J. Michael Spector · M. David Merrill
Jan Elen · M.J. Bishop *Editors*

Handbook of Research on Educational Communications and Technology

Fourth Edition

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A well-known issue of Educational Technology Research & Development in 1994 addressed the question of whether and to what extent media influence learning. Two opposing perspectives were presented in that issue by Richard Clark and Robert Kozma, both of whom have also contributed to this Handbook. One way to think about this Handbook, along with the three previous editions, is to recall that media debate and think about how research and practice have since evolved. We dedicate this Handbook to all the scholars who have contributed so much to explorations and investigations of how technology has and continues to influence the practice of learning and instruction. Many of those who have contributed so much to our understanding of educational technology have since passed away, including such luminaries as Robert Gagné, Robert Glaser, and William Winn among a list much too long to include here. We are deeply indebted to the contributions that so many have made to what we know and have yet to learn about how best to support and facilitate learning.

Foreword

Information and Communication Technologies in Education

In *Learning with Personal Computers* Alfred Bork (1987) promised a revolution in schooling due to the increasing availability of microcomputers. Twenty-five years later, on average, almost every person in economically developed countries is now blessed with one or more computers. However, the revolution that Bork imagined does not yet show definite signs of materializing soon. Upon reflection, we can say that most of us were, in the 1980s, perhaps a bit too optimistic about what information and communications technologies (ICT) could do to promote and improve education. Many are now trying to discern what added value ICT can contribute to the education enterprise, in addition to increasing the convenience of instruction and to motivating students to engage with activities that all too often are trivial. Skeptics have expressed doubts about the utility of technology in the classroom; some argue in favor of maintaining the traditional model of instruction that is exclusively reliant on teachers, print-based textbooks, and blackboards (perhaps a dry-erase whiteboard for the more progressive Luddites).

Increasing numbers of educators and scholars recognize that no technology can automatically benefit education in any significant way. Many realize that it is not about the technology after all—it is about what is done with technology to promote students' learning. When a new technology emerges, what really counts is the educational potential or learning opportunities provided to students, which are often obscured by the novelty of an innovative device. Scholars and teachers have the responsibility to discover and then to reveal those learning opportunities along with the associated potential to transform educational practice.

There is a growing and significant body of research that explores in detail and in depth the impact of new technologies on students' learning. Much of this new research is covered in this *Handbook*, which reviews research about the ways in which technology can significantly impact learning and create profound interactions between and among learners, teachers, and resources. This work is only a small part of a larger picture of ICT in the twenty-first century. The work reviewed in this *Handbook* provides one small glimpse of the revolution that is unfolding (albeit much later than Bork imagined).

There are many kinds of technologies used in present-day schools, some of which were developed specifically for the school context. Examples of commonly used educational technologies include classroom response systems, search engines, word processors, projectors, and interactive whiteboards. All of these and other technologies serve a wide variety of other non-school-based purposes. Most of these technologies were not invented for learning or teaching; however, their application to non-school settings, for which many of them were developed, is different from their use in school settings. For example, consider the word processor. Word processing facilitates the productive work of business by creating the correspondence necessary to conduct affairs. Specific features of the word processor were designed to make such business use both easy and effective. However, when one places a word processor in a classroom context, the use and purpose are not the same at all. Preparing teachers to help primary and secondary school students to make effective use of a word processor is quite different from

training an administrator to help clerks and office assistants make effective use of the word processor in a particular office setting.

How shall we treat different uses of the same technology? How can we realize the educational potential of technologies taken for granted in the workplace? A definition of educational technology might emphasize the significant pedagogical or learning uses that technology serves; such a definition acknowledges the principle that uses and training for use should fit the specific purpose. This *Handbook* focuses on these educational uses and purposes.

Of the millions of teachers, educators, and scholars around the world, only a small number are engaged in research concerning the use of ICT in education. One result of this trend is a contrast between developers and educators who may ultimately use the new technologies. Developers create and laud the features of emerging devices and innovative technologies, while educators who want to teach with those technologies may become confused and frustrated with new technologies. It is rare that the two groups exchange views and experiences, and learn from each other. For many teachers, new educational technologies and facilities can cause some discomfort or even feel threatening due to their lack of adequate preparation in effective pedagogical use and integration into teaching and learning. There has been much research on the application of technology in education, as is evident in this *Handbook*. The chapter on TPACK (technological pedagogical and content knowledge) is a case in point. There is almost always initial resistance to a new technology, and the cost effectiveness of new technologies remains controversial (see Chapter 9 in this *Handbook*). Suggestions by technologists for educational application can be general and too distant from actual classroom use; thus these recommendations all too often fall short of the actual needs of teachers. As a result, too many teachers fail to embrace and use the new technologies in constructive ways with their own students.

An encouraging indication of change is this fourth edition of the *Handbook*, which includes a new section that is subject-specific and explores technologies in different disciplines. The first and last sections of the *Handbook* also offer a range of perspectives on technology integration that are aimed at practical use and widespread application.

Educational Communication Technology (ICT for Education)

Educational communication technology is a very dynamic area of research and application; new products can become out of date within a matter of months. The popular press often disseminates stories that dwell on the novelty rather than on the practicality of a new technology. Decision makers and those responsible for procurement are presented with a dilemma regarding acquisition of newer, forward-looking but riskier technologies as opposed to the reliable, older but more mature technologies. As is shown by the many chapters pertaining to emerging technologies, innovations ranging from cloud-based technologies to tablet applications are undoubtedly worthy of our attention due to their educational potential. However, the maturity of a technology and its connection and compatibility with existing technologies and expertise present significant challenges. When venturing to deploy a new technology, there are usually many unknown factors and some risk (Spector, 2012). When a new technology is profoundly different from previous technologies, or when the application of the technology dramatically changes practices, there are bound to be a multitude of unexpected problems.

In addition to the constant change of educational technologies, there is another challenge—namely differences between theory and practice, along with differences between the natural sciences and the humanities. A new educational technology that works well in support of learning physics may not work as well in support of learning philosophy, and vice versa. Moreover, the relevant learning theories and paradigms might be quite different in different areas of application. Effective technology integration requires sensitivity to the potential of various technologies as well as a profound understanding of specific disciplines and associated pedagogical practices. In too many cases, educators adopt without hesitation a new technology

only to see it fail in practical use. As a community of professional practitioners, we are slowly coming to the realization that new tools need to be tested in the real and somewhat uncontrolled and chaotic circumstances in which everyday learning and instruction occur. Educational technology researchers and developers should carefully observe, assess, and identify the adaptability and success of the new technologies in light of actual teaching and learning; furthermore, all must keep in mind the opportunities, the benefits, the constraints, and the risks. Compulsive and hasty adoption of a new technology will very likely result in another cycle of sweet expectation followed by bitter disappointment.

Another important issue is the boundary between the two academic disciplines of educational technology and computer science. They are distinct from each other; however, a typical program of educational technology often offers many courses that are also found in a computer science curriculum. A closer scrutiny, however, reveals that educational technology courses are quite different from apparently similar courses in a computer science department. A recent IEEE-sponsored report recommends a very specific, cross-disciplinary curriculum for advanced learning technologists that could, if adopted, reduce the tensions between computer science and educational technology as separate and competing disciplines (Hartley, Kinshuk, Koper, Okamoto, & Spector, 2010). As things now stand, educational technology graduates find themselves at a disadvantage in the job market in comparison with a computer science graduate who appears equally well qualified. This state of affairs affects the growth of the discipline adversely. To avoid this waste of resources and dashed expectations, the discipline of educational technology needs to enhance its own reputation as a separate and credible area of expertise, which is what Hartley and colleagues (2010) encourage. That is to say, advanced learning technology graduates need to command abilities and skills that neither computer scientists nor education degree holders possess. However, they should be able to communicate and collaborate with both computer scientists and professional educators. In short, there is a need for a careful scrutiny of the field and a re-delineation of its academic scope and theoretical systems, along the lines of the Hartley et al. (2010) report, which identified the following domains of competence for educational technologists:

1. Knowledge competence—includes those competences concerned with demonstrating knowledge and understanding of learning theories, of different types of advanced learning technologies, technology-based pedagogies, and associated research and development.
2. Process competence—focuses on skills in making effective use of tools and technologies to promote learning in the twenty-first century; a variety of tools ranging from those which support virtual learning environments to those which pertain to simulation and gaming are mentioned.
3. Application process—concerns the application of advanced learning technologies in practice and actual educational settings, including the full range of life-cycle issues from analysis and planning to implementation and evaluation.
4. Personal and social competence—emphasizes the need to support and develop social and collaboration skills while developing autonomous and independent learning skills vital to lifelong learning in the information age.
5. Innovative and creative competence—recognizes that technologies will continue to change and that there is a need to be flexible and creative in making effective use of new technologies; becoming effective change agents within the education system is an important competence domain for instructional technologists and information scientists.

Growth of the Discipline

Since its establishment, the discipline of educational technology has been through several paradigm shifts and grown remarkably. Informed by theories and concepts from many other disciplines, including education, computer science, psychology, cognitive science, and communications, educational technology has acquired academic respectability. However, some

have expressed doubts about the field, raising the issue of educational technology borrowing from other disciplines without creating a coherent and unique discipline of its own. In rebuttal, educational technologists argue that adoption and integration are not merely effortless borrowing tasks; rather, technology integration is a dynamic, innovative, and productive process—a *transdisciplinary* process, as Hideaki Koizumi (2004) put it. According to that Japanese scholar, educational neuroscience is a product of such a transdisciplinary process. The growth of the discipline of educational technology has been a product of a similar transdisciplinary process (see Richey, Klein, & Tracey, 2010). It is through this transdisciplinary process that the discipline of educational technology has made many unique contributions to both theory and practice. The work on cognitive load theory is a recent example of the transdisciplinary nature of educational technology (see, for example, van Merriënboer & Ayres, 2005).

There is a need to reconstruct the theoretical framework for educational technology, and there is an associated need to reconceptualize its academic scope and purpose. Supporting learners and the learning process with appropriate technologies is the fundamental belief of educational technology. Therefore, the design, development and application of technologies capable of such a role should be within the sphere of this discipline, where learning and technology intersect, and numerous other disciplines mingle in creative ways. In this theater of interaction and hybridization, there is both chemistry and synergy, and participants from diverse academic backgrounds and researchers of various segments of educational technology cooperate productively. However, due to their differences in training, skills, and values, these experts view technologies with different lens and may study problems from different perspectives and interest themselves in different dimensions of the same problem. How can they work together optimally?

No doubt, their cooperation needs to be based on the common ground designated by the shared ultimate goal of assisting learning. More is needed; however, mechanisms should be created and deployed to merge horizons and promote synergy among experts from different disciplines, thus removing academic biases, increasing their appreciation of each other's paradigms and interests, and locating the possible points for connection and cooperation. The fourth edition of this AECT (Association for Educational Communications and Technology) *Handbook* represents a creative realization of such an effort.

Global Differences

In addition to overcoming the aforementioned problems, we, as professional practitioners, need to do more if we want the desired educational technology revolution to unfold on a large, global scale. We have yet to scale the formidable barriers created by global differences, which are seen in both economic development as well as in social-cultural interests and habits.

First, economic inequalities have caused disparities in educational investment between countries and regions. Even within one country, especially some large and diverse ones, there can also be seen the full spectrum of differences in educational investment and accrued educational benefits. Underdeveloped countries and regions may acquire educational equipment and facilities by virtue of inter-governmental assistance, NGO (non-governmental organizations) donations and aid, and so on, addressing part of the significant physical digital divide. Nevertheless, these facilities are not usually updated and upgraded in a regular and timely manner as they would be in developed economies. More disconcerting is the gap in human resources and expertise—the non-physical digital divide. Technical expertise that is pedagogically informed is in short supply, making the Hartley et al. (2010) report even more pertinent.

Second, schools and their administration are often constrained as much as enabled by their particular social and cultural settings, which can differ radically because of racial, ethnic, or religious distinctions. Differences in local traditions, community characteristics, and special academic/educational interest can also be determining factors in enabling or inhibiting effective use of educational technology. Consequently there exists a wide range of teaching beliefs;

major disagreements about pedagogy and educational technology may even be found among teachers employed by the same school. Such discrepancies in culture and values can result in conflicting attitudes towards technology. In extreme cases, an educational technology may become an object of distrust or even ridicule. Compared with the hardware gap and infrastructure challenges, social and cultural inequalities are more subtle and difficult to manage.

In spite of those global differences, multinational organizations, especially network technology businesses and other information technology leaders are promoting their new educational technologies and relevant products. One result of this trend is that new technologies are confronted with a huge array of economic, social, cultural, and educational settings. As a result, the performance of the same educational technology can vary from one context to another; we have such failures to replicate findings in the research literature. This phenomenon is not unlike the legendary orange in an old Chinese saying: Grown south of the Huai River, it is sweet; grown north of the river, it tastes bitter and sour. If educational technology researchers and practitioners do not take into account local situations and customize technologies and educational practices accordingly, the promised revolution in schooling due to emerging educational technologies will never take place.

To sum up, there are significant challenges to the effective pedagogical use of technologies and development of new educational technologies based on the following four conclusions:

1. Technological advancement is an endless enterprise, but technological improvement does not necessarily translate into proportionate improvements in educational effect and impact on students' learning.
2. In different economic, social, and cultural environments, the same technology may perform differently.
3. The accelerated development in technology makes more acute the shortage of instructor knowledge about the effective use of technologies; good teachers who are well prepared are always in short supply.
4. Extensive and intensive involvement of teachers and pedagogically knowledgeable instructional designers is essential for progress in educational technology. There is little that educational technology can contribute to improve formal or informal student learning without this critical involvement.

We look forward to the day when a large number of elementary and secondary school teachers become readers and/or authors of the future editions of this *Handbook*; that will be a positive sign that educational technology is penetrating deep into classrooms and adding the synergy to launch the long-awaited revolution. Therefore, let us focus our efforts and work collaboratively across multiple disciplines so that this day may come sooner rather than later. Together we can make a difference.

Shanghai, China — Youqun Ren

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Preface

As has been the case with the three previous editions of the *Handbook of Research on Educational Communications and Technology*, this volume has taken about 3 years to develop. The content is new and does not duplicate anything in the previous editions of the Handbook, all of which is available online at no cost to members of the Association for Educational Communications and Technology (AECT; see http://www.aect.org). We have a new publisher, Springer, who has agreed to do the same for this fourth edition. Springer has been most helpful in the development of this volume by making a customized version of Editorial Manager available to support submissions, reviews, and editing.

As we did with the third edition, we asked for guidance from AECT members and other professionals with regard to how best to develop the content and structure of the *Handbook*. We learned that *Handbook* users are typically doctoral students and other researchers new to a particular topic or area of research. They value a short and cogent summary of research in a focused area and especially appreciate the extensive reference sections and the indication of core references (marked with a preceding asterisk and located at the end of each chapter). Those whom we contacted in the first year of this effort also indicated a desire to see more research emphasized in additional areas. In general, there was a desire for short, focused research reviews, long and extensive references, and a discussion about research that could or should be conducted in the future. We provided all of our authors with this guidance, and we believe that they have done an excellent job in providing *Handbook* users with what they want.

Together with a large number of respondents to queries about the Handbook, including one specifically targeting AECT members, we initially developed more than 120 potential chapters. We asked the professional and academic communities to provide an extended abstract and core references for chapters that they would agree to author. The coeditors then examined the various proposals and settled on just over a 100 potential chapters. As the process evolved and potential authors were asked to deliver draft chapters, the list was narrowed to about 87. For a variety of reasons, several authors withdrew or were dropped and we ended up with 75 chapters, divided into nine sections, compared with 56 chapters in six sections in the third edition.

We retained the Foundations section but of course included completely new content with more emphasis on research as had been requested by those we asked for input. In addition to two new chapters on research, there are chapters on neuroimaging and motivation as these are both regarded as foundation areas that can and should inform instructional design and educational technology research. Ethics, human performance technology, and TPACK (technological, pedagogical, and content knowledge) are also treated in the Foundations section.

Section 2 treats qualitative and quantitative tools and methods separately and includes chapters on design-based research, action research, and program evaluation not previously addressed in the Handbook. There is an extensive section on assessment and evaluation with many new topics addressed, including stealth assessment, cost-benefit analysis, and model-based assessments.

Section 4 includes a chapter specifically addressing cultural issues per the advice we received in the initial response to our queries of what to include. Many of the same emerging

trends one finds in the New Media Consortium's *Horizon Report* (http://www.nmc.org/publications) and *A Roadmap for Educational Technology* jointly published by the Computing Research Association and the Computing Community Consortium, and the National Science Foundation (available online at http://www.cra.org/ccc/docs/groe/GROE%20Roadmap%20for%20Education%20Technology%20Final%20Report.pdf) are evident in this section—see, for example, Chaps. 35, 36, and 38.

Section 5 represents an entirely new section developed in response to the feedback we received about previous Handbooks. While we were not successful in recruiting as many chapters in this section as we had planned, readers will find very informative chapters on technology in science education, medical training, mathematics, engineering, visual arts, social studies and visual arts.

While Section 7 has been included in previous editions, all the chapters in this section are new for this edition. In addition to new treatments of instructional design models and technology-based instruction, there are topics not previously addressed such as change agency, governmental policies, and curricula for training instructional designers.

The second part of the *Handbook* contains three sections that address respectively emerging technologies, technology integration, and the future of educational technology research. Section 7 is the most extensive section of the *Handbook*, and was designed specifically in response to the feedback we received early in the process. Again we used technologies cited in the NMC *Horizon Report* and in *A Roadmap for Educational Technology* to guide input for this section. Readers will find e-books, pedagogical agents, adaptive technologies, augmented realities, and research on many other new and emerging technologies treated in this section.

Because so many scholars have commented on the ability to make effective use of new and emerging technologies, we decided to specifically address the issue of Technology Integration in a separate section in this edition of the *Handbook*. We included chapters on measuring technology readiness skills and generational differences as well as issues specific to different contexts (formal learning in schools, medical education, multicultural settings, etc.).

The final section of the *Handbook* is entitled A Look Forward and is intended as a precursor for further research. This is another new section of the *Handbook* and is meant as a kind of book-end section to go with the Foundations section. Issues involving the philosophy of science, teacher education, and prospects in developing countries are addressed, among others.

As with the third edition, we made every effort to include research from around the world as this *Handbook* has become an internationally acclaimed standard in the field of educational technology research. The third edition has now been translated into Chinese by a team of university scholars in China led by Ren Youqun. Since he is one of a very few individuals who have read every chapter in the previous edition of the *Handbook*, and because he leads an impressive group of researchers at East China Normal University, we invited him to contribute the Foreword to the fourth edition. We then invited Joost Lowyck who wrote the Foreword to the third edition and who was also familiar with all of that content to write the first chapter in this edition. His chapter provides an historical overview of educational technology aimed at bridging educational theory and practice. Lowyck provides five principles relevant to that enterprise: (1) evolutions in society and education have influenced the selection and use of learning theories and technologies; (2) learning theories and technologies are situated in a somewhat vague conceptual field; (3) learning theories and technologies are connected and intertwined with information processing and knowledge acquisition; (4) educational technologies have shifted learner support from program or instructor control toward more shared and learner control, and (5) learning theories and findings represent a fuzzy mixture of principles and applications. The reader will find an insightful discussion to accompany these five

principles. In addition, the editors have taken up these principles in the epilogue and concluding chapter of the Handbook.

We hope that the efforts of the authors, reviewers, editors, and so many others in bringing this Handbook to the educational technology research community will prove useful and result in ongoing productive research. Our final word—enjoy.

2012

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Many others have contributed to this edition of the *Handbook*, including participants at AECT sessions and respondents to queries the editors presented at various venues in the last 3 years. As is the case with any major publication, it is impossible to cite all those who contributed along the way. The order of the editors does not reflect the quantity or quality of contribution; all editors shared equally in the development of the *Handbook*. We are most grateful for having had the opportunity to edit this fourth edition of the *Handbook* and appreciative of all those who helped make it possible.

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