Teaching Coding in K-12 Schools

Therese Keane • Andrew E. Fluck
Editors

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Research and Application

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Editors
Therese Keane
School of Education
La Trobe University
Victoria, VIC, Australia

Andrew E. Fluck
School of Education
University of Tasmania
Launceston, TAS, Australia

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Foreword

The computers introduced into schools, colleges and universities from the 1980s and 1990s were very different from the computers that we see in those institutions today. One could ask – is this important? In this regard, certainly there are points worth considering. If computers are not new to education, and have been in educational institutions for more than 30 or 40 years, are educators now familiar with the functionality and application of computers for teaching and learning? If computers offer different functionalities and applications from those 30 or 40 years ago, does this mean that educators have kept pace with the changes? If computers are now more widely accessible than they were 30 or 40 years ago, does increased accessibility mean that there is greater familiarity with the potential that computers now offer in education? Researchers continue to discuss these questions, but the picture indicates that 'yes' is not always the simple answer to those three questions. Familiarity, keeping pace and maintaining awareness of applications of computers in teaching and learning are outcomes that appear not always to have kept pace with computer developments. Arguably, a part of the reason for that differential of keeping pace has been due to the focus that educational policies and practices – nationally, regionally and locally – have maintained during the past 40 years. In some ways, when comparing computers with those 30 or 40 years ago, there are similarities as well as differences. A focus on similarities has often been lacking in educational policies and practice across the age range – on computing, programming and computational thinking. In that regard, this book offers ways forward, to re-consider and re-focus policies and practices.

What has happened during the past 30 or 40 years is that computers have become much more widely used and accepted by many individuals. However, computers have become accepted to the point where many individuals worldwide can now be considered as 'consumers'; there is direct acceptance of applications of computers, both the hardware (including peripherals) and software (including online resources) for teaching and learning needs. Over the next 30 years, it is fundamentally important in my view, in the view of authors in this book and in the view of UNESCO that individuals become 'producers' with regard to computers. The current focus on developing computer education and informatics for all young people is, in my view,

an important step in that direction. We undoubtedly see the seeds of that drive within this book. This is why this book is so fundamentally important – it shows us how to explore the ways that education across the age spectrum can support a greater balance towards developing critical 'producers', and how a focus on creativity will be developed in the longer term. The contents of this book provide an invaluable set of guides for all educational sectors to support that crucially important endeavour.

Prof. Dr. Don Passey
Don Passey is a Professor in the Department of Educational Research at Lancaster University in the United Kingdom and is also an Honorary Professor of Amity University in India. He is the chair of Technical Committee 3 (Education) for the International Federation for Information Processing which has maintained strong links with UNESCO since it was established under the auspices of UNESCO in 1960.

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About the Editors and Contributors

Editors

Therese Keane For over 25 years, Professor Therese Keane has been a champion for empowering girls in STEM. Currently she is the Associate Dean of Research and Industry Engagement, and Professor of STEM Education at La Trobe University's School of Education in Melbourne Australia. Her passion and many achievements have been acknowledged by her peers in her receiving numerous international, national and state awards. She has worked in a variety of school settings where she has taught IT and led in K-12 education as the director of ICT. Her Doctorate in Education focused on ICT leadership in schools. Therese has served on several state, national and international boards, including chair of the Australian Computer Society's (ACS) ICT Educators Committee, Australian Council of Computers in Education (ACCE) and Australian representative for the International Federation of Information Processing (IFIP) Technical Committee on Education (TC3). Currently, she is the vice chair for TC3 – WG3.3 – "Research into Educational Applications of Information Technologies". Therese is deputy editor of *Education and Information Technologies* – the official journal of the IFIP Technical Committee on Education covering the complex relationship between information and communication technologies and education. Throughout her career, Therese has also been an office holder in three professional teaching associations, the Victorian Information Technology Teachers Association (VITTA), Information and Communications Technology in Education Victoria (ICTEV), and the Digital Learning & Teaching Victoria (DLTV). Therese has presented numerous seminars and workshops for teachers involved in the teaching of information technology. She has written 16 textbooks in all units of VCE Senior Information Technology in Victoria since 1995 and has worked with the Victorian Curriculum and Assessment Authority (VCAA) in the development of the VCE IT Study Design and various roles associated with VCE assessment over the past 25 years. Therese has been involved in the provision of professional development to ICT teachers and research into the use of technology, gender inequalities in STE-based subjects, robotics in education, and

computers in schools for teaching and learning purposes. Therese has developed and delivered workshops in humanoid robot (NAO) for primary and secondary school students and was also involved with the FIRST LEGO League as tournament director for Victoria and lead mentor for the RoboCats – a schoolgirl only robotics team that participated in the FIRST Robotic Competition from 2014 to 2020 (Chaps. 1, 17, and 23).

Andrew Fluck The goal of Associate Professor Andrew Fluck (retd.) has been to maximise the benefits of information and communication technology (ICT) and minimise the harms. To this end he has undertaken world class research and development on using computers for educating children with special needs, e-assessment to transform curricula, and the improvement of learning outcomes by impact factors greater than 3.0.

Andrew trained as a teacher in Bristol, England, then spent 2 years working in Afikpo, Nigeria. Returning to the UK, he taught in a high school, then became director of an advisory centre on computers for children with special needs. His family then moved to Australia, where he taught computer science before joining the University of Tasmania. Over the next 25 years, he taught and researched information technology education, authoring many academic papers. His PhD thesis was one of the most popular in the university library (37,179 downloads in 15 years).

He is deputy editor of the journal *Education and Information Technologies* (ranked third in the world for educational technology by Google Scholar). Andrew joined the IFIP Discipline Group for Quantum Computing in 2022. He is a passionate advocate for the inclusion of quantum computing programming in senior secondary schools. He is also mindful of the promises and threats of quantum communication systems.

Andrew's funded research has investigated the transformative use of computers to teach integral calculus, quantum mechanics in primary schools, and e-exams, where students take their own computers into the exam hall. He was chair of Working Group 3.3 (research into educational applications of information technologies) for IFIP/UNESCO from 2016 to 2019 and was given the IFIP Service Award in 2019. Within Australia, he was a member of the ICT Educator's Committee of the Australian Computer Society from 2017 to 2021. During this time, he led a national survey of digital technologies teaching.

Outside academia, Andrew is an avid archer (preferring the longbow), continental archery judge and director of Archery Australia. He was awarded the silver medal in the Archery Australia 2017 Club Challenge (Veteran Male Longbow) and is a Level 1 archery coach (Chap. 27).

See more details of publications, projects and Curriculum Vitae at https://Andrew.Fluck.id.au.

Contributors

Belinda Bath is an educator with over 20 years of experience teaching internationally and across Australia. She holds qualifications in early childhood and gifted education, management and leadership. Belinda's professional journey has allowed her to work in many different roles, including teacher, leader, consultant, child development officer, board member and most recently, as a student herself. Belinda is currently undertaking post-graduate studies, and her research project is investigating gender and the impact of childhood experience on later career choices in the science, technology, engineering and medical professions.

Jane Batham Since commencing teaching more than 20 years ago, Jane Batham has been an enthusiastic and innovative integrator of digital technologies in the classroom. She has fulfilled many roles in education, including as a classroom teacher, curriculum leader, digital learning facilitator and educational consultant. A dedicated lifelong learner, Jane conducted action research into using iPads to promote creativity and collaboration, and is currently investigating the development of STEM mindsets as her PhD research project. Jane is passionate about empowering teachers to embrace digital technologies and provide enriching and engaging learning opportunities that inspire students to make our world a better place (Chap. 7).

Martin Beneš is a graduate of the Faculty of Education at Charles University, MA in IT and Pedagogy for Lower and Upper Secondary School Education. PhDr Martin Beneš is currently a PhD candidate at the same faculty. As part of his thesis, he is investigating issues of minors gambling, software development and cybersecurity. He teaches on MA courses for student teachers of informatics and for IT teachers (Python programming, Didactics of Informatics) and on courses for student teachers of Primary Education (IT didactics, Digital technology in primary education, etc.) (Chap. 19).

Ludmila Bosova was born May 9, 1963 into a family of hereditary teachers of mathematics and physics. She graduated with honours both from high school (1980) and from the Belarusian State University (1985) with degree in mathematics. She

started working as a mathematician-programmer, then moved into the education system. From 1990 to the present, she has been a computer science teacher at a rural school near Moscow, combining educational and scientific activities. Ludmila is the author of more than 400 scientific papers on the theory and methodology of teaching computer science and informatisation of education, computer science textbooks for elementary and high schools. She is currently a Doctor of Pedagogical Sciences, and Head of Department of Theory and Methods of Teaching Mathematics and Informatics in Moscow Pedagogical State University. She has been a corresponding Member of the Russian Academy of Education since 2022 (Chap. 8).

Rosa Bottino is Emeritus Research Director of the Italian National Research Council (CNR) and directed for more than 11 years the Institute of Educational Technology of CNR and was also President of the CNR Research Area of Genova (Italy). She led competitive projects funded by the European Commission and Italian Institutions, and acted as research evaluator of many European, International and National research projects and Institutions. Dr. Bottino obtained national and international awards such as IFIP Silver core and outstanding service awards, SAPIO Award for "Scientific outstanding woman researchers", and best paper awards in a number of international conferences. Dr. Bottino is currently IFIP TC3 vice-chair and chair of the WCCE-2022 World Conference. She is the author of more than 150 international and national scientific papers (Chap. 5).

Miroslava Černochová completed her doctorate at the Faculty of Mathematics and Physics of Charles University, Prague. Since 1985, she has worked as a teacher educator and researcher at the Faculty of Education at Charles University. She is dedicated to the implementation of computer education in primary and secondary schools and to the development of student teachers´ digital competence. In recent years, she has contributed significantly to the national governments' strategy to integrate computing as a compulsory subject into the curriculum of primary, lower and upper secondary schools. Her research is devoted to issues around shaping computational thinking (CT) of primary education student teachers and around mastering key concepts and skills of primary school pupils when learning Computing, including developing a methodology of how to identify and measure pupils' CT level (Chap. 19).

Milorad Cerovac is a lecturer at La Trobe University in Victoria, Australia. He had 17 years of experience in the Information Technology field, as a Software Programmer and Database Specialist, before moving into teaching, where he has taught Physics, Systems Engineering and Software Development. Milorad's research interests include the innovation capabilities of students in the Technologies curriculum. Milorad has been heavily involved with the *FIRST* LEGO League in Victoria and was co-founder/lead mentor for the RoboCats – a schoolgirl only robotics team that participated in the *FIRST* Robotic Competition from 2014-2020 (Chap. 23).

Christina Chalmers is a senior lecturer in STEM and Technologies Education at the Queensland University of Technology. Her research focuses on group metacognition, computer supported collaborative learning, digital pedagogies, and robotics-based STEM education. She currently coordinates the Technologies Curriculum unit and a STEM master's unit within the Faculty of Creative Industries, Education and Social Justice. Chris is the project leader for the Robotics@QUT outreach program and is the coordinator of the Children's Technology Centre for the Australian Research Council of Excellence for the Digital Child. Chris has published in top international journals on mathematics, robotics education and STEM "Big Ideas" (Chap. 13).

Mick Chesterman teaches at the Manchester Metropolitan Faculty of Health and Education on Foundation and project-based units. His PhD studies involve families exploring cultural and ecological issues of coding platform games together. He has a history of teaching media making and web creation skills to facilitate positive change for social groups. In recent years, he has run several outreach programs in local communities and schools linked to the University. These workshops have a focus on creative coding and the use of physical materials. He is the founder of a making and repairing workshop called *Todmorden Makery* which works with adults, young people and families to repair objects and transform old technology into art projects (Chap. 12).

Augusto Chioccariello obtained his physics degree (magna cum laude) in 1980 at the University of Naples. From 1982 to 1986, he worked in physics education at the Educational Technology Centre, UC Irvine. In 1986, he joined the Institute of Educational Technology of the Italian National Research Council (CNR-ITD). Dr. Chioccariello's major research interests are science education and computational thinking. He has collaborated with Reggio Emilia infant schools, exploring the use of computational play kits as learning tools for early childhood education. More recently, in 2021 Dr. Chioccariello has worked on the European Commission study "Reviewing Computational Thinking in Compulsory Education". He is currently coordinating CNR-ITD "Programming to Learn in Primary School" project (Chap. 5).

Jody Clarke-Midura is Associate Professor of Instructional Technology and Learning Sciences in the Emma Eccles Jones College of Education and Human Services at Utah State University. Her research focuses on learning and assessment with digital media, toys and games in the context of Science, Technology, Engineering, Mathematics, and Computer Science (STEM+C). She holds a master's and doctorate from the Harvard Graduate School of Education (Chap. 3).

Nathalia da Cruz Alves is a PhD candidate of the Graduate Program in Computer Science (PPGCC) at the Federal University of Santa Catarina (UFSC) and a Data Scientist at FEESC/UFSC, Florianópolis, Brazil. She is also a researcher at the initiative Computing at Schools/INCoD/INE/UFSC focusing mainly on the learning

assessment as part of computing education. She received her BSc (2017) and MSc (2019) in Computer Science from the Federal University of Santa Catarina. Her main research interests are computing education, creativity and assessment (Chap. 20).

Valentina Dagienė is principal researcher in computer science (informatics) education at Vilnius University, Lithuania. Her main research area is informatics education in schools including teacher training, curricula development and technology enriched methodology. V. Dagienė has published more than 300 research papers in international journals, 3 monographs and 60 textbooks. She organised more than 20 international conferences, e.g. ITiCSE in Vilnius (2014), and constructionism with focus on computational thinking (2018). She is a founder and organises annual conferences during International Olympiads in Informatics, e.g., in Japan 2018, Azerbaijan 2019, Singapore 2020–2021 (online), Indonesia 2022. She established and is editor-in-chief of international journals *Informatics in Education* and *Olympiads in Informatics* (indexed by Scopus, WOS emerging list and other databases). She has coordinated more than 50 national and international projects on informatics education, STEM, teacher training, etc. (Chap. 10).

Birgit Eickelmann has been a full professor for school research and teacher education at Paderborn University in Germany since 2012 with a special focus on teaching and learning in the digital age. Among other projects and activities, she is head of the German part of the International Computer and Information Literacy Study (ICILS), and head of the part "ICT in education" in the Horizon 2020 DigiGen project (Chap. 21).

Maria Emmi leads the creative integration of innovative and emerging technologies across the school curriculum. Continually exploring and modelling next practice, she shares with teaching staff ideas and pedagogies for use in all Key Learning Areas. Maria builds teacher capacity in developing transdisciplinary programs that harness the use of digital technology. Always endeavouring to incorporate digital technology in ways that can intrinsically motivate students, create student agency and provide differentiated learning opportunities (Chap. 14).

Garry Falloon is Professor of STEM Education in the Macquarie School of Education at Macquarie University. His background includes 22 years teaching and leadership of primary and secondary schools in New Zealand, Education Foundation Manager at Telecom New Zealand, working with Microsoft in the Partners in Learning and Digital Learning Object projects, and as project lead for the New Zealand Government's $10m Digital Opportunities Project. His research interests include mobile learning, digital learning in primary and middle schools, online and blended learning, curriculum design, pedagogy and assessment in digitally supported innovative learning environments, learning in primary science and technology, and educational research methods (Chap. 16).

Miriam Nathalie Fortuna Ferreira holds a master's degree in design from the Graduate Program in Design (POSDESIGN) at the Federal University of Santa Catarina (UFSC). She graduated in Business Administration from Faculdade Estácio de Sá (2005). She works as an administrative analyst at the Fundação do Ensino da Engenharia and the National Institute for Digital Convergence (Brazil). She also participates in the initiative Computação nas Escolas especially in the area of design, aiming to integrate the teaching of design concepts into computer education to schools in Brazil (Chap. 20).

Laura Freina, a recently retired researcher from the Institute for Teaching Technologies of the National Research Council (CNR-ITD – Italy), has a degree in Mathematics and in Communication Science, followed by a PhD course in Cognitive Science. In the last working years, she focused on fostering Computational Thinking through programming activities in primary schools. Previously, she investigated the impact of the use of entertainment games on the development of basic transversal skills in primary students. In her past, she had various experiences, ranging from software and multimedia development, lab teacher in graduate courses, librarian, substitute teacher in an International School. She has been involved in several projects, both at Italian and European level (Chap. 5).

Takahisa Furuta is an associate professor in the Cooperative Faculty of Education, Gunma University, Japan. His research interests are in technology education and psychology of problem solving. Dr. Furuta has been involved in teaching computer programming and computer hardware for preservice teachers and K-12 students (Chap. 18).

Mareen Grillenberger is professor for Computer Science Education at lower secondary level at the Schwyz University of Teacher Education in Switzerland. With her research group, she currently conducts research on educational escape games, quantum computing and physical computing in lower secondary Computer Science education. For many years, her main research interest has been in physical computing. In addition to a comprehensive theoretical exposition of the field, teaching scenarios were developed and evaluated in regular lessons in close cooperation with teachers. She has conducted numerous workshops in this area and has thus been able to transport the topic into many classrooms (Chap. 15).

Matthew Harrison is an experienced teacher, researcher and digital creator with a keen passion for utilising technology to enhance social capacity building, belonging and inclusion in education. He has taught in Australia, South Korea and the United Kingdom at primary, secondary and tertiary levels. Matthew is currently coordinating Autism Intervention within the Master of Learning Intervention, and is the co-director of student experience at the University of Melbourne Graduate School of Education. His research primarily focuses on neurodiversity, inclusive education and the effective use of digital technologies as teaching and learning tools. As a gamer, he has a particular interest in digital games-based learning and intervention (Chap. 11).

Jean C. R. Hauck holds a PhD in knowledge engineering and a master's degree in computer science from the Federal University of Santa Catarina (UFSC) and a degree in computer science from the University of Vale do Itajaí (UNIVALI). He was a visiting researcher at the Regulated Software Research Centre – Dundalk Institute of Technology – Ireland. He is currently a professor in the Department of Informatics and Statistics at the Federal University of Santa Catarina, member of the Software Quality Group (GQS) and member of the initiative Computing at Schools (Chap. 20).

Herma Jonker is associate professor and teacher educator in the School of Human Movement and Education at Windesheim University of Applied Sciences in the Netherlands. As teacher educator she is involved in vocational teacher education. In her research she focuses on e-learning in general and more specific on curriculum design in blended learning environments in higher professional education (Chap. 22).

Djordje M. Kadijevich earned a PhD in informatics in education from University of Novi Sad, Serbia, in 1995, and a PhD in mathematics education from University of Joensuu, Finland, in 2004. He currently works as full research professor at the Institute for Educational Research, Belgrade, Serbia, where he conducts research in mathematics, informatics, and statistics education. His most recent co-edited book is Improving Computer Science Education (Routledge, 2013). His papers, published by Elsevier, Routledge, Springer, and Wiley-Blackwell among others, have been widely cited (about 1,400 times at present according to Google Scholar). Dr. Kadijevich is a member of Working Groups 3.1 and 3.3 of the IFIP Technical Committee on Education, the International Association for Statistical Education, and the Committee for Education of the Serbian Academy of Sciences and Arts (Chap. 24).

Gerald Knezek is Regents Professor of Learning Technologies at the University of North Texas, in Denton, Texas, USA. He was Lead Principal Investigator for a 2016-2022 NASA-funded Space Science Education Consortium project (NNX16AL63A) assessing impacts of technology-engaged computational thinking activities with robotics and drones, on middle school students. Dr. Knezek has been involved in teaching coding for K-12 students and teachers for more than 30 years (Chap. 18).

Joseph S. Kozlowski currently works at Utah State University's Edith Bowen Laboratory School where he works directly with elementary students, trains preservice teachers and conducts educational research. Kozlowski has a passion for bridging real life experiences to learning and prioritises getting students in the field to build rich experiential knowledge. His ongoing research in mathematics education relates to supporting early childhood mathematics through coding toy activities and fostering creative thinking in mathematics (Chap. 3).

Amelie Labusch works as a research assistant in the department of School Education of Prof. Dr. Birgit Eickelmann at Paderborn University in Germany. Her research interests focus on computational thinking and digitalisation processes in education, and matters related to the associated developments and changes in schools (Chap. 21).

Victor R. Lee is an associate professor in the Graduate School of Education at Stanford University. Through his research, he asks what STEM knowledge, tools and practices are important to know in order to enable active participation and critical engagement with our increasingly digitally-infused lives. Currently, this work involves researching and designing experiences for K-12 teaching and learning about data – often through a "quantified self" perspective, documenting and supporting the development of computational thinking in elementary school classrooms, and analysing and supporting maker education in out-of-school settings. Lee completed his PhD in Learning Sciences at Northwestern University (Chap. 3).

Tanya Linden is a Senior Teaching Fellow at the University of Melbourne. She has a diverse educational background with qualifications and expertise that cover information technology, enterprise systems and Web development. Her teaching has been recognised as outstanding at the University of Melbourne and Victoria University where she has been presented with teaching awards. Her research interests are in blended learning, educational technology, promoting STEM careers to female students of various ages, multimedia development practices and enterprise systems. She is well-published in all these areas and regularly presents her work throughout North America, Europe and Australasia (Chap. 17).

Konstantina Louka is a preschool teacher in the public sector. She is studying for a master's degree in ICT Education at the University of Crete. Her master's thesis is empirical research on cultivating computational thinking in preschool education using the ScratchJr programming environment. She holds a bachelor's degree in philosophy, education and psychology from the National and Kapodistrian University of Athens, which provides professional skills for teaching Greek language and literature in secondary education. She has also received a certificate of completion of advanced training for using and applying ICT in the teaching practice (B2-Level ICT teacher training) (Chap. 4).

Linda Mannila (PhD) is a researcher, educator and writer with more than 20 years of work experience at the crossroads of digitalisation and education. Her research interests lie in the area of computer science education, with particular focus on programming, computational thinking and digital competence at K-9 level from a student, teacher and organisational perspective. Currently, she is an associate professor (docent) at Åbo Akademi University in Finland, and a senior researcher at the AIICS (AI and embedded computer systems) lab at Linköping University in Sweden (Chap. 9).

Jonathon Mascorella is a leader in innovation and strategic technological integration in schools. His primary focus is on delivering strong outcomes for students and teachers in using and implementing technologies that enhance learning and teaching. In research, Jonathon focuses on the human experience through social constructs and context, intermixed with technology. His PhD focused on the interactions between power-knowledge and policy implementation at a State, school and industry level (Chap. 14).

Fiona Mayne is a senior lecturer in technology education and educational psychology with the Graduate School of Education at the University of Western Australia. Fiona has a developing international profile, and has considerable expertise in qualitative participatory measures and methodologies for meaningful research with children in the areas of young children's rights, voice and agency in research, as evidenced in her book entitled, *The Narrative Approach to Informed Consent*. Her body of work to date has made a significant contribution to empirical, theoretical and methodological knowledge in early years research ethics, children's rights-based participatory research and increasingly technology education (Chap. 6).

Andreea Molnar is an Associate Professor at the Swinburne University of Technology, Department of the Computing Technology and an Anna Boyksen Fellow at the Technical University of Munich. She was awarded a PhD in Technology Enhanced Learning from the National College of Ireland. She has worked in different countries such as the UK, USA and now in Australia. Her research focuses on computing for the social good and incorporates various aspects from information systems, HCI, educational technology and computer science education. She is a Senior Editor for Information Technology & People (Chap. 17).

Jayanti Nayak is a PhD candidate at Swinburne University of Technology. She has more than 10 years industry experience in the field of Computer science and Product development. She has been teaching Computing and Computer Programming in a high school setting in Australia. As Director of Arts and Technology at her current school, she has been encouraging STEM and computing related careers to high school students (Chap. 17).

Yoshiaki Okugi is Vice Principal of Nakanojo Junior-High School, Gunma, Japan. He mainly taught technology classes and has been involved in improving teaching methodologies and classroom management for more than 30 years. His main research interests are in the practices of information education (Chap. 18).

Hanna Palmér is Professor of Mathematics Education at Linnaeus University in Sweden. Her research is focused on early mathematics teaching and learning. Of special interest is problem solving and digital technology in mathematics education. She also studies the professional identity development of mathematics teachers. At Linnaeus University she is the Dean of teacher education (Chap. 2).

Stamatios Papadakis has been a postdoctoral researcher in Educational Technology, with an emphasis on mobile learning, in the Department of Preschool Education at the University of Crete, Greece, since 2016. He has worked in several international and national computational thinking and pedagogy projects, of Pre-K to 16 Education. His scientific and research interests include the study of mobile learning, especially on the use of smart mobile devices and their accompanying mobile applications (apps) in Preschool and Primary Education, focusing on the development of Computational Thinking and students' understanding of numbers. Furthermore, he currently investigates how a STEM learning approach influences learning achievement through a context-aware mobile learning environment in the preschool classroom and explains the effects on pre-schoolers' learning outcomes (Chap. 4).

Hasan Selcuk, PhD, is Assistant Professor at the Faculty of Education, Psychology and Art, University of Latvia. Previously, Dr. Selcuk was a postdoctoral researcher and lecturer at the Faculty of Education, Charles University in Prague. He received his PhD in Education from King's College London in 2017. In his PhD thesis, Dr. Selcuk focussed on student perceptions of peer collaboration through the medium of web-based collaborative writing among learners of English as a Foreign Language. His research interests relate to computer-assisted foreign language writing, online small group learning and teaching computational thinking to primary school pupils (Chap. 19).

Jessica F. Shumway is Associate Professor of Mathematics Education at Utah State University. She centres her research on improving elementary mathematics education, and currently investigates instructional practices and learning technologies that foster mathematical and computational thinking in preschool and elementary classrooms. Shumway was an elementary school teacher and mathematics instructional coach in U.S. schools. She is the author of *Number Sense Routines* books. She and her co-authors are members of the Coding in Kindergarten Research Team at Utah State University and Stanford University, National Science Foundation Grant #1842116 (Chap. 3).

Deborah Silvis is a Postdoctoral Researcher in Instructional Technology and Learning Sciences at Utah State University, where she examines early childhood computing. Her research primarily focuses on learning and teaching of young children and is concerned with the ways in which human-technology interactions are involved in transforming learning, society and ecologies (Chap. 3).

Peer Stechert is a teacher at the RBZ Technik Kiel. He is the coordinator for the continuing education of computer science teachers in the German federal state Schleswig-Holstein. His dissertation in the area of didactics of informatics focussed on understanding of informatics systems at lower and upper secondary level. His work interests are didactic issues of programming, especially of programming beginners and IT specialist training at vocational schools. Since 2020, he is chair of the expert committee on informatics education at schools of the German Informatics Society (Chap. 25).

Gabrielė Stupurienė is a PhD in technological sciences (informatics engineering), is a researcher at Vilnius University (Faculty of Philosophy and Faculty of Mathematics and Informatics). Her main research interest is Informatics/Computer science education, computational thinking, STE(A)M education, digital competencies, technology acceptance models. She is involved in international projects on informatics education, computational thinking, STEAM education, teacher training. She is executive editor of international journal *Informatics in Education* and has been involved for more than 10 years as a volunteer in the international Bebras challenge on informatics and computational thinking (Chap. 10).

Diane van der Linde-Koomen is ICT coordinator and researcher in the School of Human Movement and Education at Windesheim University of Applied Sciences in the Netherlands. As ICT coordinator she is responsible for teacher professionalisation in the pedagogical use of digital technology. In her research she focuses on Computational Thinking in (teacher) education (Chap. 22).

Lina Vinikienė is a project coordinator and researcher at Vilnius University Faculty of Philosophy. The areas of scientific interest are the assessment of student competencies, design and development of the digital content, non-formal and formal education activities. She is publishing scientific papers about teaching/learning approaches, computational thinking assessment, development of informatics tasks. Lina Vinikienė is involved in organising the Bebras challenge on informatics and computational thinking. She implements seminars based on informatics activities for teachers and students in primary and secondary schools. Also, she has experience with implementing Erasmus+ projects (e.g., IncluSMe, OnlineHe, 3C4Life) (Chap. 10).

Christiane Gresse von Wangenheim is a professor in the Department of Informatics and Statistics of the Federal University of Santa Catarina (UFSC), Florianópolis, Brazil, where she coordinates the Software Quality Group focusing on scientific research, development and transfer of software engineering models, methods and tools and education. She also coordinates the initiative Computing at Schools, which aims at bringing computing education to schools in Brazil. She received the Dipl.-Inform. and Dr. rer. nat. degrees in Computer Science from the Technical University of Kaiserslautern (Germany), and the Dr. Eng. degree in Production Engineering from the Federal University of Santa Catarina (Brazil) (Chap. 20).

Joke Voogt is emeritus professor ICT and Curriculum at the University of Amsterdam. Her research interests are curriculum innovation and implementation of digital technology, teacher professional development, twenty-first century skills and research-practice relationships. She is co-founder of the EDUsummIT, a global community of researchers, policymakers and educators committed to supporting the integration of technology in education by promoting active dissemination of research (Chap. 22).

Goran Vukovic holds a master's degree in media informatics. He is a teacher at the RBZ Technik Kiel. His work interests include VR programming and the subject media technology (Chap. 25).

Lise E. Welch Bond is a PhD candidate at Utah State University studying young children's multimodal indicators of mathematical and computational thinking knowledge. Her research interests include early childhood mathematics education, spatial knowledge, computational thinking, and cross-disciplinary research. Welch Bond is currently an elementary mathematics education specialist in Utah with prior experience as an elementary teacher, curriculum developer, mathematics coach, mathematics education consultant, course designer, and lecturer (Chap. 3).

Karen Woo is a PhD candidate at Macquarie School of Education at Macquarie University. Karen is researching the development of computational thinking and twenty-first century competencies through coding. She is an experienced coding and robotics educator working with pre-service teachers and primary-age students. She also consults with schools on integration of technology in the classrooms (Chap. 16).

Jason Zagami is a senior lecturer in the School of Education and Professional Studies at Griffith University on the Gold Coast in Queensland, Australia, where he teaches and conducts research on innovations in educational technologies, focusing on the identification of emerging trends, educational gaming (including VR, AR and VWs), student co-creation of secondary worlds, AI and robotic applications in teaching, neural/cognitive activity measurement, and computer science education (K12) with a focus on curriculum development and implementations involving higher-order thinking skill development, concept developments through visualisation and manipulation, and challenges for female participation in computer science education (Chap. 26).