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# Foreword

We need to think harder about how we prepare young people for tomorrow's world. In the past, education was about teaching students something. Now, it's about making sure that students develop a reliable compass and the navigation skills to find their own way through an uncertain, volatile, and ambiguous world. Now, schools need to prepare students for a world in which most people will need to collaborate with people of diverse cultural origins and appreciate different ideas, perspectives and values; a world in which people need to decide how to trust and collaborate across such differences; and a world in which their lives will be affected by issues that transcend national boundaries. Technology has become the key to bridge space and time in all of this.

These days, we no longer know exactly how things will unfold. We are often surprised and need to learn from the extraordinary, and sometimes we make mistakes along the way. And it will often be the mistakes and failures, when properly understood, that create the context for learning and growth. A generation ago, teachers could expect that what they taught would last their students a lifetime. Today, schools need to prepare students for more rapid economic and social change than ever before, for jobs that have not yet been created, to use technologies that have not yet been invented, and to solve social problems that we don't yet know will arise.

How do we foster motivated, engaged learners who are prepared to conquer the unforeseen challenges of tomorrow, not to mention those of today? The dilemma for educators is that routine cognitive skills—the skills that are easiest to teach and easiest to test—are also the skills that are easiest to digitize, automate, and outsource. There is no question that state-of-the-art knowledge and skills in a discipline will always remain important. Innovative or creative people generally have specialized skills in a field of knowledge or a practice. And as much as 'learning to learn' skills are important, we always learn by learning something. However, educational success is no longer about reproducing content knowledge, but about extrapolating from what we know and applying that knowledge in novel situations. Put simply, the world no longer rewards people for what they know—Google knows everything—but for what they can do with what they know. Because that is the main differentiator today, education today needs to be much more about ways of thinking, involving creativity, critical thinking, problem-solving, and decision-making; about ways of working, including communication and collaboration; about tools for working, including the capacity to recognize and exploit the potential of new technologies; and, last but not least, about the social and emotional skills that help us live and work together.

Conventionally, our approach to problems was to break them down into manageable bits and pieces and then to teach students the techniques to solve them. But today we create value by synthesizing the disparate bits. This is about curiosity, open-mindedness, and making connections between ideas that pre-

viously seemed unrelated, which requires being familiar with and receptive to knowledge in other fields than our own. If we spend our whole life in a silo of a single discipline, we will not gain the imaginative skills to connect the dots where the next invention will come from.

Equally important, the more content knowledge we can search and access, the more important becomes the capacity to make sense of this content—the capacity of individuals to question or seek to improve the accepted knowledge and practices of their time. In the past, you could tell students to look into an encyclopedia when they needed some information, and you could tell them that they could generally rely on what they found to be true. Today, literacy is about managing non-linear information structures, building your own mental representation of information as you find your own way through hypertext on the Internet, and dealing with ambiguity—interpreting and resolving conflicting pieces of information that we find somewhere on the Web.

Perhaps most importantly, in today's schools, students typically learn individually and at the end of the school year, we certify their individual achievements. But the more interdependent the world becomes, the more we need great collaborators and orchestrators. Innovation today is rarely the product of individuals working in isolation but an outcome of how we mobilize, share, and link knowledge. In the flat world, everything that is our proprietary knowledge today will be a commodity available to everyone else tomorrow. Expressed differently, schools need to drive a shift from a world where knowledge is stacked up somewhere, depreciating rapidly in value, towards a world in which the enriching power of communication and collaborative flows is increasing. And they will need to help the next generation to better reconcile resilience (managing in an imbalanced world) with greater sustainability (putting the world back into balance).

This is a tough agenda. What is certain is that it will never materialise unless we are able to clearly conceptualise and measure those 21st century knowledge areas and skills. Without rigorous conceptualisation, we will not be able to build meaningful curricula and pedagogies around these knowledge areas and skills. And, at the end of the day, what is assessed is what gets taught. This volume makes a major step in advancing this frontier. It examines a range of skills that are important; it looks at innovative measurement methods to make these skills amenable to quantitative assessment in ways that they become activators of students' own learning, and it looks at how we can learn to drink from the firehose of increasing data streams that arise from new assessment modes.

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# Foreword

In its landmark report *Education for Life and Work in the 21st Century*, the National Research Council (2012) described "deeper learning" as an instructional approach important in preparing students with sophisticated cognitive, intrapersonal, and interpersonal skills. The approaches recommended by advocates of deeper learning are not new, and historically these instructional strategies have been described under a variety of terms. Until now, however, they have been rarely practiced within the schools (Dede, 2014), resulting in the sad situation that students who excel in school may struggle in the real world. And students who struggle in school are likely to sink in the real world. Various "deeper learning" approaches are described below.

- Case-based learning helps students master abstract principles and skills through the analysis of real-world situations;
- Multiple, varied representations of concepts provide different ways of explaining complicated things, showing how those depictions are alternative forms of the same underlying ideas;
- Collaborative learning enables a team to combine its knowledge and skills in making sense of a complex phenomenon;
- Apprenticeships involve working with a mentor who has a specific real-world role and, over time, enables mastery of their knowledge and skills;
- Self-directed, life-wide, open-ended learning is based on students' passions and is connected to students' identities in ways that foster academic engagement, self-efficacy, and tenacity;
- Learning for transfer emphasizes that the measure of mastery is application in life rather than simply in the classroom;
- Interdisciplinary studies help students see how differing fields can complement each other, offering a richer perspective on the world than any single discipline can provide;
- Personalized learning ensures that students receive instruction and supports that are tailored to their needs and responsive to their interests (U.S. Department of Education, 2010; Wolf, 2010; Rose & Gravel, 2010);
- Connected learning encourages students to confront challenges and pursue opportunities that exist outside of their classrooms and campuses (Ito et al., 2013); and
- Diagnostic assessments are embedded into learning and are formative for further learning and instruction (Dede, 2012).

These entail very different teaching strategies than the familiar, lecture-based forms of instruction characteristic of industrial-era schooling, with its one-size-fits-all processing of students. Rather than requiring rote memorization and individual mastery of prescribed material, they involve in-depth, dif-

ferentiated content; authentic diagnostic assessment embedded in instruction; active forms of learning, often collaborative; and learning about academic subjects linked to personal passions and infused throughout life.

The chapters in this book demonstrate that new tools and media can be very helpful to many teachers who would otherwise struggle to provide these kinds of instruction for deeper learning (Dede, 2014). By analogy, imagine that you wish to visit a friend 20 miles away. You could walk (and some people would prefer to do so), but it would be much easier to use a bicycle, and it would be far easier still to use a car. In short, teachers who wish to prepare their students for the real world, as well as for further academics, don't have to use educational technology; they may prefer to walk. Realistically, however, many, if not most, teachers will be hard-pressed to get from industrial-style instruction to deeper learning without the vehicles of digital tools, media, and experiences.

In an extensive review of the literature on technology and teaching for the forthcoming American Educational Research Association (AERA) Handbook of Research on Teaching (5th Edition), Barry Fishman and I (in press) note the important distinction between using technology to do conventional things better and using technology to do better things (Roschelle et al., 2000). While there may be value in doing some types of conventional instruction better (i.e., more efficiently and effectively), the real value in technology for teaching lies in rethinking the enterprise of schooling in ways that unlock powerful learning opportunities and make better use of the resources present in the 21st-century world.

In our review, we consider how and under what conditions technology can be productively employed by teachers to more effectively prepare students for the challenges presented by a rapidly evolving world. We argue that technology as a catalyst is effective only when used to enable learning with richer content, more powerful pedagogy, more valid assessments, and links between in- and out-of-classroom learning. The examined the following technologies in depth:

- Collaboration tools, including Web 2.0 technologies and tools that support knowledge building;
- Online and hybrid educational environments, which are increasingly being used to broaden access to education but also have the potential to shift the way we conceive of teaching and learning;
- Tools that support learners as makers and creators, which have their deep roots in helping students learn to become programmers of computers (and not just users of them);
- Immersive media that create virtual worlds to situate learning or augment the real world with an overlay of computational information; and
- Games and simulations that are designed to enhance student motivation and learning.

This book provides examples of these and other powerful technologies to aid this type of instruction. If used in concert, these deeper-learning technologies can help prepare students for life and work in the 21st century, mirroring in the classroom some powerful methods of knowing and doing that pervade the rest of society. Further, they can be used to create a practical, cost-effective division of labor, one that empowers teachers to perform complex instructional tasks. In addition, these media can address the learning strengths and preferences of students growing up in this digital age, including bridging formal instruction and informal learning. And, finally, these technologies can provide powerful mechanisms for teacher learning; by which educators deepen their professional knowledge and skills in ways that mirror the types of learning environments through which they will guide their students.

At a time in history when civilization faces crises that we need the full capacity of people across the world to resolve, this volume provides an exemplary suite of practical ways to move forward with curricula, instruction, and assessments that are truly oriented to 21st-century life and work.

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# Preface

Changes in the world economy, specifically toward information industries, have changed the skillset demand of many jobs (Organization for Economic Development [OECD], 2012a). Information is created, acquired, transmitted, and used—rather than simply learned—by individuals, enterprises, organizations, and communities to promote economic and social development. Major employers and policy makers are increasingly asking teachers and educators to help students develop so-called real-world skills (Gallup, 2013). While learning basic numeracy and literacy skills still is crucial to success in the job market, developing real-world skills also is essential to success in the job market and worldwide economic development.

Real-world skills, or "21st century skills," include critical thinking, collaborative problem solving, creativity, and global competency. These skills that facilitate mastery and application of science, mathematics, language arts, and other school subjects will grow in importance over the coming decade (National Research Council, 2012; OECD, 2012a, 2012b). A wide range of initiatives and programs in education promote learning and assessment of real-world skills. These include, for example, the Common Core State Standards (National Governors Association Center for Best Practices and Council of Chief State School Officers, 2010a, 2010b), Next Generation Science Standards (National Research Council, 2013), Common European Framework of Reference (Council of Europe, 2011), Partnership for 21st Century Skills (Partnership for 21st Century Skills, 2009), Education for Life and Work (National Research Council, 2012), and assessment frameworks in the Programme for International Student Assessment (PISA) (OECD, 2013).

Because of the importance of promoting these skills, we have embarked on a journey to create a *Handbook of Research on Technology Tools for Real-World Skill Development*. Because conceptions and educational applications of real-world skills are evolving rapidly, we have welcomed a wide range of skills in the *Handbook*. The following four strands of skills are represented in the chapters: *Thinking skills* refer to higher-order cognition and dispositions such as critical thinking, complex problem solving, metacognition, and learning to learn. *Social skills* refer to attitudes and behaviors that enable successful communication and collaboration. *Global skills* refer to attitudes and behaviors that emphasize the individual's role in, and awareness of, the local as well as the global and multicultural environment. *Digital skills* emphasize information and digital literacies needed in the technology-rich world in which we live. Similarly, the chapters in this *Handbook* describe a range of technology tools to support teaching, learning, assessment for learning (e.g., Stiggins, 2005; Wiliam, 2011), feedback for learning (e.g., Hattie, & Timperley, 2007; Shute, 2008), and scoring of student responses. For example, section 1 includes chapters on curricula and frameworks for teaching real-world skills; the chapters in section 2 describe specific technology tools for teaching, learning, and assessing real-world skills; the chapters in

section 3 describe automated scoring tools for assessment and learning; and section 4 contains chapters on techniques for analyzing data from technology-based performance assessments. Helping students learn real-world skills—that is, to internalize them and use them flexibly across a range of challenges and contexts in their everyday and work lives—is a significant educational challenge. Real-world skills cannot be taught in a single course or in a single year of schooling. And assessing real-world skills to provide feedback to guide development of those skills cannot be accomplished using conventional, large-scale assessment and score reporting methods alone. The technology tools described here represent the range of current and developing capabilities of technology tools to support teaching, learning, assessment, and feedback for learning.

As technology-rich environments for teaching, learning, assessment, and feedback are being integrated into educational processes, there is much to be learned about how to leverage advances in technology, learning sciences, and assessment to develop real-world skills for the 21st century. Research findings on what works best are just emerging, possibly due to the strong multi-disciplinary approaches required to extract the greatest value. This *Handbook* is intended to serve as a first body of research in the expanding area of technology tools for teaching, learning, assessment, and feedback on real-world skills that educators can turn to in the coming years as a reference. Our aim is to bring together top researchers to summarize concepts and findings. The *Handbook* contains contributions of leading researchers in learning science, educational psychology, psychometrics, and educational technology. Assuming that many readers will have little grounding in those topics, each chapter outlines theory and basic concepts and connects them to technology tools for real-world skill development. We see this as one of the most crucial contributions of the *Handbook*, seeking to establish strong theoretical principles that can inform educational research and practice and future research and development. The *Handbook* also provides brief overviews in each topic section for more knowledgeable readers. The *Handbook* is organized into four sections.

## SECTION 1: DEFINING REAL-WORLD SKILLS IN TECHNOLOGY-RICH ENVIRONMENTS

The seven chapters in Section 1 explore conceptualization of real-world skills and the role of technology. The section includes chapters on curricula and frameworks for teaching real-world skills. To aid readers in selecting specific chapters to study, we list the technology tools described in these chapters.

**Chapter 1:** A principled approach for developing digital competency.
**Chapter 2:** A model for teaching digital competency.
**Chapter 3:** A model for measuring problem solving skills in science, technology, engineering, and mathematics (STEM).
**Chapter 4:** A model for teaching Internet research skills.
**Chapter 5:** Another model for teaching Internet research skills.
**Chapter 6:** A matrix for evaluating technology integration in K-12 instructional settings, and teacher-related professional development.
**Chapter 7:** An online team-based learning model in nursing education.

## SECTION 2: TECHNOLOGY TOOLS FOR LEARNING AND ASSESSING REAL-WORLD SKILLS

Chapters 8 through 21 deal with the core topic of technology tools and a wide range of applications aimed at learning and assessing of real-world skills. The technology tools described in these chapters include the following.

**Chapter 8:** Technology-rich simulations for learning and assessing science skills.
**Chapter 9:** The Collegiate Learning Assessment, a test to evaluate the critical thinking and written communication skills of college students.
**Chapter 10:** Guidance, based on lessons learned from developing rich-media simulations, for assessment for organization staff promotion and development.
**Chapter 11:** A personalized learning platform for developing early reading.
**Chapter 12:** Computer agent technology for assessing collaborative problem solving skills.
**Chapter 13:** A model for assessing cognitive and social skills through online collaboration.
**Chapter 14:** An approach for technology-rich learning and formative assessment of collaborative problem solving skills.
**Chapter 15:** A framework for principled thinking about a construct map assessment of a higher-order thinking skills.
**Chapter 16:** Computer-based and computer-assisted approaches for assessment of knowledge and skills.
**Chapter 17:** Technology tools for learning for students with moderate and severe development and intellectual disabilities.
**Chapter 18:** Strategies for mitigating bias for a computer-administered performance-based assessment of higher-order skills.
**Chapter 19:** An evidence-centered concept map for a critical thinking assessment.
**Chapter 20:** Facebook as a social network for learning.
**Chapter 21:** A framework for teachers' professional development in the digital age.

## SECTION 3: AUTOMATED ITEM GENERATION AND AUTOMATED SCORING TECHNIQUES FOR ASSESSMENT AND FEEDBACK

The five chapters in Section 3 address a range of technologies for automated scoring, automated item generation, and learner feedback. The technology tools described in these chapters include the following.

**Chapter 22:** Procedures for automated generation of science items.
**Chapter 23:** Automated scoring approaches for development of writing proficiency.
**Chapter 24:** A principled framework for designing automated scoring of multicomponent assessment tasks.
**Chapter 25:** Automated scoring as the basis for feedback to support improvement of writing skills.
**Chapter 26:** Automated feedback to improve writing quality.

## SECTION 4: ANALYSES OF PROCESS DATA IN TECHNOLOGY-RICH PERFORMANCE TASKS

Chapters 27 through 31 deal with analysis, interpretation, and use of learning and assessment data in technology environments. The technology tools described in these chapters include the following.

**Chapter 27:** Analysis of solution paths in a technology-rich problem solving assessment.
**Chapter 28:** Analysis of solution paths in technology-rich critical thinking assessment.
**Chapter 29:** Use of a chi-square features selection algorithm (i.e., sequential pattern mining) and N-grams representation model to analyze process data in technology-rich problem solving tasks.
**Chapter 30:** Analytic methods to induce a persistence measure from game play click stream data and a design pattern to guide future development of persistence measures in digital environments.
**Chapter 31:** An Item Engagement Index (IEI) and Student Engagement Index (SEI) for assessing engagement during the online assessment of real-world skills.

Our goal in collecting and organizing these excellent chapters is to begin a process of crystalizing what our field has accomplished to date and what it knows, collectively, about technology tools and how those tools can be used to support and enhance teaching and learning of real-world skills. Knowing what we know should help us identify what we need to know. And it should guide further development of practical applications and empirical research on the efficacy of using technology tools for teaching, learning, assessing, and providing feedback as learners work to develop the skills they need for today's high-tech, higher-order knowledge and skills world. We hope this *Handbook* will serve as a tool to encourage collaborations among researchers, educators, policy makers, employers, and the general public to promote learning, assessment, and personalized feedback technologies. By compiling the rich research and knowledge in this *Handbook*, we hope to spark innovation in education.

The *Handbook* is a recommended reading source to the following audiences:

*Educators*: This book will share essential insights for policy makers, principals, curriculum experts, and teachers who are interested in better understanding the practical challenges and opportunities in introducing new technology-rich programs aimed to promote learning, assessment, and feedback on real-world skills.

*Researcher*s: This book will provide a valuable springboard to researchers in psychology, education, assessment, and computer science to engage with the concept of technology-rich assessment and learning of higher-order thinking skills and work on new research directions. This will be aided by the emphasis of key gaps in existing research and providing details on what areas need more careful research and empirical validation.

*General audiences* with interest in upcoming trends in learning, assessment, and feedback: This book will cover a range of topics related to real-world skills and value of real-world skills in next-generation education.

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**Roger Benjamin** has been President of CAE (Council for Aid to Education) since 2005. He was a research scientist at RAND from 1990 to 2005 (director of RAND Education, 1994-1999). Previous to his appointment to RAND, he was professor of political science at the University of Minnesota, 1966 to 1983 and associate dean and executive officer, College of Liberal Arts, University of Minnesota, 1980 to 1983, vice chancellor for academic affairs and provost at the University of Pittsburgh, 1983 to 1986, and vice president for academic affairs and provost, University of Minnesota, 1986 to 1988, and professor of political science, 1988 to 1990. He is the author or co-author of numerous books, monographs and articles in political economy and public policy, including governance, strategic planning, and educational assessment. His latest book is The New Limits of Education Policy: Avoiding A Tragedy of the Commons. London: Edward Elgar, 2012. He directs CAE, an educational assessment testing organization, implementing performance assessments and related 21st century assessments throughout the K-16 education system in the United States and beyond.

**John Bielinski** has worked in educational assessment as a developer and researcher since 1995. He earned a PhD in quantitative methods through the Educational Psychology department at the University of Minnesota. His research includes gender differences in math achievement, test accommodation validation, DIF, and growth modeling. Since joining Pearson in 2002, John has directed the development of several clinical and educational assessment including the KeyMath-3 Diagnostic Assessment and the Bruininks-Oseretsky Test of Motor Proficiency, 2nd Edition, and aimsweb. He is currently leading development on next generation curriculum-based measurement and formative assessment. In addition to his research and development work, John volunteers as a middle school math coach.

**Keith A. Boughton** is a Senior Research Scientist at CTB/McGraw-Hill Education. His areas of specialization include automatic item generation, adaptive testing, mixture/latent class models, hierarchical IRT models, and multidimensional IRT models.

**Daniel G. Brenner**, a Senior Research Associate at WestEd's Science, Technology, Engineering, and Mathematics (STEM) program, is Co-Principal Investigator on multiple projects developing simulation-based assessments in various science content areas: the NSF-funded Human Body System and SimScientists Assessment System: Physical Science Links projects as well as the IES-Funded SimScientists Assessment System: Life Sciences and SimScientists Model Progressions (Genetics and Evolution) providing scientific content expertise, managing the assessment programming, and overseeing the SimScientists learning management system that serves over 10,000 students annually. Dr. Brenner is also Principal Investigator on the Institute of Education Sciences-funded Voyage to Galapagos project to develop a differentiated assistance model that is based on knowledge about what kinds of assistance are most effective for students of differing abilities as they work in an inquiry-driven learning environment for evolution science content. Brenner's research interests focus on online education and assessment, and on the application of new technologies to these areas, and on application of the arts to STEM research. He has done extensive research and project management in academic and industrial research in the areas of bioorganic chemistry and biopharmaceuticals. Prior to joining WestEd, Brenner worked as an instructional designer heading the production of over 500 in-depth online media rich courses for the Academy of Art University. Dr. Brenner received an AB in Chemistry and Visual & Environmental Studies from Harvard College, and a PhD in Chemistry from Harvard University.

**Diane Browder** is the Lake and Edward P. Snyder Distinguished Professor of Special Education at the University of North Carolina at Charlotte. Dr. Browder has over two decades of research and writing on assessment and instruction for students with severe developmental disabilities. Dr. Browder's research has been recognized through multiple awards. She received the 2009 Distinguished Researcher Award in Special Education from the American Education Research Association and was the 2009 First Citizens Bank Scholar at the University of North Carolina at Charlotte. In 2011 Dr. Browder was recognized by the state of North Carolina with the O. Max Gardner Award for research that has made a contribution to humanity.

**Barbara Buckley**, a Senior Research Associate at WestEd's Science, Technology, Engineering, & Mathematics (STEM) program is Principle Investigator of the SimScientists Human Body Systems (HBS) project funded by NSF (DR K12), and co-PI of two current SimScientists projects in the life sciences funded by IES. As a proponent of model-based learning, Dr. Buckley guides the evidence-centered

design process used by the SimScientists team to create simulation-based instructional and assessment suites that incorporate model-based learning, complex systems thinking, and Next Generation Science Standards. Prior to joining WestEd, Dr. Buckley was a researcher at the Concord Consortium, playing a central role in the Modeling Across the Curriculum Project (IERI #0115699). At TERC, she contributed to the GLOBE and Global Lab projects.

**Michael B. Bunch** is Senior Vice-President of Measurement Incorporated, a test development and scoring company serving the large-scale assessment and professional licensure/certification fields. He oversees a research and development unit of over 80 assessment professionals and serves as a company director. Dr. Bunch earned a doctorate in psychology with a specialty in measurement and human differences from the University of Georgia in 1976. Prior to joining MI in 1982, he served as research psychologist at the American College Testing Program (ACT) and senior professional at NTS Research Corporation. Since joining MI, he has been active not only in the profession but in the Durham community as well, serving on and chairing boards of local education and human service organizations. He is past chairman of the Graduate Education Advancement Board of the University of Georgia.

**Dolores Cannella** earned her PhD in Social and Health Psychology. She is the Director of Behavioral Sciences and the Acting Chair in the Department of General Dentistry at Stony Brook University, School of Dental Medicine. Her teaching and research interests focus on the development of patient-centered interprofessional healthcare teams to improve health outcomes.

**E. Lee Childress** has been superintendent of the Corinth School District for 13 years. A native of Clarksdale, Mississippi, Childress is a graduate of Delta State University. He served as a social studies teacher in the Clarksdale Public Schools before becoming Program Manager for the School Executive Management Institute for the Mississippi Department of Education, which provided training for over 2,000 Mississippi school administrators. Childress was also Director of School Improvement for the DeSoto County School District before serving for nine years as Assistant Superintendent for the Corinth School District. Dr. Childress has been active in several educational organizations and is currently serving as a Trustee for Mississippi Public Employees Retirement System representing public school and community college educators; serves as Chairman of the Mississippi Commission on School Accreditation, President, of the Program for Research and Evaluation in Public Schools; and serves on the Advisory Board for the Mississippi School for Math and Science.

**Rafi Davidson** received his PH.D in Biochemistry from the Weizmann Institute in Rechovot, Israel. He is a senior lecturer in the department of science & technology in Kaye College of education, where, for 20 years, he teaches courses for B.Ed. and M.ED. in the subjects of "ICT in education", "information literacy and critical thinking" and "teaching and learning in an information age". In 1999 he founded the Center for Educational Technology Initiatives which supports, advises and provides pedagogical-technological assistance to lecturers and student at Kaye College. For the last 4 years he is responsible for the development and implementation of programs for professional development of lecturers and pedagogical supervisors in the colleges for education in Israel. These programs are part of the national program for the adaptation of the Israeli education system to the 21st century. His areas of research and development include integration of ICT in teaching and learning, social and emotional aspects of online learning and the factors that influence the digital divide.

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**David P. Erlanger** is an educator and research director. His interests include how to apply educational theory to ensure students learn best in both traditional and non-traditional settings. He has a focus on identifying methods needed to make distance learning effective, especially for research students.

**Peter Foltz** is a Vice President for research and development and works to bring innovative technologies to learning and assessment. He is one of the original developers of automated scoring technologies and holds a patent on methods for scoring of writing. Dr. Foltz's research has focused on language comprehension, 21st Century skills learning and assessment, and uses of machine learning and natural language processing in educational technology. The methods he has pioneered improve student achievement, expand student access, and make learning materials more affordable. He has led the framework development for a new assessment of collaborative problem solving for the Organisation of Economic Cooperation and Development's Programme for International Student Assessment (PISA) test. A former professor of psychology at New Mexico State University, he has authored more than 100 journal articles, book chapters, conference papers, and other publications. He previously worked at Bell Communications Research and the Learning Research and Development Center at the University of Pittsburgh. Dr. Foltz holds doctorate and master's degrees in Cognitive Psychology from the University of Colorado, Boulder, and a bachelor's degree from Lehigh University.

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**Mark Gierl** is Professor of Educational Psychology and the Director of the Centre for Research in Applied Measurement and Evaluation (CRAME) at the University of Alberta. His specialization is educational and psychological testing, with an emphasis on the application of cognitive principles to assessment practices. Professor Gierl's current research is focused on automatic item generation and automated essay scoring. His research is funded by the Medical Council of Canada, Elsevier, ACT Inc., and the Social Sciences and Humanities Research Council of Canada. Dr. Gierl holds the Tier I Canada Research Chair in Educational Measurement.

**Amnon Glassner** was trained as a math teacher and then completed his M.A. and PhD in the center of cognition, instruction and computers at the Hebrew University in Jerusalem. He participated in some researches about learning and argumentation in the frame of Kishurim Group in the leadership of Prof. Baruch Schwarz. His current educational interest is to lead some new progressive programs of teacher training, such as those who use PBL (project or product based learning) as main direction for learning and instruction. He serves as the head of Education Department, the head of Informal Studies and a pedagogical guide in Kaye Academic College of Education in Beer-Sheva. His current researches directions include infusion of creative and critical thinking during learning of any content, learning with PBL, learning by successes, and moderation of dialogical learning discussion.

**Heather Greenhalgh-Spencer** is an Assistant Professor of Curriculum and Instruction at Texas Tech University. Her research focuses on diversity and equity issues in online education. This research has implications for the ways we teach in online spaces, and implications for creating greater access and engagement in education for underrepresented students.

**Sean T. Hanlon** creates student- and teacher-centered educational technology applications that blend assessment and instruction. He received his undergraduate degree in computer science from The George Washington University (GW), his master's degree in computer science and his Ph.D. in educational psychology from the University of North Carolina at Chapel Hill. During his senior year at GW, Sean received the Gary Bard Entrepreneur award for Blaise, an online essay-writing system with gesture-based scoring. This application was deployed in the GW Writing Center and used in the compulsory freshmen composition course. Since joining MetaMetrics, Sean has led the design, development, deployment, and enhancement of multiple educational technologies including MyWritingWeb, MyReadingWeb, MyMathWeb, Learning Oasis, EdSphere, Module Creator, and Guided Literacy. Sean supplements his technological expertise with the instructional and assessment principles necessary to create research-based technologies that impact the everyday lives of students and teachers.

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**J. Christine Harmes** is a consultant in the areas of assessment, measurement, and technology integration. She holds a Ph.D. with dual concentrations in Educational Measurement and Research and Instructional Technology. Dr. Harmes' research in computer-based testing has most recently focused on the design, cognitive processing, memorability, and usability of innovative items. Her recent projects regarding technology integration in K-12 settings have included developing tools for teacher professional development with and use of technology, and developing technology-related assessments, observation tools, and surveys. She has taught courses in mixed methods research, scholarly communication, performance assessment, computer-based testing, measurement for teachers, and instructional design.

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**Cheryl Johnson** has worked in professional, clinical, and education assessment development since 1998. She has written content and managed teams to successfully execute multi-year assessment research projects that include the Kaufman Assessment Battery for Children, 2nd Edition, the Kaufman Test of Educational Achievement, 2nd and 3rd Editions, Sensory Profile, 2nd Edition, and aimsweb. She currently leads research on early literacy, and effective progress monitoring toward achievement goals for school-aged children, as Research Director at Pearson. In addition to her research work, she is an advocate for Montessori education, approaches to help maximize cognitive and physical performance in adults, and new technology and experiences that foster a person's natural curiosity.

**Carolyn Knox** has a Ph.D. in Digital Learning with an emphasis on students with special needs and English Learners. She is Assistant Director of CATE at the University of Oregon. Dr. Knox is PI of the Stepping up to SOAR: Strategies for Online Academic Reading project, developing both the project's strategies and its video-based instructional website. She was a seminal part of the development of CATE's original "computer-based study strategies" for using technology to enhance the academic success of struggling learners. She is a nationally recognized expert on the use of digital note-taking systems in the

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**Zach Kornhauser** is an Associate Measurement Scientist at the Council for Aid to Education. Prior to joining CAE Zach worked as a Senior Research Assistant for the Community College Research Center. His research interests include examining quality of educational programming in colleges and universities, understanding factors that affect student motivation on low-stakes assessments, studying students' use of technology in college classrooms, and investigating factors that explain student performance in college over and above student ability. Zach received a Master's in Applied Developmental Psychology from Fordham University in 2011, and is currently finishing his doctorate at Fordham.

**Patrick Kyllonen** is Senior Research Director of the Center for Academic and Workforce Readiness and Success at Educational Testing Service (ETS) in Princeton, N.J. Center scientists conduct innovative research on (a) higher education assessment, (b) workforce readiness; (c) international large scale assessment (e.g., Program for International Student Assessment; PISA); and (d) 21st century skills assessment, such as creativity, collaborative problem solving, and situational interviews. Dr. Kyllonen received his B.A. from St. John's University and Ph.D. from Stanford University and is author of Generating Items for Cognitive Tests (with S. Irvine, 2001); Learning and Individual Differences (with P. L. Ackerman & R.D. Roberts, 1999); Extending Intelligence: Enhancement and New Constructs (with R. Roberts and L. Stankov, 2008), and Innovative Assessment of Collaboration (with A. von Davier and M. Zhu, forthcoming). He is a fellow of the American Psychological Association and the American Educational Research Association, recipient of The Technical Cooperation Program Achievement Award for the "design, development, and evaluation of the Trait-Self Description (TSD) Personality Inventory," and was a coauthor of the National Academy of Sciences 2012 report, Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century.

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**Edys Quellmalz** is Director of Technology-Enhanced Assessment and Learning Systems in WestEd's Math, Science and Technology program. She leads SimScientists projects funded by NSF and the U.S. Department of Education related to simulation-based science curricula and assessments for formative and summative uses that can serve as components of balanced state science assessment systems. Projects include Calipers II: Using Simulations to Assess Complex Science Learning (NSF); Foundations of 21st Century Science Assessment (NSF); Model Progressions (IES); SimScientists Assessments: Physical Science Links (NSF); SimScientists Crosscutting Concepts: Progressions in Earth Systems (NSF); SimScientists Assessment System (IES); SimScientists: Interactive Simulation-based Learning Environments (IES); Mutilevel Assessments of Science Standards (IES); Transformative Assessments for Science (Carnegie Corporation); and Integrating Science Simulations into Balanced State Science Assessment System (OESE). She co-directed the development of the framework and specifications for the 2014 Technological Literacy (TEL) National Assessment of Educational Progress and served on the Steering Committee for the 2011 NAEP Writing Framework. She has consulted for numerous state, national, international assessment programs. She was Associate Director of the Center for Technology and Learning at SRI International and the Director of Assessment Research and Design. She served on the faculty at the Stanford School of Education and as research faculty in the UCLA Graduate School of Education.

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**Jenny Root**, M.Ed. is the Snyder Fellow at UNC Charlotte where she is a doctoral student in Special Education. She is a graduate research assistant for The Solutions Project, an IES grant, developing a mathematics problem-solving curriculum for students with severe disabilities. Jenny has over seven years of experience working with children and adolescents with disabilities in school settings. Jenny's research focuses on giving students with autism and intellectual disability access to the general cur-

riculum through technology, systematic instruction, and positive behavior supports. Future directions for her research include systematic instruction to increase independence within academic tasks for students with developmental disabilities and using technology to overcome barriers to critical thinking and problem solving skills.

**Abraham Rotem**, Ph.D in Physics and Electrical Engineering, KSU USA and Ben-Gurion University, Israel (1983); Founder SENTOP Ltd (1990); Establishing Teachers Development center with Branco Weiss Institute, Israel (1994). Establishment of the first social educational network in Israel, to schools and student (1998). Wrote the Book "School turns on line" with Dr Y. Peled (2008). Lecturer in professional development courses for school administrators and teachers. Establishing with Dr E. Avni "Toward Digital Ethics Initiative", Israel, contains original articles related to technology, pedagogical and ethical aspects in learning and teaching; Academic advisor ICT program in Israel (Ministry of Education) for the last decade.

**Jean-François Rouet** is a Senior research scientist with the French Centre National de la Recherche Scientifique (National Center for Scientific Research). He was trained as a developmental and language psychologist and he has published extensively on the cognitive underpinnings of reading literacy and skilled uses of information technology (e.g., "Reading: From words to multiple documents", coedited with Britt and Goldman, Routledge, 2013). Jean-François Rouet has been involved since 2006 as an expert in the OECD's PISA and PIAAC surveys of teenage and adult literacy, respectively. He has served as the director of the Center for Research on Cognition and Learning at the University of Poitiers, France, from 2004 to 2011. After his PhD (1991), Jean-François Rouet spent several years as a post-doctoral fellow at the Learning Research and Development Center (University of Pittsburgh, USA). He has developed numerous collaborations with scholars from various countries including Argentina, Germany, Japan, Norway, Spain and the USA. He is on the board of several major academic journals and a former associate editor of Learning and Instruction.

**Gavriel Salomon** (PhD at Stanford, 1968) is professor of educational psychology at the Haifa University in Israel where he served as dean of the Faculty of Education. As editor of Educational Psychologist, he has published four books and about a 150 research, theory, and methodology journal articles. He is the recipient of the Israel Award for scientific achievements and holds an honorary doctorate from the Leuven University in Belgium. His fields are the use and abuse of computers in education and research on peace education in regions of conflict.

**Alicia Saunders**, Ph.D., is the Project Coordinator and Research Associate for the Solutions Project, an IES grant, developing a mathematical word problem solving curriculum for students with severe disabilities at the University of North Carolina at Charlotte. She has conducted research in the areas of general curriculum access, specifically in science, mathematics, and English language arts, as well as in technology, including video modeling and computer-assisted instruction. Additionally, she has published multiple peer reviewed journal articles and book chapters, developed and conducted professional development webinars on aligning instruction to alternate achievement standards and the Common Core State Standards, and is a co-author of Early Numeracy, a mathematics curriculum for students with severe disabilities. Dr. Saunders received her bachelor's degree in psychology from the University

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**Matt Silberglitt**, a Senior Research Associate at WestEd's Science, Technology, Engineering, & Mathematics (STEM) program is Co-Principal Investigator of the SimScientists Assessments: Physical Science Links and SimScientists Crosscutting Concepts: Progressions in Earth Science projects funded by NSF and the SimScientists Assessment Systems project funded by IES. As a former science teacher and experienced assessment developer, Mr. Silberglitt provides content expertise in physical science and expertise in standards for educational assessments. Prior to his current position, Mr. Silberglitt managed development of science assessments for WestEd in several states. Prior to joining WestEd, Mr. Silberglitt oversaw development of science assessments at the Minnesota Department of Education and developed assessments at Data Recognition Corporation. Mr. Silberglitt started his career as a high school science teacher.

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**Carl W. Swartz** conducts research on models and technologies for blending learning and assessment and use of technology as a component of educational programs to enhance personalized learning for students with learning, attention, and language differences. He is currently a Research Professor in the Department of Applied Developmental and Special Education in the School of Education at the University of North Carolina-Chapel Hill where he was a Research Scientist in the School of Medicine and Clinical Assistant Professor in the School of Education at The University of North Carolina at Chapel Hill. Currently, He received his undergraduate degree in education from Indiana University and his master's

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**Noel Tagoe** is the Executive Director of Education at CIMA, where he was previously Head of Research and Development. Prior to joining CIMA Noel had held accounting, strategy and financial consulting positions with BP and KMPG in Ghana. He has also taught at various universities in the UK including Manchester University and Oxford University. Noel's current interests are in designing professional accounting curricula that address business needs and ensuring that they are assessed rigorously and robustly using technology where possible.

**Fatima E. Terrazas-Arellanes** is PI of Project ESCOLAR, an OSEP-funded project to create online modules for teaching science to middle school students with learning disabilities. Dr. Terrazas-Arellanes was a teacher from Mexico, coordinating research projects in areas of Spanish literacy instruction, second language acquisition, and eText supports. Dr. Terrazas-Arellanes' areas of expertise include designing and conducting research to learn how technology addresses the educational needs of children and youths, particularly students with learning disabilities and English Language Learners. Dr. Terrazas-Arellanes received her Bachelor of Arts in Psychology from the Universidad Autonoma de Sinaloa in 2000, a Master's of Science in Special Education from the University of Oregon in 2008, as well as a Doctor of Philosophy from the University of Oregon's School of Psychology in 2009.

**Suzanne Tsacoumis** has built her professional career conducting and managing projects associated with the research, development, and implementation of personnel assessments and human capital systems, often in litigious environments. Her expertise revolves around job analysis, selection, promotion, leadership assessment, and performance evaluation. Currently, she is spearheading innovative work in the development of valid, online simulations, such as virtual role plays and interactive in-baskets, for use in both promotion systems and self-assessment processes. She often consults on a range of policy and implementation issues. In addition to her technical work, Suzanne is a corporate officer and HumRRO's vice president of business development. In this role, she is responsible for providing leadership and direction to the business development and marketing team. Suzanne has been an active volunteer for the Society of Industrial-Organizational Psychology (SIOP) and she is a fellow of SIOP and the American Psychological Association (APA). Suzanne has served as an adjunct professor at both The George Washington University and George Mason University. She earned her Ph.D. from the University of Georgia, specializing in Industrial-Organizational Psychology and her B.A. from Bucknell University.

**David Vaughn** is a software engineer with over ten years of experience in the field of artificial intelligence (AI) and machine learning. As a Senior Software Developer he designs, develops, and enhances automated scoring technologies. Mr. Vaughn was the primary architect of MI's winning submissions to the Automated Student Assessment Prize (ASAP) contest, an automated scoring competition sponsored by the Hewlett Foundation. He subsequently enhanced the AI scoring system used in the ASAP competition to improve its accuracy, speed, efficiency, and scalability for use on the Smarter Balanced Pilot Test automated scoring project. Previously, Mr. Vaughn developed and implemented machine learning algorithms in a variety of contexts including email classification, genome research, and human/computer voice dialogue systems. He received his B.S. in Computer Science from Harvard University.

**Lars Vavik** is a professor in interactive educational technology at Stord/Haugesund University College. He has been working with design of digital media since 1980 and has been given European Academic Software Award for developing of modeling and simulation tools. His work the last 15 years has been dedicated to developing a master program in ICT and learning and the leadership of several research program as "Education on Curriculum and Technology" (2008-2012) and "Learning in the 21st century" (2012-2016) supported by The Research Council of Norway.

**Alina von Davier** is a Senior Research Director and leader of the Center for Advanced Psychometrics at ETS. She also is an Adjunct Professor at Fordham University. At ETS, von Davier is responsible for developing a team of experts and a psychometric research agenda in support of next generation of assessments. Computational psychometrics, which include machine learning and data mining techniques, Bayesian inference methods, stochastic processes and psychometric models are the main set of tools employed in her current work. She also works with psychometric models applied to educational testing: test score equating methods, item response theory models, adaptive testing. She published several books, authored or edited; she also published numerous papers in peer reviewed journals.

**Matthias von Davier** is a Senior Research Director in ETS's Research & Development Division, managing the international large-scale assessment methodology group in the ETS center for global assessment. At ETS, Dr. von Davier manages a group of researchers concerned with methodological questions arising in large-scale international comparative studies in education. He is currently editor-in-chief of the British Journal of Mathematical and Statistical Psychology and co-editor of the journal "Large Scale Assessments in Education", which is jointly published with the International Association for the Evaluation of Educational Achievement (IEA) and ETS through the IEA -ETS Research Institute (IERI). His current work at ETS involves the psychometric methodologies used in analyzing cognitive skills data and background data from large-scale educational surveys, such as the Organization for Economic Co-operation and Development's upcoming PIAAC and the ongoing PISA, as well as IEA's TIMSS and PIRLS. His work at ETS also involves the development of software for multidimensional models for item response data, and the improvement of models and estimation methods for the analysis of data from large scale educational survey assessments. Prior to joining ETS, Dr. von Davier led a research group on computer assisted science learning, was co-director of the "Computer as a tool for learning" section at the Institute for Science Education (IPN) in Kiel, Germany, and was an associate member of the Psychometrics & Methodology Department of IPN.

**Zsofia Voros** is currently research associate in the Center for Research on Cognition and Learning, CNRS and University of Poitiers, France. Her research investigates cognitive dimensions that may underlie electronic reading, learning and problem solving. Previously, she worked as a research consultant for the Educational Testing Service. She explored Programme for the International Assessment of Adult Competencies (PIAAC) processing data to identify cognitive/metacognitive skills and solution strategies linked to success in various electronic problem solving tasks. She earned her Ph.D in psychology from the University of Poitiers, France (2009).

**Emily Walden**, M.A., is a Research Assistant at the Center for Advanced Technology in Education at the University of Oregon in Eugene, Oregon. She completed a bachelor's degree in English and psychology at the University of Oregon in 2010 and a master's degree in developmental psychology at the

University of Oregon in 2011. Her research with federally funded projects (ESTRELLAS, COPELLS, SSOAR, and ESCOLAR) primarily involves improving education outcomes, especially in science, for middle school students with learning disabilities and English learners through the use of technology.

**Nancy T. Walker** is currently a Professor of Education at the University of Laverne. For the past fifteen years, she has overseen the teacher education literacy faculty and worked with adjunct faculty in online learning. Her research has focused on content area literacy, disciplinary literacy, visual literacy, and online learning in higher education. Previously, she taught Language Arts at the middle school level for eight years and mentored new teachers in effective literacy instruction. Dr. Walker is a published author on the use of multiple texts in the classroom and is a frequent speaker at national and international conferences.

**James Welsh** is the Director of the Florida Center for Instructional Technology and holds a Ph.D. in Literacy Studies from the University of South Florida College of Education. A former elementary school teacher, James is the program coordinator for technology integration support in the USF College of Education and the project leader for the Technology Integration Matrix K-12 evaluation tools. James conducts research with the Contemporary Literacies Collaborative at USF. His research interests include evaluation of educational technology, critical media literacy, student creation of multimedia texts, and the role of genre in student composition.

**Joshua Wilson** is an Assistant Professor in the School of Education at the University of Delaware. He earned his Ph.D. in Special Education from the University of Connecticut in 2014. His research focuses on methods of assessing and instructing struggling writers, and on the application of automated essay evaluation (AEE) technology in Response to Intervention (RtI) contexts. He currently teaches courses on elementary special education methods. Prior to earning his Ph.D., Dr. Wilson was a special education teacher for six years.

**Roy Winkelman** has spent two decades in K-12 education and two decades in higher education. Formerly director of the Florida Center for Instructional Technology, he now works on special projects for the Center and creates digital resources for K-12 students and teachers.

**Steven Wise** is a Senior Research Fellow at Northwest Evaluation Association. Dr. Wise has published extensively during the past three decades in applied measurement, with particular emphases in computer-based testing and the psychology of test taking. In addition, he sits on the editorial board of several academic journals and provides psychometric consultation to a variety of organizations. In recent years, Dr. Wise's research has focused primarily on methods for effectively dealing with the measurement problems posed by low examinee effort on achievement tests.

**Raffaela Wolf** completed her PhD in Research Methodology from the University of Pittsburgh in December 2013. Dr. Raffaela Wolf joined CAE in January 2014 as a Measurement Scientist. In this role, Dr. Raffaela Wolf is involved in research projects that pertain to validity and reliability studies of the Collegiate Learning Assessment-Plus. Other responsibilities include running psychometric analyses for national and international clients. Research interests include equating, scaling, and linking; item response theory; structural equation modeling; and, cross-national assessments in higher education.

**Doris Zahner** joined CAE in March 2011 as the Director of Test Development and a Measurement Scientist. Her responsibilities include overseeing all item development for CAE as well as conducting research studies pertaining to the CLA+ and other CAE assessment instruments. Prior to her position with the CAE, she was a Program Director with a professional licensure and certification firm and managed a variety of clients, including a medical certification board, an information systems auditing certification program, various nursing specialties, and plastics engineers. She has experience managing large-scale item development projects and is knowledgeable about all aspects of assessment development including task analyses, test specifications, item writing, exam construction, score reporting and equating, and standard setting. She holds a Ph.D. in Cognitive Psychology and a M.S. in Applied Statistics from Teachers College, Columbia University. Her post-doctoral work at the Stevens Institute of Technology was on the use of diagrams in information systems design and her own research interests pertain to the use of diagrams in probability and mathematics problem solving. In addition to her responsibilities at CAE, Dr. Zahner is an adjunct assistant professor at Barnard College where she teaches a course on statistics to undergraduate students in the social sciences.

**Diego Zapata-Rivera**, PhD, is a senior research scientist in the Cognitive Science Research Group at Educational Testing Service. His research focuses on innovations in score reporting and technology-enhanced assessment, including work on assessment-based learning environments and game-based assessments. His research interests also include Evidence-Centered Design, Bayesian student modeling, open student models, conversation-based assessments, virtual communities, authoring tools and program evaluation. He has been a committee member and organizer of international conferences and workshops in his research areas. He is a member of the Board of Special Reviewers of the User Modeling and User-Adapted Interaction journal and an Associate Editor of the IEEE Transactions on Learning Technologies Journal. Most recently, Dr. Zapata-Rivera has been invited to contribute his expertise to projects sponsored by the National Research Council, the National Science Foundation and NASA.