four levels* (3rd ed.). Berrett-Koehler Publishers.

Kyriacou, C. (2010). Teacher stress: Directions for future research. *Educational Review, 53*(1), 27–35. https://doi.org/10.1080/00131910120033628

Laugwitz, B., Held, T., & Schrepp, M. (2008). Construction and evaluation of a user experience questionnaire. In A. Holzinger (Ed.), *Symposium of the Austrian HCI and Usability Engineering Group* (pp. 63–76). Springer. https://doi.org/10.1007/978-3-540-89350-9_6

Liu, K. (2015). The MORPG-based learning system for multiple courses: A case study on computer science curriculum. *International Journal of Distance Education Technologies (IJDET), 13*(1), 103–123. https://doi.org/10.4018/ijdet.2015010106

Loperfido, F. F., Dipace, A., & Scarinci, A. (2019). To play or not to play? A case study of teachers' confidence and perception with regard to digital games at school. *Italian Journal of Educational Technology, 27*(2), 121–138. https://doi.org/10.17471/2499-4324/1062

Mahatody, T., Sagar, M., & Kolski, C. (2010). State of the art on the cognitive walkthrough method, its variants and evolutions. *International Journal of Human-Computer Interaction, 26*(8), 741–785. https://doi.org/10.1080/10447311003781409

Mercader, C. (2019). Las resistencias del profesorado universitario a la utilización de las tecnologías digitales. *Aula Abierta, 48*(2), 167–174. https://doi.org/10.17811/rifie.48.2.2019.167-174

Mercader, C., & Gairín, J. (2020). University teachers' perception of barriers to the use of digital technologies: The importance of the academic discipline. *International Journal of Educational Technology in Higher Education, 17*(1), 4. https://doi.org/10.1186/s41239-020-0182-x

Mussgnug, M., Waldern, M. F., & Meboldt, M. (2015). Mobile eye tracking in usability testing: designers analysing the user-product interaction. In C. Weber (Ed.), *The 20th International Conference on Engineering Design (ICED15)* (pp. 349–358). Design Society.

Pasternak, A. (2019). *Informatik für alle: 18. GI-Fachtagung Informatik und Schule*. Gesellschaft für Informatik.

Prensky, M. (2001). Fun, play and games: what makes games engaging. In M. Prensky (Ed.), *Digital game-based learning*. McGraw-Hill.

Razak, A. A., & Connolly, T. M. (2013). Using games as a context for interdisciplinary learning: A case study at a Scottish primary school. *2013 IEEE Global Engineering Education Conference (EDUCON)*, pp. 1084–1092. https://doi.org/10.1109/EduCon.2013.6530243

Rice, J. W. (2007). New media resistance: Barriers to implementation of computer video games in the classroom. *Journal of Educational Multimedia and Hypermedia, 16*(3), 249–261. Retrieved from https://www.learntechlib.org/primary/p/24378/

Rosengrant, D., Hearrington, D., Alvarado, K., & Keeble, D. (2012). Following student gaze patterns in physical science lectures. *AIP Conference Proceedings, 1413*(1), 323–326. American Institute of Physics.

Rubin, J., & Chisnell, D. (2008). *Handbook of usability testing: how to plan, design, and conduct effective tests*. Wiley.

Saleem, N. E., Al-Saqri, M. N., & Ahmad, S. E. (2016). Acceptance of Moodle as a teaching/learning tool by the faculty of the department of information studies at Sultan Qaboos University, Oman based on UTAUT. *International Journal of Knowledge Content Development & Technology, 6*(2), 5–27. https://doi.org/10.5865/IJKCT.2016.6.2.005

Sandford, R., Ulicsak, M., Facer, K., & Rudd, T. (2006). *Teaching with games: Using commercial off-the-shelf computer games in formal education*. FutureLab. Retrieved from https://www.nfer.ac.uk/media/1812/futl49.pdf

Schmitz, B., Felicia, P., & Bignami, F. (2015). Acceptance and use of game-based learning in vocational education and training: An international survey. *International Journal of Game-Based Learning (IJGBL), 5*(4), 50–63. https://doi.org/10.4018/IJGBL.2015100104

Schrader, P. G., Zheng, D., & Young, M. (2006). Teachers' perceptions of video games: MMOGs and the future of preservice teacher education. *Innovate: Journal of Online Education, 2*(3). Retrieved from https://www.learntechlib.org/p/104278/

Seaborn, K., Fels, D. I., Bajko, R., & Hodson, J. (2017). Gamifying the media classroom: Instructor perspectives and the multidimensional impact of gamification on student engagement. *International Journal of Game-Based Learning, 7*(4), 22–49. https://doi.org/10.4018/IJGBL.2017100102

Selwyn, N. (2007). The use of computer technology in university teaching and learning: A critical perspective. *Journal of Computer Assisted Learning, 23*, 83–94. https://doi.org/10.1111/j.1365-2729.2006.00204.x

Shaffer, D. W. (2007). *How computer games help children learn*. Palgrave Macmillan.

Sharma, R., & Mishra, R. (2014). A review of evolution of theories and models of technology adoption. *Indore Management Journal, 6*(2), 17–29. Retrieved from https://www.iimidr.ac.in/wp-content/uploads/Vol6-2RETMTA.pdf

Sommer, A. F., Hedegaard, C., Dukovska-Popovska, I., & Steger-Jensen, K. (2015). Improved product development performance through agile/stage-gate hybrids: The next-generation stage-gate process? *Research-Technology Management, 58*, 34–45. https://doi.org/10.5437/08956308X5801236

Šumak, B., Hericko, M., & Pusnik, M. (2011). A meta-analysis of e-learning technology acceptance: the role of user types and e-learning technology types. *Computers in Human Behavior, 27*(6), 2067–2077. https://doi.org/10.1016/j.chb.2011.08.005

Tahir, R., & Wang, A. I. (2017). State of the art in game based learning: Dimensions for evaluating educational games. *European Conference on Games Based Learning* (pp. 641–650). Academic Conferences International Limited.

Takeuchi, L. M., & Vaala, S. (2014). *Level up learning: A national survey on teaching with digital games*. The Joan Ganz Cooney Center at Sesame Workshop. Retrieved from https://eric.ed.gov/?id=ED555585

Tseng, T. H., Lin, S., Wang, Y., & Liu, H. (2019). Investigating teachers' adoption of MOOCs: the perspective of UTAUT2. *Interactive Learning Environments*, 1–16. https://doi.org/10.1080/10494820.2019.1674888

Urh, M., Vukovic, G., Jereb, E., & Pintar, R. (2015). The model for introduction of gamification into e-learning in higher education. *Procedia - Social and Behavioral Sciences, 197*, 388–397. https://doi.org/10.1016/j.sbspro.2015.07.154

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly, 27*(3), 425–478. https://doi.org/10.2307/30036540

Venkatesh, V., Thong, J. Y., & Xu, X. (2012). Consumer acceptance and use of information technology: Extending the unified theory of acceptance and use of technology. *MIS Quarterly, 36*(1), 157–178. https://doi.org/10.2307/41410412

Chapter 16
Narrative, Video Games, and Performance In Situ

Evaluating Learning Within Games and Implications for Research from a Literacy Perspective

P. G. Schrader, Kenneth J. Fasching-Varner, and Michael P. McCreery

16.1 Introduction

Literacy is a concept that involves a great deal more than meaning-making from discrete acts of reading texts and writing symbols (Keefe & Copeland, 2011; Lankshear & Knobel, 2000). Literacy is not one single theory or construct; literacy is an informal amalgamation of theories and perspectives that encapsulates discrete skills and events. At the same time, literacy events and skills are cued by social, cultural, and technological contexts (Heath, 1982; Leu et al., 2017; Fasching-Varner & Dodo-Seriki, 2012). With respect to video games, the literature is replete with theoretical perspectives and ontologies that frame video games in terms of literacy, and vice versa (Gee, 2003; O'Brien et al., 2010; Schrader et al., 2009; Squire, 2006; Steinkuehler, 2005, 2006).

Gee (2003) initially characterized games as spaces to naturally acquire and develop a sundry of literacy skills; he listed 36 principles that relate to learning in schools, communities, and workplaces. These principles highlighted the relationships among theories of literacy and how players interact with games. Similarly, Squire (2006) characterized games as narrative experiences. In this sense, he described games as intentional systems that are designed to communicate the narrative through players' activity and interactions with and within the system. Additionally, Steinkuehler (2005, 2006) examined the cultural nestings of games

P. G. Schrader (✉) · K. J. Fasching-Varner · M. P. McCreery
University of Nevada, Las Vegas, NV, USA
e-mail: pg.schrader@unlv.edu

C. Aprea, D. Ifenthaler (eds.), *Game-based Learning Across the Disciplines*,
Advances in Game-Based Learning, https://doi.org/10.1007/978-3-030-75142-5_16

through a literacy lens. She argued that games are "third spaces," and players' sociolinguistic experiences are mutually informed by local and encapsulating contexts.

Building on these and other ideas, this chapter examines video games from an ecologically centered literacy perspective and literacy from an ecologically centered gaming perspective. Several key topics are addressed, including video game structures as a form of narrative, individual, and social performance as well as the sociocultural influences that shape experience (Pitt et al., 2019). Video games are isomorphic to literacy, particularly in terms of the topics noted and their sociocultural intersectionality (Crenshaw, 1991; Carbado et al., 2013; Romero-Ivanova et al., 2019). It follows that there are extant methods in both fields that inform framing research, generating hypotheses, extracting data, and drawing inferences. Collectively, these approaches coalesce into a theoretical ontology (i.e., one that deconstructs interaction, literacy, and media sciences) that has great implications evaluating learning as situated within the context of games. This alignment is exemplified through careful examination of three games: *Super Mario Bros.*, *The Deed*, and *World of Warcraft*.

16.2 Narrative and Video Games

16.2.1 Literacy

For many, the theoretical field of literacy may appear simplistic. The common experience is aligned with a developmental perspective. From this view, literacy begins with listening, which is typically considered the least complex skill. Although there is considerable overlap during students' early years, individuals are believed to transition to speaking, reading, and then writing (Teale & Sulzby, 1986; Sulzby & Teale, 1991). In terms of learning, students are typically taught each of these skills in sequence. Listening is often believed to be fundamental and the easiest to develop. By contrast, writing is believed to be the most complex, and it is taught last (Teale & Sulzby, 1986). All these modalities are applied within increasingly broad contexts (i.e., a word, a sentence, a page, a paragraph, a story, a classroom, a school, and the world in which the student lives).

As an overarching theory, literacy is considerably more broad, nuanced, and complex than common experience. Organizations dedicated to advancing our collective understanding of literacy have been hesitant to define it in concrete, pragmatic, and definite terms (Keefe & Copeland, 2011). As a result, a unified conceptualization of literacy has proven elusive. However, considerable time has been invested in terms of identifying, mapping, and researching literacy events, skills, and contexts (Lankshear & Knobel, 2000). For example, researchers have characterized postmodern literacy skills as *New Literacies* (Buckingham, 1993; Lankshear & Knobel, 2006; Lawless & Schrader, 2008; Street, 1998), *Multiple Literacies* (Bean et al., 1999; Brown, 1991; Cook-Gumperz & Keller-Cohen, 1993;

Kellner, 1998), or *Digital Literacies* (Gilster & Glister, 1997; Lankshear & Knobel, 2008; Martin, 2008; Snyder, 1999). These views characterize literacy in terms of contemporary skills in a global context.

The field of literacy has developed a greater understanding of several constructs, including those associated with technology and video games (Schrader & Lawless, 2010; Schrader et al., 2009). Rather than developing a formal and overarching structure to guide the field, there is general agreement that an understanding of literacy must "... embrace the multiple cultural, social, and technical contexts…" that drive meaning-making and literate engagement (Mirra & Garcia, 2020, p. 5). As such, literacy is more than simple acts of making meaning from reading or writing words (Heiten, 2016). Literacy is inherently contextualized cultural, social, and technological terms. Because contexts shift, literacy is continually evolving and changing. What we know as literacy is essentially influenced and "...determined by the continuously changing social forces at work" (Leu et al., 2017, p. 1). Literacy, as a theoretical site of engagement, is an overarching, dynamic amalgamation of principles that loosely frame and guide the examination of literacy events (see Heath, 1982). These events occur within and evolve because of, current technological, social, and cultural norms.

Based on this perspective, *literacy events* serve as a principal mechanism to expand our understanding of process-oriented, game-based learning. Literacy events can be understood as actions or situations that are concretely demonstrative of literacy practices (Heath, 1982). Based on this understanding, players' situated activities, decisions, and engagements within games are literacy events. Further, video games are intentionally designed systems that afford opportunities for literacy events. These events and their constituent elements are paramount in understanding and evaluating the ways users interact within these systems. This collective view offers a powerful lens to examine performance in situ from a literacy perspective.

16.2.2 Elements of a Literacy Event

Literacy is the broad set of principles that loosely guide theory and research (Keefe & Copeland, 2011). More specifically, a literacy event is any situation in which someone's actions and situations demonstrate literacy practices (Heath, 1982). With respect to a literacy event, there are four main elements to consider: text, context, skill, and application. The terms provided are neither exhaustive nor comprehensive; the concepts associated with literacy and the affordances of games are too complex to be fully explained within a single chapter. Rather, text, context, skill, and application are key elements across various orientations associated with literacy. More importantly, these elements are described as events for the specific reason that they represent a moment in which a literacy episode occurred. As such, the examples highlight a framework that demonstrates the alignment between these two domains as well as provides a list of observable phenomena for researchers who might adopt this framework.

Text. Although the text is often understood as symbolic representations of ideas in written or printed form, there has been considerable work which has established that text means much more. For example, a multimodal view of texts expands the notion that written text is a physical or digital representation that symbolizes "the writer's meanings according to the conventions of a linguistic code" (Wells, 1990, p. 371). Multimodality, then, includes elements of communication associated with graphics, text, arrangement, and overarching context to expand the notion of *text* beyond marks, icons, or symbols consistent with written systems, sounds, paralinguistics, and other elements of language constitute text (Kress, 2003, 2005, 2010; Kress & Van Leeuwen, 2001; Wells, 1990). As a result, the notion of "text" (i.e., a text event) includes words, ideas, or concepts that can be communicated by spoken, written, or consumed (aural or oral) language. Similarly, the text also includes the font choices, graphics, movements on screen, and other mechanisms for communication and meaning-making in a digital environment like games.

Context. A simple dissection of the word reveals that context means: *with* text. When leveraged in an intentional way, text-based symbols yield larger patterns and form ideas; readers make meaning from text within context and writers wield text within context to communicate ideas. Context, specifically, is the purposeful manipulation of text elements in situative, descriptive, or linguistic ways to create or derive meaning from those arrangements (Henrici & Köster, 1987). While reading, individuals interpret static text and images as individual sources of information. However, those isolated elements are always nested within some encapsulating context; readers also construct meaning from the relationships among these elements (i.e., local context) and the broader context in which the texts reside (i.e., encapsulating and intersectional context).

According to Dey (2001), context, whether local or encapsulating, refers to "any information that can be used to characterize the situation of an entity" so that the entity can be more fully understood or assessed (p. 5). An entity here refers to any person, place, or object that provides meaning for any event, statement, or idea, including the interactions between players and systems like video games, where issues of narration, situation, description, and language are relevant (e.g., the texts, rules, graphics, symbols, and objects within the game). This conceptualization also includes interactions among players (e.g., in Massively Multiplayer Online Games, or MMOGs) and the interactions among players and the broader contexts in which games reside.

For a video game, one might interpret local context to include: the location of icons, the color of the text, the story or narrative, menu options, etc. The encapsulating and intersectional context, by extension, includes both the immediate and the broader context in which the games exist. For example, the zombie classic Resident Evil exists within the immediate context of zombie-themed games and a greater context of a national zombie craze in the United States. Resident Evil is a game that exists within a global pandemic; some have used the zombie apocalypse as a psychological analogy for the precautions taken during the spread of COVID-19 (Hirshbein, 2020). In terms of video games, context informs the meaning-making of texts on screen, in relation to a genre, and within the infinitely nested, encapsulating contexts.

Skills. Skills include the capacity and agency that individuals need to work with text and its associated contexts. Given the abundance of unique texts and contexts, the literature is replete with lists and descriptions of skills. For example, the New Literacies perspective elucidates skills in the new and emerging technologies (e.g., consuming and creating text messages, videos, and content via social networks) (Coiro et al., 2008). These digital technologies change the way individuals consume and produce information, particularly as it involves communication via text, sound, and image.

It is not possible to address all skills that relate to literacy and games, although there are certain skills that are highly influential in terms of literacy and gaming. Specifically, these skills include decoding and comprehending reasoning (i.e., critical thinking/decision making), and navigation. In general, decoding and comprehending are interrelated skills of knowing how to identify and name symbols presented in a text or context with comprehension furthering that sense of identification and naming to meaning-making (Gough & Tunmer, 1986). Reasoning involves critical thinking and decision-making and refers to the ability to understand assumptions, make claims that are supported by evidence, and make conclusions that are warranted by the evidence presented (El Soufi & See, 2019).

Although each skill is important for literacy in the context of games, navigation holds special meaning in virtual and immersive environments. Navigation refers to the cognitive wayfinding through and across texts using contextual cues to ascertain meaning and location (Alexander et al., 1994; Hill & Hannafin, 2001; Kozma, 1991; Lawless & Brown, 1997; Lawless & Schrader, 2008). According to Singer and Alexander (2017), navigation involves interpreting and utilizing patterns of text across time. In other words, how the text is accessed, and the time allocated to accessing, decoding, comprehending, and engaging in critical thinking/decision-making dictate the nature of the literacy event engagement. Because most games require some form of navigation (e.g., moving an avatar through the narrative space), navigation holds special meaning in these environments (McCreery et al., 2011).

Application. Literacy application refers to any implementation of literacy skills, including the related texts and contexts of the literacy event, in a collective or comprehensive enterprise. An event becomes a full literacy event if, and only if, the established literacy skills are applied to texts within relevant contexts. In this sense, video games become a site of application for literacy events. Application within literacy frames includes numerous different sets of guidelines and orientations (e.g., expository, descriptive, persuasive, and narrative applications). Narrative, for example, expands the more general application of literacy (i.e., communication of words and ideas) by nesting skills and contexts within elements of storytelling, background, or orientation. By design, video games are well-suited to the application of narrative and, as such, games are vehicles that afford the application of literacy events.

16.2.3 Video Games, Literacy, and Narrative

Video games have been the subject of research for several decades. There are numerous meta-analyses, reviews, articles, handbooks, symposia, and more that have sought to elucidate theoretical and educational aspects of games (Baptista & Oliveira, 2019; Bediou et al., 2018; Clark et al., 2016; Connolly et al., 2012; Girard et al., 2013; Ifenthaler & Kim, 2019; Ke, 2009; Kim & Ifenthaler, 2019; Mayer, 2015; Wouters et al., 2013; Young et al., 2012; Zheng & Gardner, 2017). This theoretical discussion of games includes perspectives of video games as opportunities for situated performance and learning (Barab et al., 2010; Baek, 2017; Gee, 2008; Schrader & McCreery, 2012; Schrader et al., 2017; Schrader et al., 2019) and tools for delivering information (De Freitas, 2018; Moshirnia & Israel, 2010; Prensky, 2001). The corpus of games-based learning literature reveals a field replete with articles centered on method designs, case studies, and conceptual undertakings that provide guidance for educators and researchers (Schrader et al., 2020).

The field of video games has matured in the last several years. Recent work has paved the way for frameworks and approaches to research with games, including deep analytic techniques, assessment practices, and perspectives involving user characteristics (e.g., attitude, enjoyment, and perceived usefulness) (Alonso-Fernández et al., 2019; Baptista & Oliveira, 2019; Baek, 2017; Ifenthaler & Kim, 2019). Although several new approaches have been posited, there remains an ongoing need for research findings and frameworks to interpret these results (Mayer, 2015; Schrader et al., 2019, 2020; Young et al., 2012). Researchers argue that one reason for this involves the very nature of games. Specifically, games vary from one example to the next (Schrader & McCreery, 2012). Games are inherently interdisciplinary and cross-disciplinary in nature (De Freitas, 2018; Schrader et al., 2019). Each game exhibits distinct content and approaches to users' experiences (Schrader et al., 2019). Similarly, encapsulating contexts, affordances, and designs of these games is unique to each example (Schrader & McCreery, 2012; Schrader et al., 2017, 2020; McCreery et al., 2015; McCreery et al., 2019).

In terms of research, the field typically adopts an implicit definition of games that characterizes them as interactive systems with specific ludic properties. There have been a few notable attempts to operationally define games in ways that enhance the field's ability to conduct research and exchange findings. Some of these efforts involve the nature of their characteristics to classify examples of these systems. Mayer (2014), for example, provided a definition of games that relied on elements like the presence of rules, responsiveness, challenge, score or record keeping, and inviting or appealing elements. From a design perspective, this view characterized systems that qualify as games (or not) in a way that is independent of context and users' experiences. Alternatively, McGonigal (2011) approached the definition of games in a similar manner and described a game as any system that exhibited four traits: a goal, rules, a feedback system, and voluntary participation. Although there are similarities, McGonigal's characterization of games relied more on the actualization of the system's affordances in tandem with users' experiences.

Mayer and colleague's (Mayer, 2014; Mayer & Johnson, 2010) views differ from McGonigal (2011) in terms of agency. Mayer and Johnson articulated games in concrete terms, characteristics, and as mechanisms that have an influence on learners and learning. McGonigal, by contrast, described games in a reciprocal relationship with the players that interact with them, players have agency with these systems in a way that both are mutually interdependent. More importantly, McGonigal characterized game context in local and global terms. The former view aligns with classical, decontextualized perspectives on learning while the latter is in step with contemporary views of learning as a contextualized process (Bransford et al., 2000; Jonassen et al., 1994; Salomon et al., 1991; Schrader, 2008).

Expanding the characteristics or traits approach, contemporary views of game-based learning tend to agree that video games are process-oriented and facilitate learning as a function of the interactions within as a result of their characteristics (Gee, 2008; Plass et al., 2010; Schrader et al., 2017, 2019; Squire, 2011). Most agree that players' experiences occur within a broader context, in addition to all local influences (Barab et al., 2010; Steinkuehler, 2005, 2006; Squire, 2011). Kafai (1996), as an example, examined gender differences in girls' preferences related to games. Work of this nature is ongoing, but some researchers have begun to examine the intersectional characteristics of video games, including race, gender, and sexuality (Malkowski & Russworm, 2017).

Although a highly contextual and intersectional perspective of video games continues to evolve, the notion of intersectional contexts has been a long-standing focus within the field of literacy. The relationship between literacy and games has been explored on several occasions. For example, Steinkuehler (2005, 2006) examined the cultural exchanges in the MMOGs *Lineage* and *Lineage II* for 2 years. She characterized the cultural exchanges and practices within MMOGs as literacy practices in which players read a wide variety of texts, including those in print and not in print. Schrader et al. (2009) and Schrader and Lawless (2010) also posited that video games were intertextual in nature; players rely on their comprehension of multiple texts across a variety of external sources for their in-game success. Players employ skills like navigation and multiple source comprehension where they can "… interpret, evaluate, and appreciate texts" across multiple formats and sources (p. 315, Steinkuehler, 2007). For these reasons, video games provide a valuable mechanism for players to exhibit literacy skills within a specific gaming application.

16.2.4 Game-Based Learning, Text, Context, Skills, and Application

Game-based learning has typically been defined in terms of outcomes as a result or consequence of gameplay (Lamb et al., 2018; Plass et al., 2010). An outcome orientation of game-based learning is common, but some have suggested an expanded view of this perspective (Schrader & McCreery, 2012; Schrader et al., 2019). Games exhibit a variety of design elements grounded in behaviorist, cognitivist, and constructivist structures that are implemented in order to support player skill levels

(Plass et al., 2015). Moreover, these design elements leverage music, narrative, aesthetics, game mechanics, and incentives through a challenge, response, feedback system (Plass et al., 2015). This complexity highlights the problematic nature of viewing learning as an outcome, as it strips away the nuance associated with learning in situ (Schrader & McCreery, 2012; Schrader et al., 2017). However, the examination of game-based learning as a literacy event distinctly aligns with the view that learning occurs within the multilayered challenge, response, and feedback systems.

At its core, game-based learning is grounded in the principles of semiotics (Gee, 2003). Players must construct meaning during gameplay through the interpretation of narrative, signs, and symbols within an encapsulating context (Lasley, 2017). For example, the change in the cursor to an open hand reflecting interaction with an in-game object. From this perspective, learning is not an outcome but rather a process. It is the process of semiosis occurring across a stream of text events that are structured within systems that presents a challenge, response, and feedback. Similarly, because game-based learning is grounded in a semiotic experience, event-based, broader narrative-based, and encapsulating contexts become the catalyst *for* (emphasis added) literacy skill development and application. For example, a player comes to a door that is marked with runes (i.e., event context). The change in cursor reflects the player's ability to interact with the runes (i.e., one of several text events that are occurring), and prior narrative experience (i.e., broader context) provides knowledge on how to interpret the runes. The player is then required to engage in critical thinking, integrating prior knowledge with current experience (i.e., skills) in order to solve the runic puzzle on the door (i.e., application).

16.3 Examples

The connection between video games and literacy has been the subject of considerable discussion, with both disciplines being performance-oriented and requiring grit, hardiness, and perseverance. An epistemological exploration of literacy and game-based learning demonstrates theoretical alignment throughout the literature (Gee, 2003, 2008; Schrader & Lawless, 2010; Schrader et al., 2009; Steinkuehler, 2005, 2006, 2007). In terms of ***text***, video games present information using aural and auditory conventions (e.g., words, ideas, or concepts). Video games use image, graphics, movement, and similar mechanisms to communicate meaning (e.g., chat windows, maps). In terms of ***context***, video games rely heavily on contextual cues in a local sense. For example, in Tetris, players arrange blocks in direct relation to each other, attempting to avoid gaps in their stack. Tetris was also a game created by Russian software engineer Alexey Pajitnov in 1984. Tensions among the Soviet Union and many other countries at the time provided an interesting global context for the game. In terms of ***skills***, most video games rely on some form of navigation within the system. Players often demonstrate literacy skills like multiple source comprehension and multimodal reasoning. Overall, these texts, context, and skills coalesce in games, which become sites of ***application*** for literacy (Steinkuehler, 2007).

The premise that video games are isomorphic to literacy events is best demonstrated through example. As a result, what follows is a careful examination of three games: *Super Mario Bros.*, *The Deed*, and *World of Warcraft (WoW). Super Mario Bros*. reflects classic side-scrolling and platform jumping mechanics. The story unfolds through each level, but the emphasis in *Super Mario Bros*. is the enjoyment of the game. By contrast, *The Deed* is more closely related to a "choose your own adventure" interactive, clickable narrative. The gameplay in *The Deed* serves the story and players' experience as a character in the story. *WoW* is quite different from a game-play perspective; it is a highly interactive, 3D immersive world. In terms of story, narrative, and plot, *WoW* falls somewhere in between *Super Mario Bros*. and *The Deed*. In WoW, the story provides context for a wide variety of actions, events, and activities. These experiences are open-ended and predominantly nonlinear.

Although there are numerous examples that might suit this purpose, the games were selected because they vary in terms of user interactions, genre, graphics, play style, and are situated in different contexts and game-based cultures. These examples serve as a valuable demonstrative cross-section of the connections between literacy and video games. Each game is unpacked in terms of its text, context, skills, and application, as well as its overall relationship with a literacy event. The application of literacy in three games is summarized in Table 16.1.

Table 16.1 The Application of Literacy in Three Games

Element	Super Mario Bros.	The deed	World of Warcraft
Text	• Outlines progression • Differentiates with sound • Orients narrative basis	• Progressive storytelling elements • User interacted (user-driven)	• Text-based chat and communication • Sound provides feedback • Iconographic cues (e.g., map, avatar, character sheet)
Context	• Visio-spatial elements • Layered • Replication through difference • Consistency through progression	• Small map, room by room local cues • Macabre game genre • Independent game developer	• Visio-spatial orientation via landmarks • Encapsulating culture of machinima, informational sites, and strategy repositories
Skill	• Navigation (intra- interlevel) • Multisource narrative • Multisource navigation • Network of players to skill build • Progress, die, repeat.	• Navigation among rooms • Comprehension of narrative/plot • Decision-making and strategy • Play and repeat choices	• Multiple source comprehension • Social collaboration • Decision making • Critical thinking

16.3.1 *Super Mario Bros. (1985, 2020)*

Description. The original *Super Mario Bros.* was released by Nintendo (1985) in Japan on September 13, 1985. Gaming hardware was in its infancy when the original Nintendo was released, and the system was one of the first systems to penetrate the global market. *Super Mario Bros*. is referred to as a platform game, in which a player controls an avatar (i.e., Mario or Luigi). The player must move left or right and jump over obstacles, including enemies, between the eponymous platforms. The brothers in *Super Mario Bros*. are plumbers, and the entire game is themed using interconnected pipes and worlds matching context to metaphor.

Text. In *Super Mario Bros*., there are elements of text, graphics, and sound. Each gives some indication of both story and interactive elements within the system. On the most basic level, players select a one- or two-player game using the initial menu. Similarly, the text is an important mechanism to orient players within levels and worlds. There are key informational elements at the top of the screen, which provide cues about which player is active, the world and level number, the number of coins, and the number of lives remaining.

In addition to symbolic representations of text, sound also plays an instrumental role within *Super Mario Bros*. Designers incorporated subtle but important differences in sound, including different total qualities for different jumps (i.e., normal vs. high jumps), different sounds for landing on enemies, and a recurring soundtrack that provided information about the level. Sound provides important cues for players to inform their actions and shape their decisions within the game.

Context. Perhaps the best example of the context within *Super Mario Bros*. relates to the hidden elements and secret zones that were embedded within the game that players could discover. Hidden elements (e.g., level-ups, power-ups, or extra lives) were hidden among normal blocks. Secret zones were accessible by moving through false walls, ducking into special pipes, or jumping above the top of a level. In terms of local context, players would have to identify the relative position of these elements via static visual cues. Using these cues, players would hit the appropriate block or enter the secret zone. Once inside a secret zone, the notion of local context is underscored as background graphics, sounds, and elements within the zone would change to reflect the new environment.

In addition to these local and hidden elements, *Super Mario Bros*. existed within a wider context, one that was relatively new at the time. Within 2 years of its release, Nintendo had spawned a global fan club, the Nintendo Power magazine, and a burgeoning video game culture that included television shows, among other things. This was partly due to the widespread success of *Super Mario Bros*. and other Nintendo titles. Regardless, *Super Mario Bros*. players had access to tips, strategies, clues, and maps to promote their success within the game. Similarly, they experienced the game within a growing context of peers who also enjoyed the games. Recursively, each of these elements informed players' ability to interact with and within the game.

Skills. There are a few key literacy skills that are evident within *Super Mario Bros*. These include navigation, decision-making, contextual decoding, assessment, and multiple source comprehension. In terms of navigation, there are numerous ways to overcome challenges while controlling Mario or Luigi. A player can run, jump, or attack opponents by landing on them. Alternatively, they could find hidden passageways through secret zones and bypass the challenges altogether. Players who have uncovered enough of these secrets may even be able to pick up on design-level cues (e.g., a pipe that may seem out of place) to find them. Otherwise, these options were located through a trial-and-error process, making intentional decisions to play the game for these treats. Alternatively, players also exchanged ideas and strategies via conversation or written form (e.g., Nintendo Power). They often consumed considerable outside resources to promote better play and a more enjoyable experience. Lastly, players made specific decisions in terms of navigation and strategy to accomplish these goals. Ultimately, the interaction with the game relied on an expansive set of literacy skills within and outside *Super Mario Bros*.

Application. These examples of text (e.g., symbolic and non-symbolic text), context, and relevant literacy skills within the game coalesce within *Super Mario Bros*. and are demonstrated as a result of players engaging with the game. Playing *Super Mario Bros*. affords the application of text within a local and broader context and enables numerous literacy skills. Fundamentally, the act of playing *Super Mario Bros*. is isomorphic to the application of literacy. Similarly, the system itself (i.e., independent of the player) affords the application of literacy and is referred to as a site of application.

16.3.2 The Deed (2015)

Description. *The Deed* is a commercially available game developed by Pilgrim Adventures and GrabTheGames Studios (2015) that applies a novel twist to the murder-mystery genre. Created with RPGMaker, *The Deed* is an adventure/role-playing game that incorporates a choose-your-own adventure style of play that is focused on getting away with murder. *The Deed* is designed for a single player and uses stylized graphics reminiscent of mid to late 1980s adventure games (i.e., ¾ view of the rooms). Players make choices throughout the game and collect evidence that they "plant" later. Rather than solve a murder mystery, the principal goal is to commit murder and convince others you are innocent. This is accomplished by collecting and planting evidence to frame another non-player character. The game is partitioned into four acts: (1) exploration of the house (prefaced by an introduction), (2) dinner, (3) a time to plant evidence and commit the murder, and (4) an interview with the Inspector who comes to investigate the murder. The game concludes with the inspector's decision.

Text. From a literacy perspective, *The Deed* employs traditional narrative elements through a choose-your-own adventure mechanic. In terms of text, *The Deed* leverages abundant symbolic text (i.e., typical) to convey information. Players are given options in text-based, multiple-choice format when interacting with elements. These notices are also tagged relative to items like weapons and evidence.

Context. Locally, the game adopts a monochromatic and dark color scheme. The map is small and is presented as a series of rooms/screens. Doors and hallways mark separation and provide some local context for players' location and navigation. Beyond the local elements, *The Deed* is situated within several genres of games. *The Deed* was created using RPGMaker. This tool is popular among role-playing game (RPG) enthusiasts. This type of game fits with others like it, most of which are inexpensive and produced by smaller companies. In addition to the RPG genre, *The Deed* is also a macabre murder-mystery, thematically dark, and inverts the more common narrative. Players are challenged to engage in morally reprehensible decisions if they intend to accomplish the main goal in a time when there is abundant violence in the news and reported via social media.

Skills. Like most games, *The Deed* relies on the navigation to help orient users within the game and story. Users control Arran Bruce (i.e., the main character) using a keyboard or mouse and navigate through Arran's childhood home. Throughout these rooms, players can interact with several family members and staff, search through different rooms, and are given the choice of picking up objects. *The Deed* also relies on decoding, comprehension, and decision-making skills to execute the perfect murder. Players must first understand the written information, then they must make appropriate decisions about their actions. They aren't able to accomplish the main goal if they are unable to read, understand, and act on the written information that is presented on the screen.

Application. *The Deed* is a robust example of a literacy application in terms of symbolic text. Written text is pervasive throughout the game and necessary for play. The game is structured like a choose-your-own adventure narrative that is spatially cued in terms of item location and navigation. Literacy skills and local context play a crucial role in the application of literacy in *The Deed*.

16.3.3 World of Warcraft (2004)

Description. *World of Warcraft* (WOW) was created by Blizzard Entertainment (2004) and is an MMOG set in a medieval world of dragons, elves, dwarves, orcs, and magic. WOW is currently in its 16th year and has radically transformed the gaming market. Arguably the most influential MMOG, WOW has been lauded for its immersive worlds, dynamic gameplay, and vibrant multiplayer interactions. Players create a character, choosing from one of eight races and one of nine classes. After character creation, players secured experience points by exploring content and accomplishing challenges throughout the world.

Text. WOW was designed as a massively multiplayer game and included a robust and interconnected social chat system. This system allows players to communicate with others located near them as well as players in their guilds and friend's group. The same window also provides feedback for combat, damage received and inflicted, status updates, and more. The symbolic text is one of the principal mechanisms to provide information and make meaning within WOW.

WOW also contains numerous symbols involving sounds and other elements to convey meaning. Icons are used to provide information about enemies, resources, and objectives on a local and world map. Player's health and resource amounts are visually represented on screen. A character sheet also provides important visual cues for players' equipment, status, and other signs and signifiers. WOW numerous text elements that are based on written systems, sounds, and paralinguistics of language.

Context. WOW implemented a vast, immersive, 3D world through which players controlled an avatar and interacted with the environment, non-player characters, and other players. The original game consisted of two principal continents that were divided into multiple zones. Each zone was rendered to exhibit different characteristics, climates/biomes, colors, and thematic elements. WOW included beach zones, swamps, tundra, deserts, jungles, forests, and many other regions. These regions also included appropriate animals, fauna, and geographic features. These contextual cues provided players with information about quests, items, reagents, resources, and many other game-related elements. On a local level, players navigated the environment using contextual cues like landmarks. They also used similar contextual information to discern their local objectives.

Since its release in 2004, there have been seven expansions, and the company reports maintaining millions of subscribers (Clayton, 2018). The record for active subscribers was set in 2010 at 12 million subscribers. The widespread popularity of WOW also spawned numerous websites, information repositories, and resources for players. Player groups (i.e., guilds) developed pages specifically designed to track membership and accomplishments. There are numerous videos and guides that were created to help players develop strategies and group compositions for some of the game's more difficult challenges. In addition to these purposeful sites, WOW was also a cultural phenomenon and subject matter for TV shows and entertainment videos.

Skills. WOW is a highly intricate game and involves numerous skills to achieve game-related goals. Players control the complex actions of their avatars while they navigate an expansive, immersive environment. Players must consume and understand vast amounts of information in text and alternative symbolic formats that are native to the game in relation to quests, feedback systems, and social systems. This content is also complemented by the information available across multiple external sources; players must be able to seek, identify, comprehend, and apply this information. Players must also communicate with peers, friends, and other players; collaboration is a principal mechanic of any MMOG.

Application. There are many ways that players experience the *World of Warcraft*, they adopt either a role that follows the alliance or horde. Players decide if they would like to provide support, become a leader, or a character that specializes in dealing damage to enemies. WOW also includes several trade skills and opportunities for players to increase their in-game wealth, chances to interact socially, explore the environment, accomplish complicated goals and activities, and develop a powerful character that can overcome any challenge. These activities represent a few of the many ways players may interact with and within WOW. Similarly, each also represents an application of literacy.

16.4 Implications for Future Research

The field of game-based learning continues to develop in terms of accepted theory and research practices. The examples and perspective outlined here are intended to provide some additional tools and resources for researchers associated with operational definition of variables (i.e., literacy skills and events), data extraction (e.g., literacy research practices), interpretation of findings (i.e., intersectional contexts), and development of advanced theory. In terms of game-based learning, traditional and contemporary literacy researchers have described numerous literacy skills, activities, and events. These might cue games-based learning researchers in terms of which activities within games are useful for observation. Literacy researchers have also examined the exchange of information and ideas using various codes (e.g., formal codes like text and informal codes like gestures). This might be a useful perspective when considering the exchange or interchange of ideas within games. In WOW, for example, researchers could observe avatars' gestures, movements, and players' texts as indicators of the application of literacy.

Games-based learning researchers may also find some of the extant procedures for identifying, coding, and interpreting data beneficial. Similarly, traditional and contemporary literacy that literacy skills and events, which are analogous to gaming activities, are also highly contextual and interrelated. These strategies might inform the study of a game like Super Mario Bros. in terms of high-frequency inputs and outputs, player performance, and player understanding of hidden elements (i.e., local context). Overall, games-based learning researchers might examine learning as a process using the interactions among elements, literacy events, agents, and nested contexts. More importantly, the systems could be of benefit for researchers in terms of log files, video recordings, chat transcripts, and server data mining. Finally, literacy addresses intersectional concepts involving sociopolitical aspects of the contexts. As such, the future of both gaming and literacy is brighter, better, and bolder by being linked together through the frames presented here.

Collectively, a literacy-oriented games-based learning epistemology has implications for the ongoing development of theory and game-based learning research. This orientation also highlights additional potential across several disciplines. For example, the fields of human–computer interactions and engineering might benefit from a perspective that the human agents within systems exist within numerous sociological contexts and states involving intentions, experiences, acceptance, or skills might vary for reasons external to the user. Taking this possibility into account might further shape how systems are created and how they are introduced to users. Similarly, a literacy and gaming isomorphism has implications for the broader study of sociology in contemporary spaces, like games. In addition to defining interactions in digital spaces, the literacy/gaming perspective adds context and skills that are informed by societal cues. The ideas presented here outline a theoretical perspective that characterizes the intersection of key components on multiple scales (e.g., local and global). Ultimately, human existence relies on the creation, exchange, and understanding of information. A literacy perspective empowers researchers across domains to examine phenomena in different ways, thus expanding our collective understandings in those areas.

16.5 Discussion and Conclusion

To accomplish the linking of gaming as literacy events, the concepts of literacy that bind our focus must be outlined. This chapter has examined the characteristics and properties of three games to demonstrate transversal elements of literacy as literacy events described earlier. An isomorphic relationship between the field of video games generally to literacy events is exemplified through *Super Mario Bros.*, *The Deed*, and *World of Warcraft*. One of the challenges in a variety of disciplines where literacy and gaming overlap is the reduction of key concepts to a particular theoretical or disciplinary home. By linking the two here, the reciprocal ways in which literacy supports and understanding of games, and games model, in the application, the elements of literacy events is demonstrated.

The implications of the linking done here are myriad. First, we acknowledge that while some work has been done to articulate connections between gaming and literacy writ large that work mostly falls short of providing specifics that could drive forward the conceptual understandings of literacy in meaningful and substantive ways. To that end, we have outlined specific qualities of literacy and showed how they can be applied and demonstrated in gaming generally and through the three games, we highlighted. Second, literacy has generally wanted to focus much of its attention and pedagogical thrust on print relationships between reading and writing. Our work here expands the implications of literacy by suggesting that reading and writing do not necessarily engage solely around print text; through an understanding of context and the positionality of the players within these games we see reading and writing behaviors as well as listening and speaking modalities consistent with a broad-based conceptualization of literacy. Finally, we posit that the technological demands of the twenty-first century have created a hyper digitally engaged generation for whom traditional conceptualizations of literacy and their ensuing paper/pencil-based assessments fall short of engaging the multimodal nature of children.

In conclusion and as a basis for further thinking, four key points are provided below. These provide ideas on framing the discussion for games researchers and literacy researchers alike:

1. An orientation involving literacy and gaming functions better through a bi-focal pairing. While each field may be strong on their own, together they constitute a

more robust and thoughtful analytical enterprise relative to their scope and engagement.
2. Literacy elements are not traditionally linked in practice outside of the print text, particularly in out-of-school contexts. The literacy elements we outlined in terms of text, context, skill, and application in general terms. They are analytically robust within the context of gaming and have an ability to responsively morph to ever-changing and digitally connected contexts.
3. Independently, gaming and literacy have less depth than when considered in the context of each other; the collective sum is greater than either part alone. Literacy provides a new analytic language to expand how the gaming community can think through their work, whereas gaming gives literacy practitioners new, novel, and engaging contexts. Both disciplines benefit from an isomorphic connection.
4. The structural elements of literacy that we have modeled through the game examples expand venerable perspectives involving literacy events. Heath's (1982) originally conceptualization of literacy events dominated the discipline, and these events are often framed traditionally (e.g., print text, media, and writing). Gaming adds a new perspective and modern orientation into conceptual thinking in literacy that is now nearly 40 years old.

These four key ideas derive from the arguments substantiated in the chapter, but they are invitations open for input, expansion, and redefinition themselves. The area of literacy research is venerable and reflects an amalgamation of numerous research methods, methodologies, and ontologies within it. Although game-based learning research is more recent, it reflects a purposeful combination of novel applications and techniques that leverage the technologies and contexts as a means to gather and interpret findings. Collectively, the two areas exhibit opportunities for extracting data, interpreting findings, and adding to theory.

Acknowledgments This work is supported by an ongoing collaboration among members of the Gayle A. Zeiter Literacy Development Center and the Interaction and Media Sciences Lab at the University of Nevada, Las Vegas.

References

Alexander, P. A., Kulikowich, J. M., & Jetton, T. L. (1994). The role of subject-matter knowledge and interest in the processing of linear and nonlinear texts. *Review of Educational Research, 64*(2), 201–252.

Alonso-Fernández, C., Calvo-Morata, A., Freire, M., Martínez-Ortiz, I., & Fernández-Manjón, B. (2019). Applications of data science to game learning analytics data: A systematic literature review. *Computers & Education*, *141*. https://doi.org/10.1016/j.compedu.2019.103612

Baek, Y. (2017). *Game-based learning: Theory, strategies and performance outcomes*. Nova Science.

Baptista, G., & Oliveira, T. (2019). Gamification and serious games: A literature meta-analysis and integrative model. *Computers in Human Behavior, 92*, 306–315.

Barab, S. A., Gresalfi, M., & Ingram-Goble, A. (2010). Transformational play: Using games to position person, continent, and context. *Educational Researcher, 39*(7), 525–536.
Bean, T. W., Bean, S. K., & Bean, K. F. (1999). Intergenerational conversations and two adolescents' multiple literacies: Implications for redefining content area literacy. *Journal of Adolescent and Adult Literacy, 42*(6), 438–448.
Bediou, B., Adams, D. M., Mayer, R. E., Tipton, E., Green, C. S., & Bavelier, D. (2018). Meta-analysis of action video game impact on perceptual, attentional, and cognitive skills. *Psychological Bulletin, 144*(1), 77–110.
Blizzard Entertainment. (2004). *World of Warcraft*. Activision Blizzard.
Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn: Brain, mind, experience, and school*. National Academies Press.
Brown, R. (1991). The one-literacy schoolhouse in the age of multiple literacies. *Educational Horizons, 69*(3), 141–145.
Buckingham, D. (1993). Towards new literacies, information technology, English and media education. The English and Media Magazine, 2025.
Carbado, D. W., Crenshaw, K. W., Mays, V. M., & Tomlinson, B. (2013). Intersectionality: Mapping the movements of a theory. *Du Bois Review, 10*(2), 303–312.
Clark, D., Tanner-Smith, E., & Killingsworth, S. (2016). *Digital games, design and learning: A systematic review and meta- analysis (executive summary)*. SRI International.
Clayton, N. (2018, September 27). World of Warcraft's active subscriber count hits its highest point since 2014. *PC Games Insider*. Retrieved from https://www.pcgamesinsider.biz/news/67848/world-of-warcrafts-active-subscriber-count-hits-its-highest-point-since-2014/#:~:text=Blizzard%20hasn't%20released%20subscriber,release%20of%20Cataclysm%2C%20still%20stands
Coiro, J., Knobel, M., Lankshear, C., & Leu, D. J. (2008). *Handbook of research on new literacies*. Lawrence Erlbaum.
Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education, 59*, 661–686.
Cook-Gumperz, J., & Keller-Cohen, D. (1993). Alternative literacies in school and beyond: Multiple literacies of speaking and writing. *Anthropology & Education Quarterly, 24*(4), 283–287.
Crenshaw, K. (1991). Mapping the margins: Intersectionality, identity politics, and violence against women of color. *Stanford Law Review, 43*(6), 1241–1300.
De Freitas, S. (2018). Are games effective learning tools? A review of educational games. *Journal of Educational Technology & Society, 21*(2), 74–84.
Dey, A. K. (2001). Understanding and using context. *Personal and Ubiquitous Computing, 5*(1), 4–7.
El Soufi, N., & See, B. H. (2019). Does explicit teaching of critical thinking improve critical thinking skills of English language learners in higher education? A critical review of causal evidence. *Studies in Educational Evaluation, 60*, 140–162.
Fasching-Varner, K., & Dodo-Seriki, V. (2012). Moving beyond seeing with our eyes wide shut: A response to "There is no culturally responsive teaching spoken here." *Democracy and Education, 20*(1), 1–6.
Gee, J. P. (2003). *What video games have to teach us about learning and literacy*. Palgrave Macmillan.
Gee, J. P. (2008). Learning and games. The ecology of games: Connecting youth, games, and learning. In K. Salen (Ed.), *The John D. and Catherine T. MacArthur foundation series on digital media and learning* (pp. 21–40). MIT.
Gilster, P., & Glister, P. (1997). *Digital literacy*. Wiley Computer Pub.
Girard, C., Ecalle, J., & Magnan, A. (2013). Serious games as new educational tools: how effective are they? a meta-analysis of recent studies. *Journal of Computer Assisted Learning, 29*(3), 207–219.

Gough, P. B., & Tunmer, W. E. (1986). Decoding, reading, and reading disability. *Remedial and Special Education, 7*(1), 6–10.

Grabthegames Studios. (2015). The Deed. Grabthegames Studios.

Heath, S. B. (1982). What no bedtime story means: Narrative skills at home and school. *Language in Society*, 49–76.

Heiten, L. (2016). Digital literacy: An evolving definition. Education week.

Henrici, G., & Köster, L. (1987). Verfahren der Erklärung von lexikalischen Bedeutungen im Fremdsprachenunterricht. Zielsetzungen, Untersuchungsmethoden und erste Ergebnisse aus einem empirischen *Projekt*. *Fremdsprachen Lehren und Lernen, 1*(6), 25–61.

Hill, J. R., & Hannafin, M. J. (2001). The resurgence of resource-based learning. *Educational Technology Research and Development, 49*(3), 37–52.

Hirshbein, L. (2020, June). The zombie apocalypse and COVID-19. *Academic Psychiatry, 17*, 2020.

Ifenthaler, D., & Kim, Y. J. (Eds.). (2019). *Game-based assessment revisited*. Springer.

Jonassen, D. H., Campbell, J. P., & Davidson, M. E. (1994). Learning with media: Restructuring the debate. *Educational Technology Research and Development, 42*(2), 31–39.

Kafai, Y. B. (1996). Electronic play worlds: Gender differences in children's construction of video games. In Y. Kafai & M. Resnick (Eds.), *Constructivism in practice: Designing, thinking, and learning in a digital world* (pp. 97–123). Erlbaum.

Ke, F. (2009). A qualitative meta-analysis of computer games as learning tools. In R. Ferdig (Ed.), *Handbook of research on effective electronic gaming in education* (Vol. I, pp. 1–32). Information Science Reference.

Keefe, E. B., & Copeland, S. R. (2011). What is literacy? The power of a definition. *Research & Practice for Persons with Severe Disabilities, 36*(3/4), 92–99.

Kellner, D. (1998). Multiple literacies and critical pedagogy in a multicultural society. *Educational Theory, 48*(1), 103–122.

Kim, Y. J., & Ifenthaler, D. (2019). Game-based assessment: The past ten years and moving forward. In D. Ifenthaler (Ed.), *Game-based assessment revisited* (pp. S.3–S.11). Springer.

Kozma, R. B. (1991). Learning with media. *Review of Educational Research, 61*(2), 179–211.

Kress, G. (2003). *Literacy in the new media age*. Routledge.

Kress, G. (2005). Gains and losses: New forms of texts, knowledge, and learning. *Computers and Composition, 22*(1), 5–22.

Kress, G. (2010). *Multimodality: A social semiotic approach to contemporary communication*. Routledge.

Kress, G., & Van Leeuwen, T. (2001). *Multimodal discourse: The modes and media of contemporary communication*. Oxford University Press.

Lamb, R., Annetta, L., Firestone, J., & Etopia, E. (2018). A meta-analysis with examination of moderators of student cognition, affect, and learning outcomes while using serious educational games, serious games, and simulations. *Computers in Human Behavior, 80*, 158–167.

Lankshear, C., & Knobel, M. (2000). Mapping postmodern literacies: A preliminary chart. *The Journal of Literacy and Technology, 1*(1), 1–22.

Lankshear, C., & Knobel, M. (2006). *New literacies: Everyday practices and classroom learning*. Open University Press.

Lankshear, C., & Knobel, M. (2008). *Digital literacies: Concepts, policies and practices* (Vol. 30). Peter Lang.

Lasley, E. (2017). Twenty-first century literacy, game-based learning, and project-based learning. *Journal of Literacy and Technology, 18*(3), 38–55.

Lawless, K. A., & Brown, S. W. (1997). Multimedia learning environments: Issues of learner control and navigation. *Instructional Science, 25*(2), 117–131.

Lawless, K. A., & Schrader, P. G. (2008). Where do we go now? Understanding research on navigation in complex digital environments. In J. Coiro, M. Knobel, C. Lankshear, & D. J. Leu (Eds.), *Handbook of new literacies* (pp. 267–296). Lawrence Erlbaum Associates.

Leu, D. J., Kinzer, C. K., Coiro, J., Castek, J., & Henry, L. A. (2017). New literacies: A dual-level theory of the changing nature of literacy, instruction, and assessment. *Journal of Education, 197*(2), 1–18.

Malkowski, J., & Russworm, T. M. (2017). *Gaming representation: Race, gender, and sexuality in video games*. Indiana University Press.

Martin, A. (2008). Digital literacy and the "digital society.". In C. Lankshear & M. Knobel (Eds.), *Digital literacies concepts, policies, and practices* (pp. 151–176). Peter Lang.

Mayer, R. E. (2014). *Computer Games for learning: An evidence-based approach*. MIT Press.

Mayer, R. E. (2015). On the need for research evidence to guide the design of computer games for learning. *Educational Psychologist, 50*(4), 349–353.

Mayer, R. E., & Johnson, C. I. (2010). Adding instructional features that promote learning in a game-like environment. *Journal of Educational Computing Research, 42*(2), 241–265.

McCreery, M. P., Schrader, P. G., & Krach, S. K. (2011). Navigating massively multiplayer online games: Evaluating 21st century skills for learning within virtual environments. *Journal of Educational Computing Research, 44*(4), 473–493.

McCreery, M. P., Vallett, D., & Clark, C. (2015). Social interaction in a virtual environment: Examining socio-spatial interactivity and social presence using behavioral analytics. *Computers in Human Behavior, 51*, 203–206.

McCreery, M. P., Schrader, P. G., Krach, K., Lafferiere, J. R., Bacos, C. A., & Fiorentini, J. P. (2019). Examining designed experiences: A walkthrough for understanding video games as performance assessments. In D. Ifenthaler & Y. J. Kim (Eds.), *Game-based Assessment Revisited* (pp. 105–119). Springer.

McGonigal, J. (2011). *Reality is broken: Why games make us better and how they can change the world*. New York, NY: The Penguin Press.

Mirra, N., & Garcia, A. (2020). I hesitate but I do have hope: Youth speculative civic literacies for troubled times. *Harvard Educational Review, 90*(2), 295–321.

Moshirnia, A., & Israel, M. (2010). The educational efficacy of distinct information delivery systems in modified video games. *Journal of Interactive Learning Research, 21*(3), 383–405.

Nintendo (1985). Super Mario Bros. Nintendō Kabushiki gaisha.

O'Brien, D. A., Lawless, K. A., & Schrader, P. G. (2010). A taxonomy of educational games: Genres and applications. In Y. K. Baek (Ed.), *Gaming for classroom-based learning: Digital role playing as a motivator of study* (pp. 1–23). Information Science Reference.

Pitt, A. N., Schultz, C. A., & Vaske, J. J. (2019). Engaging youth in public lands monitoring: opportunities for enhancing ecological literacy and environmental stewardship. *Environmental Education Research, 25*(9), 1386–1399.

Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of Game-Based Learning. *Educational Psychologist, 50*(4), 258–283.

Plass, J. L., Perlin, K., & Nordlinger, J. (2010). *The games for learning institute: Research on design patterns for effective educational games.* Paper presented at the Game Developers Conference, San Fran-cisco, CA.

Prensky, M. (2001). *Digital game-based learning*. McGraw-Hill.

Romero-Ivanova, C., Kingsley, T., & Mason, L. (2019). *Three conceptions of literacy: media, narrative, and gaming literacies*. Oxford University Press.

Salomon, G., Perkins, D. N., & Globerson, T. (1991). Partners in cognition: Extending human intelligence with intelligent technologies. *Educational Researcher, 20*(3), 2–9.

Schrader, P. G. (2008). Learning in technology: Reconceptualizing immersive environments. *AACE Journal, 16*(4), 457–475.

Schrader, P. G., Carroll, M. C., McCreery, M. P., & Head, D. L. (2020). Mixed methods for human-computer interactions research: An iterative study using Reddit and social media. *Journal of Educational Computing Research, 58*(4), 818–841.

Schrader, P. G., & Lawless, K. A. (2010). The Hidden literacies of massively multiplayer online games. In D. L. Pullen, C. Gitsaki, & M. Baguley (Eds.), *Technoliteracy, discourse, and social* *practice: Frameworks and applications in the digital age* (pp. 200–219). Information Science Reference.

Schrader, P. G., Lawless, K. A., & McCreery, M. (2009). Intertextuality in massively multiplayer online games. In R. E. Ferdig (Ed.), *Handbook of research on effective electronic gaming in education* (Vol. III, pp. 791–807). Information Science Reference.

Schrader, P. G., & McCreery, M. (2012). Are all games the same? Examining three frameworks for assessing learning from, with, and in games. In D. Ifenthaler, D. Eseryel, & X. Ge (Eds.), *Assessment in game-based learning: foundations, innovations, and perspectives* (pp. 11–28). Springer.

Schrader, P. G., McCreery, M. P., Carroll, M. C., Head, D., & Lafferiere, J. R. (2019). Assessing learning from, with, and in games revisited: A heuristic for emerging methods and commercial-off-the-shelf games. In D. Ifenthaler & Y. J. Kim (Eds.), *Game-based Assessment Revisited* (pp. 13–35). Springer.

Schrader, P. G., McCreery, M. P., & Vallett, D. B. (2017). Performance in situ. In Y. Baek (Ed.), *Game-based Learning: Theory, Strategies and Performance Outcomes* (pp. 421–437). Nova Science Publishers.

Singer, L. M., & Alexander, P. A. (2017). Reading on paper and digitally: What the past decades of empirical research reveal. *Review of Educational Research, 87*(6), 1007–1041.

Snyder, I. (1999). Digital literacies: Renegotiating the visual and the verbal in communication. *Prospect, 14*(3), 13–23.

Squire, K. D. (2006). From content to context: Videogames as designed experiences. *Educational Researcher, 35*(8), 19–29.

Squire, K. D. (2011). *Video games and learning: Teaching and participatory culture in the digital age*. Teachers College Press.

Steinkuehler, C. (2005). The new third place: Massively multiplayer online gaming in American youth culture. *Tidskrift Journal of Research in Teacher Education, 3*, 17–32.

Steinkuehler, C. (2006). Why game (Culture) studies now? *Games and Culture, 1*(1), 97–102.

Steinkuehler, C. (2007). Massively multiplayer online gaming as a constellation of literacy practices. *E-Learning and Digital Media, 4*(3), 297–318.

Street, B. (1998). New literacies in theory and practice: What are the implications for Language in Education. *Linguistics and Education, 10*(1), 1–24.

Sulzby, E., & Teale, W. H. (1991). Emergent literacy. In R. Barr, M. L. Kamil, P. B. Mosenthal, & P. D. Pearson (Eds.), *Handbook of reading research* (Vol. II, pp. 727–757). Longman.

Teale, W. H., & Sulzby, E. (Eds.). (1986). *Emergent literacy: writing and reading. Writing research: multidisciplinary inquiries into the nature of writing series*. Ablex Publishing Corporation.

Wells, G. (1990). Talk about text: Where literacy is learned and taught. *Curriculum Inquiry, 20*(4), 369–405.

Wouters, P., Van Nimwegen, C., Van Oostendorp, H., & Van der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games. *Journal of Educational Psychology, 105*(2), 249–265.

Young, M. F., Slota, S., Cutter, A. B., Jalette, G., Mullin, G., Lai, B., Simeoni, Z., Tran, M., & Yukhymenko, M. (2012). Our princess is in another castle: A review of trends in serious gaming for education. *Review of Educational Research, 82*(1), 61–89.

Zheng, R., & Gardner, M. K. (2017). *Handbook of research on serious games for educational applications*. IGI Global.

Chapter 17
Could Minecraft Be a School?

What Are the Transdisciplinary Implications of This Game-based Learning Environment?

Bryan P. Sanders

17.1 Minecraft: A Learning Environment

School tends to repeat itself. Educators and administrators often choose projects and practices from prior years. Something that worked before likely will work again. This assumption dominates the thinking and proliferation of "downloadables" readily available for free and for purchase on the Internet today. Computers in classrooms are often used to digitize and distribute worksheets and exercises that were once on paper. Computers are less used by students for computing or work that could only be done with a computer than they are for completing tasks within a generically designed content management system that favors administrator oversight, information dissemination, and information gathering.

Traditional school arrangement supports the generalized and simplistic use of computers as an electronic grade book or paper collection and dissemination tool. The traditional school model relies on predetermined student outcomes for the grade level and course completion. The prerequisites for gaining entrance into higher levels of a subject combined with established and planned curricula suggest narrow pathways to getting educated and earning degrees. However, one can simultaneously expect to hear discussion of teaching the whole child and read school mission statements about the importance of the individual student, holistic goals that become difficult to achieve in a lockstep environment. School as an institution seems to be of two minds about how to engage with the students' interest and also maintain order and focus. Flexibility and responsiveness to students are often exchanged for standardization.

In the USA, the national criterion-referenced assessments show flat progress for many years. Any growth in test scores within any of the standard subjects at the

B. P. Sanders (✉)
Loyola Marymount University, Los Angeles, CA, USA

C. Aprea, D. Ifenthaler (eds.), *Game-based Learning Across the Disciplines*, Advances in Game-Based Learning, https://doi.org/10.1007/978-3-030-75142-5_17

three benchmark grades, 4th, 8th, and 12th, is slight and not sustained in a steady manner over time since 1992 (NAEP, 2020). Standardized and predictable experiences for students have yet to demonstrate an impact on how much content they can understand and retain for tests. And while there exist pilot programs and thought experiments in individual schools and classrooms that advocate for different approaches to learning environments, most students are guided along well-worn paths to graduation and matriculation.

Game-based learning environments present new ways for students to encounter, interact with, and create information. Minecraft is a block-building game environment where the player can theoretically create almost anything imaginable. It can be used in a sandbox style without health and score points, or it can be played in a manner aligned with game objectives and obstacles. Sandbox style is called “creative mode” and gives players unlimited access to all of the items in the game without having to find or craft them. The objective style is called “survival mode” and it requires players to battle creatures as well as find all resources to craft more advanced items. In either case, though, the software architecture of Minecraft is open enough to allow both the sandbox and the objective approach to be modified, and this adds significant value to its reach, intrigue, and purpose. Custom components can be created or imported to make the game environment match the intended look, feel, or purpose. As a computer game, it is the first of its kind to reach over the culture war lines to grab the attention of gamers and educators alike.

Furthermore, Minecraft grows in its potential as a virtual learning environment when collaboration occurs. It aligns with the constructivist philosophy and offers many entry points for students to engage. The current education version can allow thirty players at once in a shared world, and the original Java version of the game can allow thousands of players. Collaboration and sharing are further encouraged in Minecraft since there is no official instructional manual or official manner in which the game must be played. This openness aligns with constructivist principles due to the reliance on the players themselves to develop the materials. And in the 10 years since its inception, Minecraft has inspired people of all ages to create and share innumerable guides, articles, videos, and playable worlds. While this serves as a testament to the power and reach of Minecraft as a game-based learning environment, some criticism of Minecraft comes from the strong possibility that students’ skills and knowledge of the game far exceed their teachers’—this unusual power relationship may deter educators from engaging in a new approach.

Of late, there is a marked increase in interest and use of Minecraft: Education Edition in schools. Microsoft’s education department created an opt-in cohort of educators willing to volunteer to work on Minecraft: Education Edition lessons, activities, units, teacher training, and campus deployment at schools around the world. The game has significant interest and logged gameplay hours from both children and adults in schools, but is it malleable and engaging enough to move away from mostly completing lessons, activities, and units? Could Minecraft be a school? What are the implications for teaching and learning if schools stopped requiring a planned curriculum and instead engaged in an immersive game-based learning environment?

17.2 Current Research on Minecraft in Education

Many proponents of new pedagogical approaches still have concerns regarding student performance on traditional criterion-referenced assessments. These concerns are not new and have been addressed with some studies over the decades, though their impact appears to be small when taking a longitudinal look at the dominant culture of traditional schooling. In an important case study conducted in 1990, Dr. Seymour Papert led the way with Idit Harel to demonstrate and document how a constructionist approach using computers could help students acquire knowledge and have memorable learning experiences. Indeed, the study showed the positive impact of their Logo mathematics experimental approach where students worked on computers in an interactive learning environment covering traditional material. The same material taught to a control group via traditional methods resulted in the students in the experimental group scoring higher on a classroom examination than the students learning via the traditional method (Harel & Papert, 1990). Thirty years later, however, this remains an open question for some educators and policymakers.

A recent though small study of using gamification in Minecraft as an intervention "to help respondents improve their understanding and skills in probability" indicated an increase in performance on a traditional paper-pencil test. This was measured by a pretest and posttest method with Minecraft used as an experiential approach in between (Ming, 2020). A qualitative method was also mixed into this study that offered students an opportunity to examine and reflect on the remedial efforts and their impact on helping them understand the material.

A study of this sort is still needed on a large scale across continents to test for impact in bigger sample sizes. If replicated, it will be useful to see if these conclusions using Minecraft gameplay hold true. Ming argues that it can "positively impact students' abilities to master mathematical concepts and skills. The use of these gamification elements can help students cope with the difficulties they face as well as facilitate and speed up their task of solving. Minecraft can enhance students' confidence and curiosity as they work hard to complete the tasks provided in the Minecraft virtual world." (Ming, 2020) These claims are tempered by the sample size but also reside in a thoughtful and powerful subsection of constructivist learning that focuses on student-centered experiences with games and projects. A growing number of educators have combined their traditional classroom approaches with computers, and while software companies dominate the public conversation, more researchers than ever before are studying Minecraft.

A recent literature review study of 28 articles published between 2012 and 2019 found in the ProQuest database about Minecraft in educational settings demonstrated some intriguing trends in student behavior and educator attitudes toward the use of the game. The review also raised some worthwhile provocations for further pursuit in research and action, such as highlighting the problem of time that classes face when they engage in a game-based learning experience. Furthermore, many educators encounter tensions from stakeholders as informal and formal learning coupled with pedagogy are blended together via games.

The study "examined Minecraft integration strategies in classrooms, as well as student benefits in terms of engagement, interest, academic achievement, and knowledge acquisition." (Baek et al., 2020) A noteworthy limitation acknowledged in the study points to a need to continue looking for ways to quantify some of the observations and hunches that educators and researchers have about Minecraft: "The lack of related verified theory or frameworks only indicates the scarcity of experimental studies employing Minecraft; there are significantly more qualitative than quantitative studies of Minecraft in education." (Baek et al., 2020) Also of interest is that the 28 articles they studied had a majority focus on elementary school, language arts, and playing the game instead of engaging in other activities, such as building in Minecraft or modifying the game. This can serve as inspiration to continue studying the use of Minecraft as an educational environment and help determine where educators go next when considering creating immersive experiences for students. Certainly, some of the articles in the review focused on other grade levels, subject matters, and activities in the game, but this weighted set of data suggests a trend of how Minecraft might so far be used and understood by teachers and researchers alike.

The table below organizes the data put forth by Baek et al. and will help anchor some thinking. The authors of the study highlighted specific educational benefits and educational experiences students can encounter in classroom Minecraft gameplay (Table 17.1).

While the majority of the work covered in the 28 articles from the literature review by Baek et al. emerged from Language Arts lessons, the table summary demonstrates far more documented potential for using Minecraft in school. Not only a range of subjects was documented but also many mindsets and pedagogical stances. That said, the documented use in the articles studied by Baek et al. tends to be supplementary lessons or companion experiences to immerse in content, while simultaneously the authors acknowledge that full immersion provides the greatest gameplay for students to discover and uncover new features and ways to collaborate. Some educators were described as encountering issues of time management and task management, which is at odds with a fully immersive gameplay approach that might follow student inquiry and choice to co-create the curricula.

As the number of classrooms with Minecraft gameplay grows, and the research about them grows in kind, more opportunities to refute or confirm some of these findings will emerge. However, the suggestion is clear that if families and educators were willing to forego imposed restrictions from external sources then there would exist far different data for researchers to analyze, as "curriculum inflexibility also offers resistance to incorporating digital game play." (Baek et al., 2020) This desire to decouple the classroom from the curriculum connects to the idea designed into the Harel & Papert (1990), which boldly abandoned the traditional method in its research design hypothesis.

Yet another recent review of 59 articles regarding digital game-based learning environments ventured into a similar territory but with a specific focus on studying

Table 17.1 Summary of ideas regarding Minecraft uses found in 28 articles discussed by Baek et al. (2020). Any of the benefits in column one can link with any of the experiences in column two

Educational benefits of using Minecraft	Educational experiences students can have in Minecraft
Hands-on learning	Experiment with and simulate socioeconomic and environmental conditions (Biology)
Immersive learning	Generate different biomes and explore a variety of naturally occurring materials (Biology)
Constructive learning	Create models of biological structures (Biology)
Connect and interact with previously studied materials	Illustrate the phases of matter through simulations (Chemistry)
Exploration of material, landscapes, and structures	Interact with a three-dimensional periodic table (Chemistry)
Independence of thought	Simulate phenomena (Chemistry)
Stimulate curiosity and creativity	Build recognizable structures and calculate area, volume, and perimeter (Mathematics)
Interact with objects	Measure surface area and volume of unusual shapes (Mathematics)
Connect to personal experience	Manipulate formulas while building and creating (Mathematics)
Alternative to memorization	Examine and build historical entities (Social Science)
Alternative to static images	Navigate through the virtual historical space (Social Science)
Capitalize on student interest, motivation, and engagement	Observe the scenes that simulate real-life situations (Social Science)
Encourage deeper knowledge of specific subjects and specialized knowledge	Plan the details and refinements of building with accuracy (Social Science)
Promote global participation and intercultural competencies	Collaborate with others in large-scale construction (Social Science)
Increase interest in writing topics	Use time spent in-game as impetus and content for writing compositions (Language Arts)
Facilitate writing topics	Write in-game books and loan them to one another inside Minecraft (Language Arts)
Develop literacy and information literacy	Design characters and landscapes in-game and use them as content for expository writing (Language Arts)
Develop composition skills	Develop storylines about characters' adventures (Language Arts)
Employ problem-solving and critical thinking	Explain the building process (Language Arts)
Stimulate critical thinking, creativity, and collaboration	Participate in ongoing tasks that require collaboration and conversation (Language Arts)
Reduce student self-perception of barriers to learning	Link in-game interactions to musical compositions (Music)
Steady stream of student-generated peer communication	Create musical compositions inside of Minecraft (Music)
Boost student drive to learn	Engage in social gaming to increase communication among language learners (Language Acquisition)
Reticent students emerge as leaders	Exchange in-game messages (Language Acquisition)
Flipped classroom potential	Develop maps to interact with the study of language and culture (Language Acquisition)
Promote informal learning processes	

English language acquisition. Xu et al. (2019) studied articles published from 2000 to 2018 with the intent of putting together a cohesive summary that would help propel further specific research diving deep into commercially made games as immersive environments to engage students in new ways of imagining the classroom. Their findings indicate that nearly 80% of the 59 studies “reported a positive impact on English language acquisition” while also acknowledging that about 75% of the 59 studies contained a small sample size of under 100 human subjects.

The call for more large-scale, large sample size research on using Minecraft as an immersive gameplay educational environment is clearly needed and also suggested in the review by Xu et al. (2019). A noteworthy additional aspect from their work asks for game designers to involve more educators and educational researchers in the development of their commercial game products. They also added a complex suggestion that classrooms using game-based play approaches implement “more standardized tests that align with commercial games, because this may improve the reliability and validity of research results.” (Xu et al., 2019) While a sound suggestion to vertically align these inputs and outputs, it also demonstrates a philosophical underpinning in favor of traditional measurement. This could be interpreted as working against the aims of immersive constructivist and constructionist gameplay; however, it could also be interpreted as an attempt to pull together disparate strands of education and gameplay to unify and advance a shared vision for enhancing student learning environments.

Similar to the discussion of incorporating makerspaces into schools as standalone spaces with their own curriculum, the discussion of incorporating Minecraft receives a treatment that presents it more as a place to go instead of a way to think. This cognitive split in the research presents itself as the conflict worth addressing head-on and directly studying in both the classroom and research experiments that next emerge. A thorough exposition of how to play and what to do in Minecraft resides in a thoughtful chapter by H. Chad Lane and Sherry Yi (2017) which also makes clear the philosophical connection to Papert’s constructionism (Papert, 1980). It is worth noting that this remains the most frequently discussed stance that educators raise in their anecdotes and articles: “Constructionism challenges the idea that ‘verbally expressed formal knowledge’ is a sufficient end point for education. It suggests that knowledge can be constructed by learners rather than simply being told, and that this learning should occur in the context of creation, invention, and exploration.” (Lane & Yi, 2017) This flies in the face of traditional schooling and assessments. It is where private schools may have an advantage due to their freedom to create learning sequences free of standardized tests and textbook guidance that are required in public schools. This is also an issue of equity, then, as public school students may lack experiences that are provided to families with means. In their book, *Invent to Learn*, about inventing and making with games, computers, robotics, and crafts in the classroom, Dr. Gary Stager and Sylvia Martinez write that “quality work takes time, disobeys bell schedules, doesn’t result in neat projects that work with canned rubrics, and might not have any impact on test scores” (Stager & Martinez, 2019). Again, the knowledge created by students when they *do things* that are constructive toward their own interests and goals overshadows their coerced focus on worksheets and examinations. There exists a large historical body of work supporting learning by doing, and while there are limitations and controversies within the more recent studies and musings in game-based learning, it still is early in its own timeline as an approach to school that merits attention. Alternatively, as short as 5 years ago, the current hardware and software capabilities combined with the current interest from adults shows us that something new is rapidly emerging and captivating both students and teachers alike.

17.3 Children, Computers, and Powerful Ideas

A tradition of working with computers in classrooms with students is highly reliant on the work of Dr. Seymour Papert and his contemporaries. It was true then as it is now that classroom work with computers requires time dedicated to exploration, and this sits at odds with many school dictums for graduation outcomes and requirements. Students are asked to make sense of the world by making things when they engage in games, projects, and inquiries with a computer. This is the opposite of a planned curriculum and a battery of examinations that have been written years prior.

Of further interest in the study of working with computers is that the work people do with computers creates microworlds of the world outside of the computer. This alone is an engaging enterprise for it pushes on both the logic and the creativity of the individual to enter into an almost allegorical relationship with reality. This then dovetails into the microworld joining back into the world outside when one shares the “thing” that was made. The microworld expands via commentary, critique, and user interaction and then returns to the laboratory table where the creator debugs, augments, and improves the project. This feedback cycle has a further impact on how students view both their work and the larger world.

This experience briefly described earlier resembles to most people as a hobby or a business but not necessarily a classroom activity, learning experience, or pedagogical approach, let alone a school philosophy. Far more common is to segment off the computer class time from the rest of the week of academic work or to make it an elective or afterschool club. Programming, robotics, and web design courses are the most frequently separated components of students’ experience in school, if there at all.

The sense that more could be done with the time spent in schools with students and computers is not one that is shared by all. In part, the dilemma stems from a history of the behaviorist method where computers were put to work as a delivery machine. The earliest teaching machines created by Dr. Sidney Pressey were rote learning devices designed for ensuring students had essentially memorized the content presented. A student would receive an initial output from the machine, and then the machine would receive input from the student in reply. Next, the machine would deliver a result indicating whether the student had the correct answer. From its inception, this worked well for technical knowledge such as operating heavy machinery or knowing the order of wires in a complicated electrical circuit. But when applied to the classroom, there is far more to do than ask students to answer questions.

Applying a constructivist approach to using computers in schools would likely commit a significant amount of available classroom minutes so that students could freely explore the potential. It would no doubt take away from other things students are required to complete. This begs the question about the value of those subjects and tasks, as well as the value of computers, computing, and technology-based learning environments—or even using the computer as an object-to-think-with. The recent research cited above on using Minecraft as a game-based learning environment demonstrates some reluctance of schools to push past using it for much more than a substitution of previously planned lessons and activities. However, the long view of meaningful change in school recognizes the unique potential of each student and strives to design a learning environment suited specifically for each of their powerful, creative, and inventive minds. Students need engagement in experiences that keep them curious. And for some, Minecraft could very well be where students reject the worksheet and instead take control of their own minds, thinking, and creations.

17.4 What Could We Do If Minecraft Were a School?

The limits don't have to exist. Minecraft only has the limitations of one's imagination and access to reliable equipment. If one were to situate a school inside of Minecraft, it would acknowledge that educators often hold hostage the most engaging and transformative projects in their planned curricula. It would demonstrate that quarantining student-led work in specialty courses reserves the best practices for only a small percentage of students. It would perhaps prove that the common approach to experiential learning occurs when students behave in a manner consistent with the authority's wishes.

If Minecraft were a school, many long-held assumptions about how schools are organized would crumble. Instead of competing goals, there would be more cooperation of goals. Many have already questioned the need and value of ranking and ordering students in school. The goal of constructivist education places an emphasis on students finding their voices and purpose through learn-by-doing experiences. Grades and scores are by-products of a system that enforces compliance. That compliance is powerful and permeates so much of how a school asks students and teachers alike to operate. The sheer volume of tasks that students and teachers complete out of compliance is astonishing. In this submissive process, they all slowly abandon some portion of their autonomy, creativity, and thought production.

But in Minecraft, all players are immersed in a newly imagined multiplayer present that consumes their thinking and imagination in a longitudinal collaborative effort. With an infinite number of blocks with which to build, and the possibility to modify those blocks with infinite permutation, never before have students and teachers alike had the ability to move around and make things together inside of a simulated environment. And as with any endeavor that has no specific goals predetermined by an outside agency, work and play in Minecraft can span over years and grow as its inhabitants bring to bear their inspiration, diligence, thinking, and creativity.

What will this experience of school in Minecraft look like? Done well, it ought to begin through exploratory play from the start. There is no better way to ruin a game or a project with students than to teach them every step or move or reaction of a newly encountered set of playthings. Let them find their way and mimic each other. No teacher would explain every rock, twig, or animal in the forest before going on a hike. Likewise, the act of discovery in Minecraft, and there is so much to discover and uncover, remains essential. Furthermore, it would behoove teachers to know how to play Minecraft, but they need not be experts.

As the work and play unfold, the dialogue and questions naturally occurring among students will create a curriculum of ideas to pursue. While some will certainly be about the mechanics of the game itself, many more will display the students' thinking processes and value systems. Most students enter a Minecraft world, see how big it is, and want to first work on creating a house to call their own. This instinct is one that might have in another lesson plan been a writing prompt about basic needs and the role of safety and comfort in creating a just society. Perhaps a debate or seminar would follow based on a text that discusses the balance of individual freedom and coexisting within a civilization. Those texts and discussions can and should still happen, although they can be ordered differently now that educators are asking students to immerse themselves in a game as the classroom. The texts can be scattered throughout the game world. The conversations can happen as a natural consequence of the power struggles that will emerge from the mostly harmless decision to build a house a little too close for comfort near a classmate.

No collaborative effort ever happened without conflict. Gameplay actually thrives on that conflict, though, for it creates an interactive visual of the conflict and also allows for rapid rebuilding or expansion. With an analog experience of physical materials manipulated with hands, conflict over the design or purpose of a structure leads to just as much strife as with digital, but with little room for the rebuilding. This element of computer-based collaboration could actually provide a healthy environment to explore and reinforce social skills that oftentimes are questionably taught by punishment in school. Restorative practices in communication and community building might have more success, particularly in the younger ages, when working in a digital project or game-based environment.

Educators also have an opportunity to engage deeply with students over long periods inside of Minecraft. Furthermore, educators can meet each other in the game to develop ideas together and prepare challenges or curricular materials to bring to their students. Even further, students and teachers from different physical classrooms in different subject matters but meeting at the same clock hour can all gather in a Minecraft world to work, innovate, and explore together. This potential speaks to what some researchers are hoping happens in a school that allows them to study such a project, for it will push the boundaries and the goals of game-based learning. Interestingly, this concept feels right at home inside of a summer camp or a pilot program, but when regular school is in session it is difficult to obtain consensus.

Confusion surrounds using computers and computing in the classroom. Books, paper, pencils, blocks, scissors, glue, rulers, markers, pipe cleaners? The storeroom is stocked. Tablet, laptop, software program, mouse, camera, robotics kit? The storeroom is not only locked, but it might also be empty. The child's most powerful tool in school is either inaccessible or controlled by adults. There are no research journals putting out calls today for studies about the benefits of worksheets and predetermined outcomes. Nobody seems to be asking for educators and researchers to spend their time justifying why student voice and inquiry should be suppressed.

Minecraft is currently the most powerful learning environment available for creating and collaborating together both in synchronous and asynchronous time. Working in a Minecraft world, students can informally learn specific subject matter at rates that might not be possible to document. A worksheet or test might reinforce knowledge of a few mathematical concepts. What documented value can be placed on an immersive play experience where the student interacts with those very same mathematical concepts? It seems odd to compare a worksheet against standing inside of a virtual three-dimensional coordinate geometry system. The two are vastly different learning experiences.

Using Minecraft as the playground for these student thoughts to coexist and commingle will provide rich opportunities where innovations will undoubtedly emerge, and educators can both join and observe to provide useful guidance. Instead of the once-a-week "one and done" Minecraft computer class, we need to revise our expectations. One hour in Minecraft per week goes so quickly it will not be a terribly productive or meaningful experience. But if classes played there on a daily basis and tracked their ideas and questions, they would find new focal points to explore outside of the game. And that work outside of the game would dovetail back into what happened when logged in again.

It would not fit the purpose or philosophy of computers in education to take the child's most powerful tool, and have any educator or researcher dictate or predetermine exactly what lessons or actions should happen when kids play in Minecraft together as part of the school. The same goes for anything that students might create with a computer. They will figure things out that teachers never thought of doing. Would any educator tell students to mimic their every move with cotton balls, glue, paper, and crayons?

It just so happens that Minecraft is the most powerful real-time collaborative virtual learning environment for making things. Maybe there will be something else better in the future, but we have not yet fully explored this one. Ask your principal if you can stop turning in lesson plans for approval and instead conduct a self-study of your students working together in a Minecraft world. Unleash the power of your students' minds. They are interesting people and we should listen to them. They live in the world, too, and will naturally encounter and explore through game-based play all of the ideas we have for decades split up into artificially disparate classes and curricula. Let's put it all back together.

References

Baek, Y., Min, E., & Yun, S. (2020). Mining educational implications of minecraft. *Computers in the Schools*. https://doi.org/10.1080/07380569.2020.1719802

Harel, I., & Papert, S. (1990). Software design as a learning environment. *Interactive Learning Environments, 1*(1), 1–32.

Lane H., & Yi, S. (2017). Playing With Virtual Blocks: Minecraft as a Learning Environment for Practice and Research. In F. Blumberg & P. Brooks (Eds.), Cognitive Development in Digital Contexts (pp. 145–166). Academic Press. https://doi.org/10.1016/B978-0-12-809481-5.00007-9

Ming, G. (2020): The Use of Minecraft Education Edition as a Gamification Approach in Teaching and Learning Mathematics among Year Five Students, *Proceedings: International Invention, Innovative & Creative (InIIC) Conference,* Series 1/2020.

NAEP. (2020). *National assessment of educational progress: An overview of NAEP*. Washington, D.C.: National Center for Education Statistics, Institute of Education Sciences, U.S. Dept. of Education.

Papert, S. (1980). *Mindstorms: children, computers, and powerful ideas*. Basic Books.

Stager, G., & Martinez, S. (2019). *Invent to learn: making, tinkering, and engineering in the classroom*. Constructing Modern Knowledge Press.

Xu, Z., Chen, Z., Eutsler, L., Geng, Z., & Kogut, A. (2019). A scoping review of digital game-based technology on English language learning. *Association for Educational Communications and Technology*. https://doi.org/10.1007/s11423-019-09702-2

Chapter 18
Looking Back and Moving Forward with Game-Based Learning Across the Disciplines

Carmela Aprea and Dirk Ifenthaler

18.1 Introduction

Game-based learning is a dynamic field that has recently garnered much interest from different areas, including digital game design, human–computer interaction, and different branches of education and psychology, such as cognitive, motivational, and social psychology. As emphasized in this edited volume, the various subject domains (e.g., business and economics, social studies, STEM) are also pivotal. Although game-based learning is not limited to digital games, and has in fact a long-standing history in human learning and development far beyond the times of digitalization (Huizinga, 1971; Leontiev, 1978), the growing interest—not to say "game hype"—in educational settings can also be attributed to technological advances as well as to particular preferences in users' digital media behavior. Nowadays, digital games are strongly anchored in the everyday life of especially (but not only) young people. According to a recent study (JIM, 2020), 68% of young people in Germany play on a regular basis, only 8% of the 12- to 19-year-olds do not play. Boys have a higher gaming affinity overall than girls. On average, young people of this age group of both genders played computer, console, tablet, and mobile games for around 121 min per day from Monday to Friday and 145 min at weekends. In comparison to 2019, this represents a plus of 40 min during the week and 28 min at weekends, respectively, a growth that is presumably related to the

C. Aprea
University of Mannheim, Mannheim, Germany

D. Ifenthaler (✉)
University of Mannheim, Mannheim, Germany

Curtin University, Perth, WA, Australia
e-mail: dirk@ifenthaler.info

C. Aprea, D. Ifenthaler (eds.), *Game-based Learning Across the Disciplines*, Advances in Game-Based Learning, https://doi.org/10.1007/978-3-030-75142-5_18

current COVID-19 lockdown situation. These developments are not limited to Germany but are also to be found in a similar way in other (industrialized) countries.[1]

If games exert such a fascination, it is only natural to ask whether and how they can be used to successfully promote learning by merging game activities with learning activities. This purpose, however, is what differentiates games for learning from purely entertaining games, although there is significant overlapping, since motivation and fun are also crucial for game-based learning.

This edited volume presents a wide-ranging collection of work and findings on game-based learning inside and across various disciplines. Overall, it features chapters that are routed in various disciplines, theoretical foundations, and research traditions. It also addresses different educational fields, including kindergarten, secondary, vocational, professional, and higher education and covers multiple game genres, such as board games, adventure games, or simulation games.

In this concluding chapter, we aim to situate the single contributions of the volume within more general reflections on the potential benefits of game-based learning (Sect. 18.2) as well as to provide an analysis and synthesis of major themes that have emerged in the previous chapters (Sect. 18.3). Finally, we intend to sketch ideas for future research on game-based learning from an inter- and transdisciplinary perspective (Sect. 18.4).

18.2 Potential Benefits of Game-Based Learning Across the Disciplines

As Whitton (2012) notes, there are many similarities between the characteristics of games and the characteristics of effective learning experiences in that they should be challenging but attainable, engaging, and interactive. It is no wonder, then, that the potential benefits of digital games become particularly evident from the perspective of contemporary learning theories, notably constructivist, situated, and experiential approaches (e.g., Collins et al., 1989; Greeno, 1998; Lave & Wenger, 1991; Moon, 2004). These theories, in turn, are inspired by tenets from pragmatism (e.g., Dewey, 1963), sociocultural and cultural-historical psychology (e.g., Vygotsky, 1978) as well as fundamental findings in cognitive and motivational psychology (e.g., Malone & Lepper, 1987; Suchman, 1987). In particular, they view learning as an active, contextually bounded, and socially mediated process of making meaning out of individual experiences. This process aims at the formation of a multidimensional and, first and foremost, transferable set of competencies. Teaching, in turn, is conceived as the provision of adequate learning opportunities, i.e., the design of learning arrangements that stimulate students' active participation and guide their

[1] For data on the situation in France, India, Italy, Japan, Singapore, South Korea, United States and United Kingdom as well as a global score see, for example, the latest "State of Online Gaming" research report issued by Limelight Networks https://www.limelight.com/resources/white-paper/state-of-online-gaming-2020/

experiences. Within the frame of contemporary approaches, the following (non-exhaustive) advantages of digital learning games can be emphasized:

- *Digital games may support domain-related knowledge construction and higher order cognitive skills*. In digital games, learning is at its essence a kind of performance, as students learn by doing within the affordances and constraints of information-rich virtual worlds, instantiated through software and social systems. The primacy of game-based learning is on experience, constantly inviting the learner to understand and manipulate complex situations, learn through failure and related feedback, and develop identities as expert problem solvers (Squire, 2008). Thus, game-based learning provides what Barab et al. (2010: 525) call "consequential engagement" and is particularly expected to foster the acquisition of different forms of domain-related higher order knowledge and skills, such as conceptual understanding, strategic decision-making, and/or problem-solving (Eseryel et al., 2011).
- *Digital games can promote enjoyment, intrinsic motivation, and positive attitudes.* Due to their entertaining qualities, digital games are believed to be fun and thus much more attractive for learners, especially the ones from the digital native generation. This may lead to more effective involvement as well as to sustained intrinsic motivation. As Malone (1981) proposed, the primary factors that make an activity intrinsically motivating are challenge, curiosity, control, and fantasy. Digital games incorporate these factors, for example, through the need to attain goals, through sensory and cognitive activation, or with the help of narratives. In addition, their immersive nature may also enable the experience of flow (e.g., Csíkszentmihályi, 2008). In sum, these characteristics may positively influence attitudes toward learning both in general and in specific domains (Eseryel et al., 2014).
- *Digital games may foster generic abilities as well as psychomotoric and interpersonal skills.* As, for example, Granic et al. (2014) assume digital games may also foster more generic, often meta-cognitive abilities such as handling of complexity or information processing under the condition of risk and uncertainty as well as persistence, ambiguity tolerance, and self-efficacy. Depending on the specific game condition, they are moreover expected to (1) support psychomotoric skills (e.g., speed of reaction, eye-hand-coordination) and (2) if addressing facets of role-playing, or if played in teams of learners, to promote social skills.

In addition to these theoretical considerations, there is an ever-growing number of individual research studies on the effectiveness of game-based learning. Moreover, there are a dozen or so literature reviews (e.g., Boyle et al., 2015; Connolly et al., 2012; Donovan, 2012; Granic et al., 2014), both narrative and systematic, and a handful of meta-analyses (e.g., Clark et al., 2015; Sitzmann, 2011; Vogel et al., 2006; Wouters et al., 2013). The findings of this empirical research base show that games as a medium can, indeed, support productive learning under certain circumstances, but drawing general conclusions about their effectiveness is difficult because of the large range of areas and topics they cover, genres they represent, and age groups they target. However, what has become clear from the available empirical investigations as well as from the contributions in this book is that we need to take an evidence-based approach for the study of learning with games. This includes evidence-based design principles for game-based learning as well as subsequent research efforts to further our understanding of how and under which conditions game-based learning works (Ge & Ifenthaler, 2017). Both of these issues will be addressed in the sections that follow.

18.3 Key Themes Emerging from Current Research

Several key themes on game-based learning inside and across the disciplines have emerged from the chapters in this book. From the perspective of designing effective learning arrangements, we have identified four main aspects that are important for harnessing the potentials of games in the different domains. These aspects will therefore be highlighted and analyzed further here, and include the following: (1) integrative design, (2) activity-oriented design, (3) context-sensitive design, and (4) participatory design.

18.3.1 Integrative Design: Taking Domain Knowledge into Account and Connecting it with Educational Theories

Since the 1980s, research has brought increasing attention to the importance of domain-related knowledge in human performance, learning, and development (e.g., Chi et al., 1988; Glaser, 1984; Glaser et al., 1987). As Patricia Alexander (1998) highlights, it is not a question of whether the "what" of learning (i.e., subject matter or domain knowledge) influences the "how" (i.e., the learning activities and processes). Such an influence is assumed. It is rather the question of how domain knowledge could be effectively considered when designing learning arrangements. Thus, in the wake of this recognition of domain knowledge, numerous instructional design models have been developed that call for appropriate analysis and mapping of the domain as a starting point for the development of any type of learning arrangement (e.g., Clark et al., 2008; Jonassen et al., 1999; Van Merriënboer & Kirschner, 2018).

These considerations have also made their way into game design. While some less elaborate, naive approaches simply add game elements as a "fun factor" to content learning, newer, more theory-driven, and empirically grounded models emphasize the need to purposefully integrate domain-specific learning contents into game design and to merge them with principles derived from educational theories, especially theories of learning, motivation, and engagement (Plass et al., 2020). This concern is also evident in many chapters of this volume. Schultheis and Aprea (Chap. 1) explicitly use insights from behavioral finance, a state-of-the-art approach to financial theory, to elaborate human heuristics, and biases in financial decision-making. They also demonstrate how these features of the domain could be merged with considerations from educational psychology and ultimately be incorporated into the design and development of a decision-oriented financial literacy serious game. A financial decision-oriented approach to financial literacy is also evident in Chap. 4 by Andrea Pfändler, who additionally applies findings from happiness research to map the domain and to develop a holistic financial literacy board game. Similarly, Weber and colleagues (Chap. 6) start their activities to create a game that intends to assess sustainability competence in retail by analyzing and modeling the domain, providing a detailed picture of situations related to sustainability and their specific requirements.

While the aforementioned authors model the domain in a decision- or situation-oriented manner, Warren, Roy, and Robinson (Chap. 5) choose an alternative modeling approach by referring to key domain concepts. In their specific case, they identify "boundary of the firm," "explore and exploit," and "creative destruction" as core business concepts on which they base their subsequent business simulation game activities.

Ge and colleagues (Chap. 12) focus on another important yet often disregarded domain-related issue, which game designers and researchers should consider, namely, the difficulties that students experience with specific learning content, in this case, algebra. Finally, arguing from a design process perspective, Schuldt and Niegemann (Chap. 13) consider a proper analysis of the respective domain as the departure point of the decision-oriented instructional game design model they propose.

18.3.2 Activity-Oriented Design: Carefully Drafting Game Mechanics and Other Game Design Features

Along with the recognition of domain knowledge, recent learning theoretical accounts also emphasize the central role of learning activities as the primary means by which learners engage with the learning content (e.g. Chi, 2009; Honebein et al., 1993). Learning activities have long been relegated to the role of a vehicle for practicing a skill or process. In contrast, modern approaches inspired by constructivist philosophy, such as problem- and case-based learning or cognitive apprenticeship, have placed the activity that students engage in during learning firmly at the heart of any curriculum (Reeves et al., 2002). Learning activities structure, direct, and control the learning processes. Therefore, learning activities fulfill important cognitive and metacognitive functions when they are carried out appropriately. Given that learning activities are the means to bridge the gulf between (learning) goals and (learning) results or outcomes, they also play an essential role from a motivational point of view.

As pointed out in the introduction of this chapter, the distinctive feature of game-based learning is that it combines game activities with learning activities. This linkage is therefore of utmost importance in any game design process and is addressed (implicitly or explicitly) in all the contributions of this volume. The main game design element through which this linkage could be realized is game mechanics (Plass et al., 2020). According to Salen and Zimmerman (2004) game mechanics can be considered as the experiential building blocks of player interactivity, representing the moment-to-moment activity of players, something that is repeated over and over throughout a game.

For example, Yu and Denham (Chap. 11) specifically describe how the game mechanics of their augmented reality mathematics board game are inspired by the principles from three prominent learning science theories, i.e., cognitive load theory, multimedia theory, and collaborative learning theory. Paeßens and Winther (Chap. 3) also particularly feature the latter aspect, i.e., collaborative gameplay, in the context of basic financial education for adult learners. Similarly, Rosenblum and colleagues (Chap. 7) provide insights into the game mechanics of an experiential strategy designed to challenge college students to cooperatively tackle the complex problem of achieving peace in the Middle East. Moreover, these authors particularly stress the need for culturally sensible and responsive game design.

Lindberg and Naxer (Chap. 8) focus on motivational aspects of game mechanics by outlining how self-determination theory (Deci & Ryan, 2012) can be used to enhance the game design. They illustrate their considerations by providing examples from game-based learning in business and law online higher education at a small scale (i.e. within a learning activity) and a large scale (i.e. within a full course). A similar concern underlies the considerations of Platz, Jüttler, and Schumann (Chap. 2) who ask how an educational game could be used to promote learners' interest in economics. And again, the importance of game mechanics is stressed in Schuldt and Niegemann's decision-oriented instructional game design model mentioned earlier (Chap. 13).

Besides game mechanics, other game design elements shape the way in which learning activities can be performed during gameplay. An important element directly connected to the learning activities is how learning supports are designed and implemented in a game. Kim et al. (Chap. 8) address this aspect. They argue that learning supports should not impair flow experience during gameplay and be specific in the sense that they cater to the cognitive and affective states of the learners. In their contribution, the authors provide examples for learning supports from two case studies on authentic and complex problem-solving in secondary school and special needs STEM education.

In addition, narratives are an essential game feature. As especially Schrader and colleagues (Chap. 16) underline, all video games are implicitly or explicitly oriented in the narrative. Their contribution sheds light on this prominent design element by focusing on the epistemological relationship between the field of literacy and game-based learning. Furthermore, they examine the characteristics and properties of three prominent video games to demonstrate transversal elements of literacy and describe reciprocal ways in which literacy supports an understanding of games, and games model, in the application, the elements of literacy events.

18.3.3 Context-Sensitive Design: Bearing in Mind the Needs and Constraints of the Implementation Setting

Games for learning purposes do not only provide contexts through their narratives, but they also need to work in specific contexts, settings, or environments. As especially approaches close to ecological systems theory (Bronfenbrenner, 1989) as well as such from ecological psychology (Gibson, 1966; Noë, 2009) and activity theory (Leontiev, 1978; Vygotsky, 1978) highlight, these contexts shape the way in which human thought and performance are carried out through their respective affordances and constraints. This powerful impact of the context is particularly important when it comes to the implementation of innovations in social settings such as schools or companies, mainly because these innovations usually require multilevel change or transformation processes to be successful. This is no exception for social and/or technological innovations, such as those involved with the implementation of digital learning arrangements (Aprea & Cattaneo, 2019; Ifenthaler et al., 2021), including serious games and game-based learning.

Acceptance from key actors in the context in which the innovation is ought to function is crucial. This aspect is the focus of the contribution by Nieland et al. (Chap. 15), who investigate teachers' acceptance as a critical factor for the successful implementation of game-based learning in vocational school settings. Similarly, Li and colleagues (Chap. 10) explore what STEM teachers consider important for successfully integrating digital games into classrooms. Both chapters confirm the critical role of teachers as "gatekeepers." In addition, the alignment of game-based learning with educational goals and openness for new pedagogical approaches seem to be crucial for the effective use of game-based learning in applied settings. Both chapters also provide stimulations insights for teacher education and development.

However, the success of game-based learning is not only dependent on the setting in which it should be implemented, but games may also change the respective contexts. Thus, the relationship needs to be conceived as reciprocal, as Bryan Sanders elaborates in Chap. 17. Based on the observation that traditional educational practices are very perseverant, this author uses a kind of thought experiment by asking "Could Minecraft be a school." He also describes how the surge of interest in complex game-based learning platforms could contribute to a disruption of many reliable but outdated fixtures in school settings, and eventually to a complete revision of educational efforts, also giving more space to true inter- and transdisciplinarity.

18.3.4 Participatory Design: Incorporating the Expertise from Different Fields and Perspectives

The foregoing should have made clear that game-based learning is a complex design endeavor and, as such, typically requires cooperation. Cooperative—or synonymously also named participatory design—is a general approach to the design of all kinds of material or immaterial products (so-called design artifacts) attempting to actively incorporate expertise from different fields and to involve perspectives from various stakeholders into the design process. This should help to ensure that the results meet the intended needs and are usable. Participatory design is focused on processes and procedures of design, and is not a design style. The term is used in a variety of fields, such as software design, urban design, architecture, landscape architecture, product design, sustainability, graphic design, planning, and even medicine as a way of creating environments that are more responsive and appropriate to their inhabitants' and users' cultural, emotional, spiritual, and practical needs. Recent research suggests that designers create more innovative concepts and ideas when working within a co-design environment with others than they do when creating ideas on their own (e.g., Mitchell et al., 2015; Trischler et al., 2018).

Participatory design is also eminent in recent studies of game-based learning (e.g., Pereira et al., 2019) as well as in many chapters of this volume. For example, Schultheis and Aprea (Chap. 1), Paeßens and Winther (Chap. 3), and Lindberg and Naxer (Chap. 14) all describe game-based learning design projects that involve many parties, such as game and media designers, content experts from diverse fields, parents, teachers, and learners. Moreover, participatory design is at the center of the contribution by Heinz and Born-Rauchenecker (Chap. 9), who report the cooperative development of a game-based learning app intended to raise prospective kindergarten educators' awareness of STEM learning opportunities. To identify their expectations about the app, these researchers conducted workshops and developed questionnaires aimed at users of the app, teachers employing the app in their lessons, experts in early STEM education, and experts in the area of digital media.

18.4 Future Directions of Research on Game-Based Learning Across the Disciplines

The contributions in this edited volume provide rich and valuable insights into the fascinating and growing field of game-based learning. In particular, they have demonstrated how games could be productively used to support learning in a wide range of domains, including business studies, economics, and finance as well as science, technology, engineering, and mathematics at different levels of the educational system in several countries. As specifically highlighted in the previous section of this concluding chapter, the contributions also shed light on the question of how game-based learning should be designed to promote intended learning purposes in different fields. In this way, they contribute to a still-pending but practically and scientifically highly relevant question in this field of research. For example, Young et al. (2012) reviewed trends in serious gaming for education and stated a lack of studies that explore the complex interplay of purposefully designed games with different kinds of learners, learning contexts, contents, and outcomes. Similarly, Clark et al. (Clark et al., 2015: 116) conclude in their meta-analysis that "games as a medium provide new and powerful affordances, but it is the design within the medium to leverage those affordances that will determine the efficacy of a learning environment." They further recommend that we should "shift our attention to studies exploring how theoretically driven design decisions influence situated learning outcomes for the broad diversity of learners within and beyond our classrooms." The contributions of this volume demonstrate how this gap could be filled by drawing on the body of knowledge from the learning sciences and expanding it with theoretical and empirical research from other domains to inform the design of effective game-based learning environments across the disciplines. In addition, the contributions pinpoint several ideas and requirements for future research studies, including the following:

- Most of the research included in this edited volume are case studies. A few are usability studies or design-based research studies. According to Plass et al. (2020), there are various other types of studies, including: (1) value-added studies that focus on the effectiveness of specific design features; (2) impact studies that focus on the cognitive, motivational, affective, and sociocultural consequences of game-based learning on learning processes and outcomes; and (3) relational effectiveness studies that compare game-based learning with other media. As the authors further explain, these types of studies can be seen as a progression in the sense that they recommend first conduct user and design-based research before conducting value-added studies or studies on impact and relative effectiveness. Altogether, these considerations could point to an interesting pathway for continuing the research efforts presented in this book.
- An issue that deserves further attention, and is closely related to what has been said previously, concerns the lack of a common or standard framework for evaluating game-based learning. As All et al. (2014) point out, this lack of an overarching methodology has led to the use of different outcome measures for assessing effectiveness, varying methods of data collection, and inconclusive or difficult to interpret results. Given the complexity of game-based learning, Tobias et al. (2014) claim that an evaluation framework necessarily needs to be multidimensional to make it possible to understand the various relationships between games, contents, contexts, players, their social interactions with one another, their game-play, their cognitive, meta-cognitive, affective and motivational reactions as well as their learning processes and outcomes. Despite some promising advances, the current methodological and empirical research regarding this aspect is not yet consolidated. However, a shared evaluation methodology is an important prerequisite for coming to valid conclusions with regard to the

effectiveness of game-based learning. These include the possibilities (1) to replicate studies, (2) to conclusively compare results across studies, (3) to make claims regarding the effectiveness of game-based learning on a more general level, and (4) to set a baseline for quality, which could serve as an evaluation tool for published studies. The development of such a framework should thus be brought forward with high priority.

- Also closely connected to what has been mentioned above are questions regarding assessment in game-based learning (Ifenthaler et al., 2012; Ifenthaler & Kim, 2019) and related analytics functions (Alonso-Fernández et al., 2019). The implementation of assessment features into game-based learning environments is still emerging. While assessment after learning in a game-based environment often focuses on the outcome, it may neglect important changes during the learning process. In contrast, assessment while learning in a game-based environment mostly focuses on the process. The benefits of this assessment method are manifold. First, assessing learners while playing a game will provide detailed insights into underlying learning processes. Second, tracking motivational, emotional, and metacognitive characteristics while playing a game will help us to better understand specific behavior and the final outcomes. Third, immediate feedback based on the embedded or stealth assessment can point to specific areas of difficulties learners are having while playing the game. Further research is required to identify assessment features, which support the game flow and game mechanics and also inform about changes in learning processes and how to support possible barriers in the learning process (Kim & Ifenthaler, 2019). Closely related to issues of assessment in the game are games analytics which focuses on (a) improving gameplay and make the games more enjoyable to the players, and (b) improve game design and create content that players like in order to increase post-sale revenues (Loh et al., 2015). In contrast, serious games analytics focuses on actionable metrics developed through problem definition in learning scenarios and the application of statistical models, metrics, and analysis for skills and human performance improvement and assessment, using game-based learning as the primary tools for learning (Loh et al., 2015). Clearly, research focusing on learning analytics in game-based learning is scarce and requires frameworks, methodologies, and experimental studies to shed light into the opportunities of analytics for game-based learning (Ifenthaler & Gibson, 2019).
- A final issue for future research concerns the design and development of game-based learning environments. As already mentioned in Sect. 18.3 of this chapter, this is a complex process that often demands distributed expertise. A profound understanding of this process is pivotal for assuring the quality of the emerging product and ultimately the learning effects of game-based learning environments. To garner such an understanding, the field of research on game-based learning across the disciplines could profit from incorporating insights from the so-called design science, a discipline concerned with the exploration of design processes in different fields of application. Design science, which has been heavily influenced by the groundbreaking workings of Simon (1996) and successfully implemented in other areas of technology-based learning environment design

(e.g., Aprea & Cattaneo, 2019), could provide an inter- and transdisciplinary lens to further investigate design processes in game-based learning. Besides the organization of design processes, this investigation should consider epistemological issues, and promote respective design recommendations and tools for designers and researchers.

We hope that our volume is helpful for all those interested in exploiting the benefits of game-based learning and understanding its effects on learning and performance in different domains. We also hope that it will serve as a stimulus for the above and other future research efforts.

References

Alexander, P. A. (1998). The nature of disciplinary and domain learning: The knowledge, interest, and strategic dimensions of learning from subject-matter text. In C. Hynd (Ed.), *Learning from text across conceptual domains* (pp. 263–287). Lawrence Erlbaum Associates.

All, E., Nuñez Castellar, P., & Van Looy, J. (2014). Measuring effectiveness in digital game-based learning: A methodological review. *International Journal of Serious Games, 1*(2), 3–18.

Alonso-Fernández, C., Calvo-Morata, A., Freire, M., Martínez-Ortiz, I., & Fernández-Manjón, B. (2019). Applications of data science to game learning analytics data: A systematic literature review. *Computers & Education, 141*. https://doi.org/10.1016/j.compedu.2019.103612

Aprea, C., & Cattaneo, A. (2019). Designing technology-enhanced learning environments in vocational education and training. In D. Guile & L. Unwin (Eds.), *The Wiley handbook of vocational education and training* (pp. 373–394). Wiley-Blackwell.

Barab, S. A., Gresalfi, M., & Ingram-Goble, A. (2010). Transformational play: Using games to position person, content, and context. *Educational Researcher, 39*(7), 525–536.

Boyle, E. A., Hainey, T., Connolly, T. M., Gray, G., Earp, J., Ott, M., Lim, T., Ninause, M., Ribeiro, C., & Pereira, J. (2015). An update to the systematic literature review of empirical evidence of the impacts and outcomes of computer games and serious games. *Computers & Education, 94*, 178–192.

Bronfenbrenner, U. (1989). Ecological systems theory. In R. Vasta (Ed.), *Annals of child development* (Vol. 6, pp. 187–249). JAI Press.

Chi, M. T. H. (2009). Active-constructive-interactive: A conceptual framework for differentiating learning activities. *Topics in Cognitive Science, 1*(1), 73–105.

Chi, M. T. H., Glaser, R., & Farr, M. J. (1988). *The nature of expertise*. Erlbaum.

Clark, R. E., Feldon, D., van Merrienboer, J., Yates, K, & Early, S. (2008). Cognitive task analysis. In Spector, J. M., Merrill, M. D., van Merriënboer, J. J. G., & Driscoll, M. P. (Eds*.),* Handbook of research on educational communications and technology (3, pp. 577–593). : Lawrence Erlbaum Associates.

Clark, D. B., Tanner-Smith, E. E., & Killingsworth, S. S. (2015). Digital games, design, and learning a systematic review and meta-analysis. *Review of Educational Research, 86*(1), 76–122.

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 453–494). Lawrence Erlbaum Associates.

Connolly, T. C., Boyle, E. A., Hainey, T., McArthur, E., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education, 59*, 661–686.

Csíkszentmihályi, M. (2008). *Flow: The psychology of optimal experience*. Harper Collins Publisher.

Deci, E. L., & Ryan, R. M. (2012). Self-determination theory. In P. A. M. Van Lange, A. W. Kruglanski, & E. T. Higgins (Eds.), *Handbook of theories of social psychology* (pp. 416–436). Sage Publications.

Dewey, J. (1963). *Experience and education*. Collier MacMillan. (Original work published 1938).

Donovan, L. (2012). *The use of serious games in the corporate sector: A state of the art report*. Retrieved from http://www.learnovatecentre.org/research-report-the-use-of-serious-games-in-the-corporate-sector/

Eseryel, D., Ge, X., Ifenthaler, D., & Law, V. (2011). Dynamic modeling as cognitive regulation scaffold for complex problem solving skill acquisition in an educational massively multiplayer online game environment. *Journal of Educational Computing Research, 45*(3), 265–287.

Eseryel, D., Law, V., Ifenthaler, D., Ge, X., & Miller, R. B. (2014). An investigation of the interrelationships between motivation, engagement, and complex problem solving in game-based learning. *Journal of Educational Technology & Society, 17*(1), 42–53.

Ge, X., & Ifenthaler, D. (2017). Designing engaging educational games and assessing engagement in game-based learning. In R. Zheng & M. K. Gardner (Eds.), *Handbook of research on serious games for educational applications* (pp. 255–272). IGI Global.

Gibson, J. J. (1966). *The senses considered as perceptual systems*. Hughton Mifflin.

Glaser, R. (1984). Education and thinking: The role of knowledge. *American Psychologist, 39*, 93–104.

Glaser, R., Lesgold, A., & Lajoie, S. (1987). Toward a cognitive theory for the measurement of achievement. In R. R. Ronnig, J. A. Glover, J. C. Conoley, & J. C. Whit (Eds.), *The influence of cognitive psychology on testing* (pp. 41–85). Erlbaum.

Granic, I., Lobel, A., & Engels, R. C. M. E. (2014). The benefits of playing video games. *American Psychologist, 69*(1), 66–78.

Greeno, J. (1998). The situativity of knowing, learning, and research. *American Psychologist, 53*, 5–26.

Honebein, P. C., Duffy, T. M., & Fishman, B. J. (1993). Constructivism and the design of learning environments: Context and authentic activities for learning. In T. M. Duffy, J. Lowyck, & D. H. Jonassen (Eds.), *Designing environments for constructive learning* (pp. 87–108). Springer.

Huizinga, J. (1971). *Homo ludens: A study of the play element in culture*. Beacon Press. (Original work published 1938).

Ifenthaler, D., Eseryel, D., & Ge, X. (2012). Assessment for game-based learning. In D. Ifenthaler, D. Eseryel, & X. Ge (Eds.), *Assessment in game-based learning. Foundations, innovations, and perspectives* (pp. 3–10). Springer.

Ifenthaler, D., & Gibson, D. C. (2019). Opportunities of analytics in challenge-based learning. In A. Tlili & M. Chang (Eds.), *Data analytics approaches in educational games and gamification systems* (pp. 55–68). Springer.

Ifenthaler, D., Hofhues, S., Egloffstein, M., & Helbig, C. (Eds.). (2021). *Digital transformation of learning organizations*. Springer.

Ifenthaler, D., & Kim, Y. J. (Eds.). (2019). *Game-based assessment revisted*. Springer.

Jonassen, D. H., Tessmer, M., & Hannum, W. H. (1999). *Task analysis methods for instructional design*. Erlbaum Associates.

Jugend, Information, Medien (JIM) (2020). *Basisuntersuchung zum Medienumgang, 12- bis 19-Jähriger.* Retrieved from https://www.mpfs.de/fileadmin/files/Studien/JIM/2020/JIM-Studie-2020_Web_final.pdf

Kim, Y. J., & Ifenthaler, D. (2019). Game-based assessment: The past ten years and moving forward. In D. Ifenthaler & Y. J. Kim (Eds.), *Game-based assessment revisted* (pp. 3–12). Springer.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.

Leontiev. (1978). *Activity, consciousness and personality*. Englewood Cliffs.

Loh, C. S., Sheng, Y., & Ifenthaler, D. (Eds.). (2015). *Serious games analytics. Methodologies for performance measurement, assessment, and improvement*. Springer.

Malone, T. W. (1981). What makes computer games fun? *Byte, 6*(12), 258–277.
Malone, T. W., & Lepper, M. R. (1987). Making learning fun: A taxonomy of intrinsic motivations for learning. In R. E. Snow & M. J. Farr (Eds.), *Aptitude, learning and instruction III: Conative and affective process analyses* (pp. 223–253). Erlbaum.
Mitchell, V., Ross, T., Sims, R., & Parker, C. J. (2015). Empirical investigation of the impact of using co-design methods when generating proposals for sustainable travel solutions. *CoDesign, 12*(4), 205–220.
Moon, J. (2004). *A handbook of reflective and experiential learning: Theory and practice*. Routledge Falmer.
Noë, A. (2009). *Out of our heads*. MIT Press.
Pereira, L., Craveirinha, R. & Roque, L. (2019). A canvas for participation-centered game design. In *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*, October 22–25, 2019, Barcelona, Spain. Retrieved from https://dl.acm.org/doi/pdf/10.1145/3311350.3347154?casa_token=Rx_7F_nD53EAAAAA:moLq8F__SxYEbtkmvQchtLYrPJiclKT6xHQjO-tQmnQZEezH4vBPsYRtgUe-s3BIFAC8a-Ba5ZSd
Plass, J. L., Homer, B. D., Mayer, R. E., & Kinzer, C. K. (2020). Theoretical foundations of game-based and playful learning. In J. L. Plass, R. E. Mayer, & B. D. Homer (Eds.), *Handbook of game-based learning* (pp. 3–24). MIT Press.
Reeves T. C., Herrington, J. & Oliver, R. (2002). Authentic activities and online learning. In Quality Conversations, Proceedings of the 25th HERDSA Annual Conference, Perth, Western Australia, 7–10 July 2002. Retrieved from https://core.ac.uk/download/pdf/41533321.pdf
Salen, K., & Zimmerman, E. (2004). *Rules of play: Game design fundamentals*. MIT Press.
Simon, H. A. (1996). *The sciences of the artificial*. MIT Press.
Sitzmann, T. (2011). A meta-analytic examination of the instructional effectiveness of computer-based simulation games. *Personnel Psychology, 64*, 489–528.
Squire, K. (2008). Video games and education: Designing learning systems for an interactive age. *Educational Technology* March/April, 17–26.
Suchman, L. (1987). *Plans and situated actions: The problem of human-machine communication*. Cambridge University Press.
Tobias, S., Fletcher, J., Bediou, B., Wind, A., and Chen, F. (2014). "Multimedia learning with computer games," in The Cambridge Handbook of Multimedia Learning, ed R. Mayer (Cambridge: Cambridge University Press), 762–784. https://doi.org/10.1017/CBO9781139547369.037
Trischler, J., Pervan, S. J., Kelly, S. J., & Scott, S. R. (2018). The value of codesign. *Journal of Service Research, 21*, 75–100.
Van Merriënboer, J. J. G., & Kirschner, P. A. (2018). *Ten steps to complex learning: A systematic approach to four-component instructional design* (3rd ed.). Routledge.
Vogel, J. J., Vogel, D. S., Cannon-Bowers, J., Bowers, C. A., Muse, K., & Wright, M. (2006). Computer gaming and interactive simulations for learning: A meta-analysis. *Journal of Educational Computing Research, 34*(3), 229–243.
Vygotsky, L. (1978). *Mind in society: The development of higher psychological functions*. Harvard University Press.
Whitton, N. (2012). Game-based learning. In N. Seel (Ed.), *Encyclopedia of the sciences of learning*. Retrieved from https://link.springer.com/referenceworkentry/10.1007%2F978-1-4419-1428-6_437
Wouters, P., van Nimwegen, C., van Oostendorp, H., & van der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games. *Journal of Educational Psychology, 105*(2), 249–265.
Young, M. F., Slota, S., Cutter, A. B., Jalette, G., Mullin, G., Lai, B., Simeoni, Z., Tran, M., & Yukhymenko, M. (2012). Our princess is in another castle: A review of trends in serious gaming for education. *Review of Educational Research, 82*(1), 61–89.

Index

C. Aprea, D. Ifenthaler (eds.), *Game-based Learning Across the Disciplines*, Advances in Game-Based Learning, https://doi.org/10.1007/978-3-030-75142-5