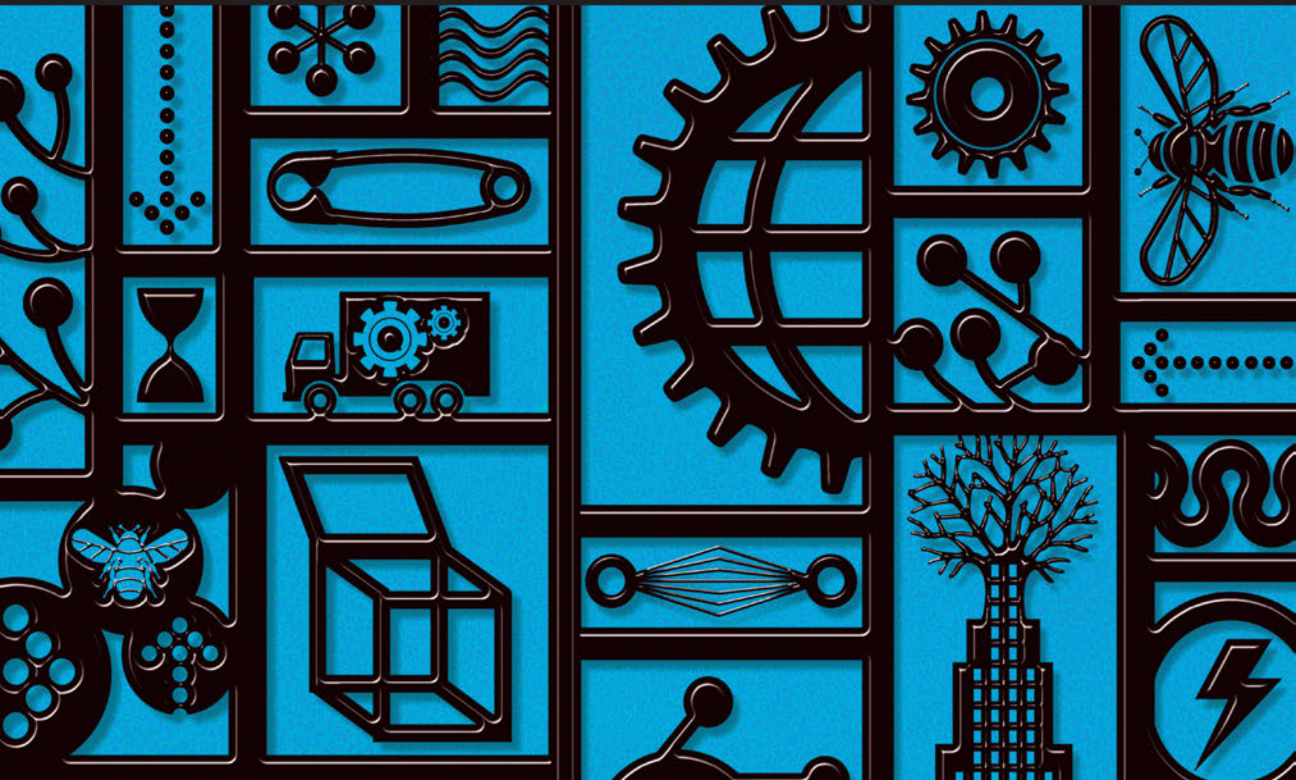
J. MICHAEL SPECTOR

SECOND EDITION

FOUNDATIONS OF EDUCATIONAL TECHNOLOGY

INTEGRATIVE APPROACHES AND INTERDISCIPLINARY PERSPECTIVES



ROUTLEDGE

Foundations of Educational Technology

An engaging book for professional educators and an ideal textbook for certificate, masters, and doctoral programs in educational technology, instructional systems, and learning design, *Foundations of Educational Technology*, *Second Edition* offers a fresh, interdisciplinary, problem-centered approach to the subject, helping students build extensive notes and an electronic portfolio as they navigate the text. The book addresses fundamental aspects of educational technology theory, research, and practice that span various users, contexts, and settings; includes a full range of engaging exercises for students that will contribute to their professional growth; and offers the following four-step pedagogical features inspired by M. D. Merrill's *First Principles of Instruction*:

- TELL: Primary presentations and pointers to major sources of information and resources;
- ASK: Activities that encourage students to critique applications and share their individual interpretations;
- SHOW: Activities that demonstrate the application of key concepts and complex skills with appropriate opportunities for learner responses;
- DO: Activities in which learners apply key concepts and complex skills while working on practice assignments and/or projects to be created for their electronic portfolios.

The second edition of this textbook covers the core objectives addressed in introductory educational technology courses while adding new sections on mobile learning, MOOCs, open educational resources, "big data," and learning analytics along with suggestions to instructors and appendices on effective writing, professional associations, and journals and trade magazines.

J. Michael Spector is Professor and former Chair of the Department of Learning Technologies at the University of North Texas, USA. Dr. Spector has served as Executive Vice President on the International Board of Standards for Training, Performance and Instruction (ibstpi), on the Executive Committee of the IEEE Learning Technology Task Force, and as past-President of the Association for Educational and Communications Technology (AECT). He was lead editor on the third and fourth editions of the *Handbook of Research on Educational Communications and Technology*, edited the *Encyclopedia of Educational Technology*, and has more than 150 journal articles, book chapters, and books to his credit.

Interdisciplinary Approaches to Educational Technology

Series Editor: J. Michael Spector

Current and forthcoming series titles:

Foundations of Educational Technology: Integrative Approaches and Interdisciplinary Perspectives
J. Michael Spector

Design for Learning in Virtual Worlds
Brian C. Nelson and Benjamin E. Erlandson

Foundations of Educational Technology: Integrative Approaches and Interdisciplinary Perspectives, Second Edition
J. Michael Spector

Foundations of Educational Technology

Integrative Approaches and Interdisciplinary Perspectives

Second Edition

J. MICHAEL SPECTOR

Routledge
Taylor & Francis Group
NEW YORK AND LONDON

Second edition published 2016
by Routledge
711 Third Avenue, New York, NY 10017

and by Routledge
2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

Routledge is an imprint of the Taylor & Francis Group, an informa business

First edition published by Routledge 2012

Library of Congress Cataloging in Publication Data
Spector, J. Michael.
Foundations of educational technology: integrative approaches and interdisciplinary perspectives/
J. Michael Spector.—Second edition.
pages cm
Includes bibliographical references and index.
1. Educational technology. I. Title.
LB1028.3.S6295 2015
371.33—dc23
2014046337

ISBN: 978-1-138-79027-8 (hbk)
ISBN: 978-1-138-79028-5 (pbk)
ISBN: 978-1-315-76426-9 (ebk)

Typeset in Minion Pro, Helvetica Neue and Copperplate Gothic
by Florence Production Ltd, Stoodleigh, Devon, UK

This volume is again dedicated to those who shaped my understanding of educational technology: Walter Davis (a computer scientist and mathematician), Robert M. Gagné (an educational researcher and psychologist), David H. Jonassen (an educational researcher and instructional design theorist), M. David Merrill (an instructional engineer and technologist), and Robert Tennyson (an educational psychologist). In addition, I have several of my philosophy professors to thank for training me to think more clearly and to write more coherently: Edwin B. Allaire, Oets K. Bouwsma, John P. Murphy, and Stuart Spicker.

This page intentionally left blank

Contents

Preface

This is a revised second edition of the introductory volume in the Routledge series entitled "Integrative Approaches to Educational Technology: Interdisciplinary Perspectives on Technology in Support of Learning, Performance, and Instruction." This book introduces the topics to be covered in more detail in subsequent volumes in the series. In addition, this volume establishes a general four-part, problem-centered framework that will be used in all volumes in this series.

Part I of this volume provides an overview and introduction to the field of educational technology. Chapter topics include an elaborated definition of educational technology, a foundations and values perspective on educational technology, a discussion of learning and performance as well as teaching and training, issues pertaining to technology support, and integrative approaches to planning and implementing educational technologies.

Part II provides an elaboration of some of the theoretical perspectives informing the profession. Theories of human development, learning and performance, information and communications, instruction, and instructional design are reviewed. Leading researchers and scholars associated with the most influential theories are briefly discussed.

Part III provides a more detailed elaboration of practical perspectives and prominent technologies associated with the profession. Issues involved in implementing pilot efforts on a larger scale, the diffusion of innovation, and change agency are introduced along with the challenges of teaching with technology and implementing educational technologies in workplace settings. Principles of design and lessons learned with regard to integrating technology successfully are discussed in this part of the volume. Prominent technologies are also highlighted in this part of the book. In addition, many variations in professional practice are noted, along with how professional practitioners are being prepared in various university and enterprise settings.

Part IV is entitled "Broadening the Context" and contains an initial chapter that discusses some of the factors relevant to successful design and implementation of educational technology in K-12, higher education, business and industry, governmental agencies, and nonprofit and nongovernmental organizations. Emphasis is placed on the recruitment and training of professional practitioners in these various settings, including recommendations for professional development. There are three new chapters included in this part of the book that round out the concept of a broadened context: (a) Professional Preparation and Training, (b) Scalability, and (c) Emerging Technologies.

Each of the chapters is structured to provide introductory remarks followed by a discussion of the major points covered. In some cases, there are classroom and online discussion forum activities suggested, and occasional quizzes are spread throughout. Each chapter also includes an end-of-chapter test that can be used as an assignment, self-test, or discussion thread. After the test of understanding, there is a representative educational technology challenge intended to provide students and other readers with a sense for the kinds of complex problems that educational technologists and instructional designers are expected to solve. Following the representative educational technology challenge, there is a suggested learning activity that is most often tightly connected with the representative problem. References, links, and other resources are also included at the end of every chapter.

This is by no means a definitive treatise on educational technology. It is intended to be a useful textbook to help orient those new to the profession and discipline to the many dimensions of complexity with which educational technologists and instructional designers work. There are some discussions of theory and principles that might be regarded as scholarly tidbits, but there are also discussions of practical issues that are encountered in everyday practice. The intent is to blend theory and practice based on the notion that well-informed practitioners and well-grounded researchers are the kinds of people who contribute the most to the advancement of the broadly defined enterprise of educational technology.

A particular challenge in writing this book was to introduce technology-enhanced examples and discuss some general aspects of various types of technologies while limiting elaboration of specific technologies. The reason for this approach is that specific technologies come and go at an alarming rate, and new technologies emerge and evolve quite rapidly. If a great deal of detail were provided on specific technologies, the volume would probably be out of date before it was even in print. However, there is a discussion of emerging technologies (e.g., massive open online courses (MOOCs), mobile devices, and personalized learning) that are likely to influence the future of educational practice toward the end of the book.

There are, of course, other good books in this area, and several of these are referenced herein. Because research, development, and teaching involving educational technologies are inherently complex domains of inquiry and practice, one should always consider alternative perspectives and approaches.

Acknowledgments

I wish to thank my editor at Routledge, Alex Masulis, for his guidance and patience in putting together this textbook series and encouraging me to get this second edition in print. I have to thank many people who provided feedback on the first edition, and who, as a result, have helped me think more clearly about the foundations of the complex enterprises of educational technology and instructional design.

part one

INTRODUCTION AND OVERVIEW

This page intentionally left blank

one
Defining Educational Technology

"We shape our tools and afterwards our tools shape us"
(from Marshall McLuhan's Understanding Media*)*

Technology

Consider refrigeration as a technology. Refrigeration has changed a great deal over the years. People have known for thousands of years that food stored in cool places or packed in snow would last longer than food not kept cool. Refrigeration is not a new technology. There were not many advances in refrigeration until it was discovered (perhaps in the 1500s) that the temperature of water could be lowered by the addition of certain chemicals such as sodium nitrate. Icehouses became popular in the 1800s and various insulating techniques for slowing the melting process were devised. Mechanical refrigeration took off in the middle of the nineteenth century as methods to compress a gas, such as ammonia, methyl chloride, or sulfur dioxide, circulate it through radiating coils, and then expand it were devised in America, Australia, France, and elsewhere. In the early part of the twentieth century, chlorofluorocarbons such as Freon replaced the more toxic gases that had been in use. Fifty years would pass before it was discovered that chlorofluorocarbons had a harmful effect on the atmosphere (ozone depletion) and indirect toxic effects on humans. Technology is usually considered to be the disciplined application of knowledge to benefit mankind, but technology can also have harmful effects.

The means used to control the vaporization and condensation of the gases used in refrigeration have also changed over the years. A gas or propane refrigerator is able to control these processes by simply heating a gas such as ammonia that first vaporizes, and then dissolves and condenses in water. This process involves no motor and is quite simple. However, gas refrigerators did not do as well in the marketplace as electric refrigerators that used a motor to control expansion and compression. In modern electric refrigerators there are automatic defrosters, ice-makers, and many other features. When my grandmother passed away in the 1980s at the age of 94, she had four refrigerators in her farmhouse in Alabama. One was an icebox that had an upper compartment to hold a block of ice and a lower compartment to hold food. She also had a propane refrigerator and two electric refrigerators, one of which had an icemaker and automatic defroster. All four refrigerators were in working order and in use. She used the icemaker in the newest refrigerator to keep the icebox supplied. She was fascinated by the technology of refrigeration and used the technology to preserve the food she produced on her farm. Her use of refrigeration technology definitely benefited our family.

Why begin a book about educational technology with this short history of refrigeration? There are several reasons. First, this example will be used to develop a definition of technology. Second, this example emphasizes a key aspect of technology—namely, change. Third, the example suggests that technology by itself is neither good nor bad; rather, it is how technology is used that is good or bad. Finally, there are effects on society and the marketplace to be considered when planning and evaluating technology.

Defining Technology

From the refrigeration example, one might be inclined to say that technology involves a tangible thing such as a block of ice or a refrigerator. However, such a definition would omit the processes used in evaporation and condensation, the various gases involved, techniques for insulating ice, methods for producing the gases used, and more. Some refrigeration units were fully specified on paper but never manufactured. Is the detailed specification for a refrigerator a technology? Is the process used in propane-powered absorption a technology? These are good questions to discuss in class, by the way. The word 'technology' is derived from two Greek words—*techne* (art, craft, or skill) and *logia* (words, study, or body of knowledge). The etymology of 'technology' suggests knowledge about making things, which would seem to include the specification for a refrigerator as a technology.

The classical view of a definition involves the essence of the thing being defined—that which makes it what it is and not something else. One might be tempted to ask about the essence of technology, perhaps in the form of necessary and sufficient conditions or characteristics. However, a modern view of a definition also considers how the term is used. It is true that many people use the word 'technology' to refer to manufactured objects such as computers, telephones, and refrigerators. If one listens carefully, one will also hear people talk about the means of transmission used by different kinds of telephones as technologies or the different generations of computer technology. Those uses of 'technology' refer to something more abstract than a particular telephone or computer. What seems to run through most uses of the word 'technology' is the application of knowledge for a practical purpose. My grandmother used the icebox to preserve food; she wanted to feed her family (the practical purpose), and she knew the icebox would help make the food last longer (the knowledge).

Let us agree that a *technology involves the practical application of knowledge for a purpose*. One way to make this notion concrete is through the concept of a patent. Nearly everything that is or could be patented represents a technology according to this definition. This broad definition also will allow us to focus on different kinds of knowledge and different purposes to which that knowledge might be applied. Of course, the general purpose with which we are concerned is education, but this is also a broad area that is examined in the next section.

Before moving on, though, it is worth noting that this definition of technology allows for change. In fact, change might be considered a basic aspect of technology since knowledge is generally progressing and the goals and intentions of people are dynamic. *Technology changes*. Just as refrigeration technology has changed dramatically over the years, most technologies tend to change. As technology changes, what people do changes. People preserve food for longer and longer periods of time and start to eat things grown in one season or in a different part of the world in a different season or region of the world. *Technology changes what people do and what they can do*. Technology can also influence what people want to avoid doing. Can you think of examples? That which a technology makes possible is called an *affordance*. Refrigeration technology affords us the opportunity to eat things grown elsewhere or out of season.

Test Your Understanding

Which of the following is/are (is/are not) a technology and why (why not) (refer to specific knowledge and purpose involved)?

1. a. White sand on the beach at Gulf Shores, Alabama.
   b. Sand poured into a hollowed box container large enough for a block of ice.
   c. Sand glued to a piece of sturdy paper.
   d. White sand in the desert near Tularosa, New Mexico.
   e. A procedure to turn sand into glass.

2. a. A laptop computer.
   b. A mobile telephone (cell phone).
   c. The Internet.
   d. A wireless network.
   e. An electric toothbrush.

3. a. A procedure to sort items into ascending alphabetical order.
   b. An algorithm for determining the standard deviation of a set of scores.
   c. A blueprint for a digital design studio.
   d. The pictographs and petroglyphs at Hueco Tanks, Texas.
   e. Picasso's painting entitled "Guernica."

Education

Education, like technology, is quite broad in terms of what it encompasses. The word 'education' comes to us from Latin *educare*, which means upbringing, training, or support based on the combination of *ex* or more simply *e* (from, or out of) and *ducere* (to lead, to guide). The derivation of the modern term is informative as it suggests that education involves a purpose or a goal, and a process of support or guidance toward the achievement of that goal.

However, to be sure we do not deviate too much from common sense and popular usage, it is worth noticing how the word 'education' is used. It is not uncommon to hear someone say of another person that he or she is well educated (or not). I have been told that my education is lacking in some areas—notably the arts. The word 'education' is often combined with a modifier to indicate a subject area or general approach, as in 'engineering education' or 'liberal education.' Occasionally, one might hear someone sum up a particularly unusual or unexpected experience by saying "that was certainly educational." In these uses of 'education' we again see the notion of a purpose and some kind of knowledge involved. There is typically the suggestion of a person or institution involved in the educational experience, although the person doing the educating might be oneself (as in 'self-educated'). Often, the word 'education' is used in a résumé to indicate the institutions attended and degrees earned by an individual.

It would seem that both knowledge and a process of learning are involved in an educational experience. Rather than dig a deeper and deeper hole and fill it with more words, let us agree that learning involves a change in what a person is able or inclined to do or believe. Why introduce the notion of change here? Well, 'education' already has knowledge and purpose in common with 'technology.' Perhaps the notion of 'change' is a third common element. Indeed, if one claims that learning has occurred, then it would seem reasonable to ask "How do you know?" The answer could be that before the educational process occurred, the person could not do X but now that the person has learned something, he or she is able to do X (Gagné, 1985). Note that there is no attempt here to make fine distinctions between being educated and having learned, nor is there an effort to distinguish education from training, as many others have done. Rather, the intention is to maintain a broad definition of education that is closely associated with learning and that encompasses training.

It is possible to make a distinction between learning well-defined and fully specified tasks and procedures (often called training) and learning more open-ended kinds of knowledge, such as historical interpretations of events or philosophical principles (a broader kind of learning than training). In our view, many things to be learned by humans involve a mixture of things that could be considered best learned by training (e.g., a routine procedure to determine the acidity of a fluid) and things that can be best learned by a broader kind of education (e.g., environmental planning). The concept that things to be learned involve multiple kinds of knowledge linked together can be found in a landmark journal article by Robert M. Gagné and M. David Merrill (1990; see www.ibstpi.org/Products/pdf/chapter_5.pdf for the reprinted article in *The Legacy of Robert M. Gagné*) and also in an important book by Jeroen van Merriënboer (1997).

Defining Education

Drawing on this discussion of the etymology and general use of the term 'education' we can now define education as a process of improving one's knowledge, performance, and understanding through a systematic and sustained effort. While one use of the term 'education' implies that education can be unplanned and incidental (as in "my unexpected inability to perform was both enlightening and educational"), most uses of the term involve an intentional and effortful activity. Learning and knowledge are associated with education. While education is sometimes differentiated from training, in the view presented here education includes training as one supporting type of instruction appropriate for well-defined, recurrent tasks. Typically, education includes a broad range of learning activities and instructional sequences aimed at a broad goal, such as becoming a computer scientist, an engineering designer, a lawyer, a nurse, a refrigeration technician, or a teacher. Being an educated professional implies a certain level of competence in solving problems and performing tasks as well as a high level of knowledge about the subject area.

Educational goals, as reflected in universities around the world, can be clustered around the following: (a) develop productive workers (emphasized in the Industrial Age and now being re-emphasized in the competitive global economic era); (b) develop effective problem solvers (emphasized in many disciplines and increasingly important in the Digital Age); (c) develop analytical and critical thinkers (long emphasized in engineering and management programs and increasingly important in the Information Age); (d) develop responsible citizens (a hallmark of a liberal education dating back at least to Dewey, 1907, 1916 and probably much further back in history); and (e) develop life-long learners (mostly a tacit educational goal until the twentieth century when lifespans increased and people began to have multiple careers and leisure time to pursue other interests). The point here is that education certainly involves change, as reflected by the use of 'develop' in each of the above goal clusters, those goal clusters themselves have been relatively stable over the years, although emphasized differently at different times and in different circumstances, as suggested in the parenthetical remarks above.

In summary, our definition of education is broad and involves intentional and systematic study, guidance and support from others and often from an institution, along with changes in one's ability and knowledge. Education involves learning, instruction and performance, all of which are addressed in this volume. Education, like technology, involves change in addition to being purposeful and specific to a subject domain.

Test Your Understanding

Which of the following involve (or not) education and why (why not) (refer to specific knowledge and purpose involved)?

1. a. Learning to repair the compressor on a refrigerator.
   b. Moving a nonfunctioning refrigerator to a garbage collection site.
   c. Learning about the Jornado Mogollon people who lived around Hueco Tanks, Texas.
   d. Reading about the conversion of gypsum into dry wall used in construction.
   e. Memorizing common phrases in a foreign language prior to visiting a country where that language is spoken.

2. a. Getting a driver's license.
   b. Obtaining a high school diploma.
   c. Having a transcript from a four-year university.
   d. Getting an award for outstanding performance in sports.
   e. Winning a prize in a school-sponsored raffle.

3. a. Sorting items into ascending alphabetical order.
   b. Determining the standard deviation of a set of scores.
   c. Developing a blueprint for a digital design studio.
   d. Drawing replicas of the pictographs and petroglyphs at Hueco Tanks, Texas.
   e. Searching the Internet for a restaurant that serves fresh fish.

Educational Technology

Having established broad boundaries for technology and education, we are now in a position to consider the general subject area of this book—educational technology. It is almost impossible to think of education without also thinking about the many different kinds of technology used to support education. A common technique used to teach children concepts is to provide an example, state the rule that makes it an example, point at more examples and also at some nonexamples explaining how the nonexamples violate the rule, and then allow the child to test his or her understanding on new examples, providing feedback on the child's performance. To teach the concept 'fruit,' one could point at a banana, an orange, and an apple and say of each one that it is an example of a fruit. When one then introduces a common definition of a fruit as the edible, seed-bearing portion of a plant, a teacher is likely to encounter all sorts of questions from children, such as "where are the seeds in a banana?" or "are tomatoes and squash fruits since they are edible and have seeds?" or "what about seedless watermelons?" Definitions are such fun and children are wonderful at finding counterexamples and problematic cases. We ought to preserve that talent. Next come the nonexamples such as nuts of various kinds, potatoes, sesame leaves, and turnip greens. Such a lesson might involve more than the concept 'fruit.' It might, for example, involve multiple concepts (fruits, nuts, vegetables) and the higher order concept of a balanced or nutritious diet. Nonetheless, basic concepts and terminology are important in many cases and for many learners—not just young children. One might say that one step in becoming an educated professional in a particular domain is learning to speak the professional language associated with that domain. This book is about learning to speak the language of educational technology.

What happens when we try out that four-part technique (examples, nonexamples, categorizing rule, practice) of concept learning with 'educational technology.' Well, here are some examples of things people call educational technologies: (a) a computer tutorial introducing a new user to the use of a particular computer program; (b) an interactive whiteboard on which a computer screen is projected and then touched to activate a particular menu selection; (c) a discussion forum in an online learning management system; (d) a computer program that converts a formula into a curve; and (e) a database that contains detailed historical information about politicians and their votes.

What rule might we generate that would help a novice correctly characterize these examples as educational technologies? Suppose we try out a simple rule such as this: a technology that can help a person learn something is an educational technology. These examples might all satisfy such a rule. Then we might try adding more examples such as (a) a handheld calculator; (b) a procedure for converting Farenheit to Celsius; (c) a formula for determining the volume of a sphere; (d) a Web-based tool to introduce, illustrate, and solve the Towers of Hanoi problem for an arbitrary number of disks (for an example, see www.mazeworks.com/hanoi/index.htm); or (e) a slide rule.

A slide rule is an educational technology. Really? Really. It is one of the most effective educational technologies ever devised. A slide rule allows one to perform division and multiplication by simply adding and subtracting logarithms. A very nice introduction to the slide rule and a self-guided tutorial on its use can be found at the website for the International Slide Rule Museum: http://sliderulemuseum.com/SR_Course.htm (see Figure 1.1). This website integrates history, procedures for performing calculations, and mathematical knowledge quite nicely.

So, how is a slide rule an educational technology? One can learn about logarithms using a slide rule. One can perform calculations used in many mathematical and engineering enterprises with a slide rule. In short, a slide rule can support learning and performance and has many educational affordances, so it qualifies as an educational technology.

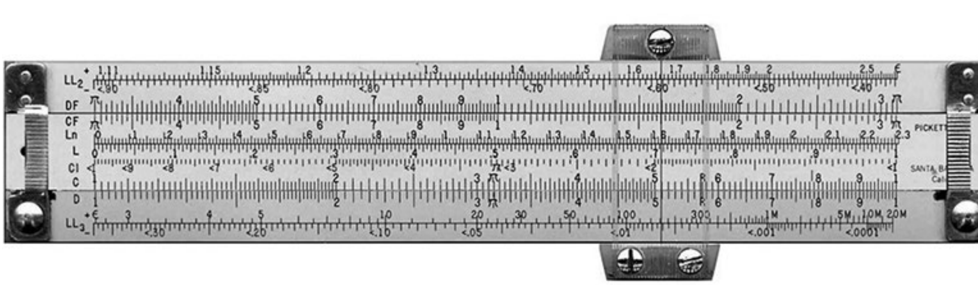


FIGURE 1.1 A slide rule (see http://sliderulemuseum.com/SR_Course.htm)

What makes a slide rule an exceptionally effective educational technology, however, is the fact that it requires very careful use of the sliders and scales. A very minor error in moving the sliding cursor and reading the scale with the hairline indicator can result in a major error. This forces slide-rule users to understand the problem being solved in advance well enough to formulate a range for what a reasonable answer would be. If the slide rule does not yield something in the anticipated range, the user would first suspect user error and perform the calculation again. In other words, what made the slide rule so effective was that it forced users to think about the problem being solved—users would typically reflect on the problem and formulate a rough answer prior to using the technology. While the slide rule has been replaced by powerful handheld calculators and computers, it reminds us that *a powerful affordance of an educational technology is to get one to think about the problem* one is trying to understand. The educational principle here is that reflecting on the nature of the problem being solved is often effective in promoting learning and understanding—a principle well worth remembering.

We shall omit providing nonexamples of educational technology to teach the concept of educational technology to someone new to the field. Such an activity might prove to be insightful in a classroom setting. As soon as a nonexample is postulated, I would expect someone to think of an educational application, however. That might prove to be fun to try in a classroom setting or discussion forum. When implementing concept learning in a classroom setting, the notion of practice with timely and informative feedback is important. Simply stating the rule and providing a few examples may be expedient but can easily result in misconceptions.

Defining Educational Technology

The prior discussion implies that one could define educational technology using an intersection of technology and education. How would that look?

Figure 1.2 depicts a Venn diagram with two intersecting ovals: education and technology, creating four areas: (1) neither education nor technology; (2) education but not technology; (3) technology but not education; and (4) education and technology.

Clearly, area 4 is the general focus of this book. However, while there is a certain logical appeal to such a figure, it creates the task of identifying examples in each area, which is not so easy—give that a try as a class discussion activity or as a personal project.

We still require a usable definition of educational technology to guide our explorations and further discussion. Here is a definition based on the common elements of purpose, knowledge, and change: *Educational technology involves the disciplined application of knowledge for the purpose of improving learning, instruction, and/or performance*. The notion of disciplined application of knowledge is included here to reflect the view that educational technology is an engineering discipline in the sense that principles based on theory, past experience, and empirical evidence guide what professional educational technologists do. These principles are derived from basic science and empirical research in such areas as cognition, cybernetics, information science, human factors, learning

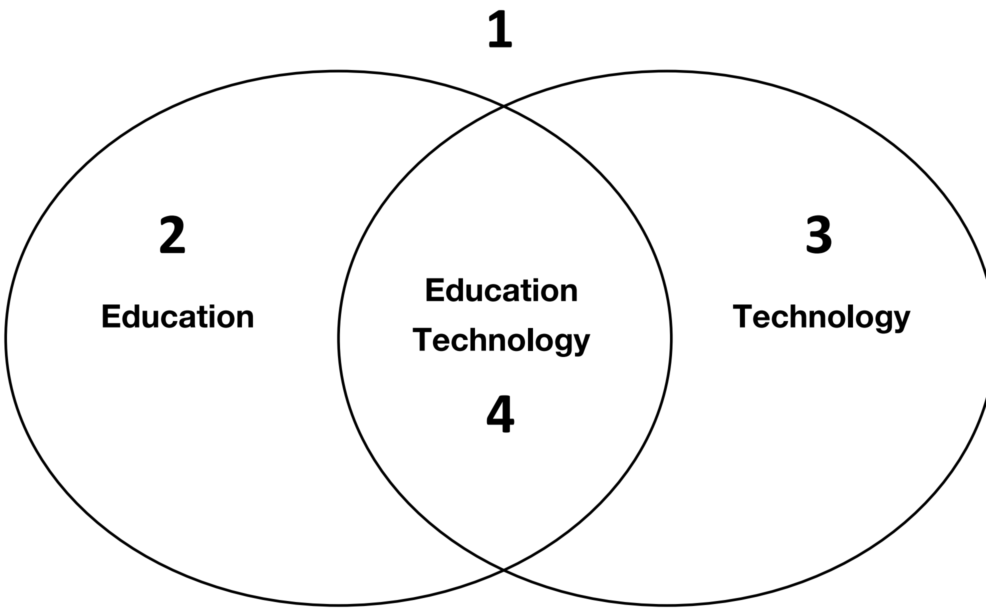


FIGURE 1.2 Educational technology Venn diagram

theory, mass communications, message design, organizational theory, and psychology. Educational technology is inherently an interdisciplinary enterprise. The principle of encouraging problem solvers to reflect on the nature of the problem first can be traced to research in cognitive psychology (perhaps it goes back much further).

Educational technology draws on the work of multiple disciplines. Because multiple disciplines are involved and because problems in educational technology are often complex and challenging, it is especially important to think about what one does (and of course how and why) in a disciplined and systematic manner. A systems perspective has long been a hallmark of educational technology. The systems perspective involves (a) a long-term view of the problem and solution (from imagination through implementation to interment); (b) a broad and holistic view of relevant factors (from the immediate context to incidental and unanticipated activities); and (c) a dynamic view of the problem space (things are likely to change).

Educational technology involves multiple disciplines, multiple activities, multiple people, multiple tools, and multiple opportunities to facilitate meaningful change. There are a number of principles drawn from different disciplines that guide what educational technologists do. Many tools and technologies have been developed to help educational technologists perform their responsibilities. Figure 1.3 is a notional concept of educational technology created using a knowledge modeling tool called *MOT plus* developed at the LICEF Research Centre affiliated with the University of Montreal, Canada (see www1.licef.ca). In Figure 1.3, rectangles represent concepts, ovals represent procedures or processes, hexagons represent rules or principles, and octagons represent facts. Connections of various types exist, such as components (steps) of procedures,

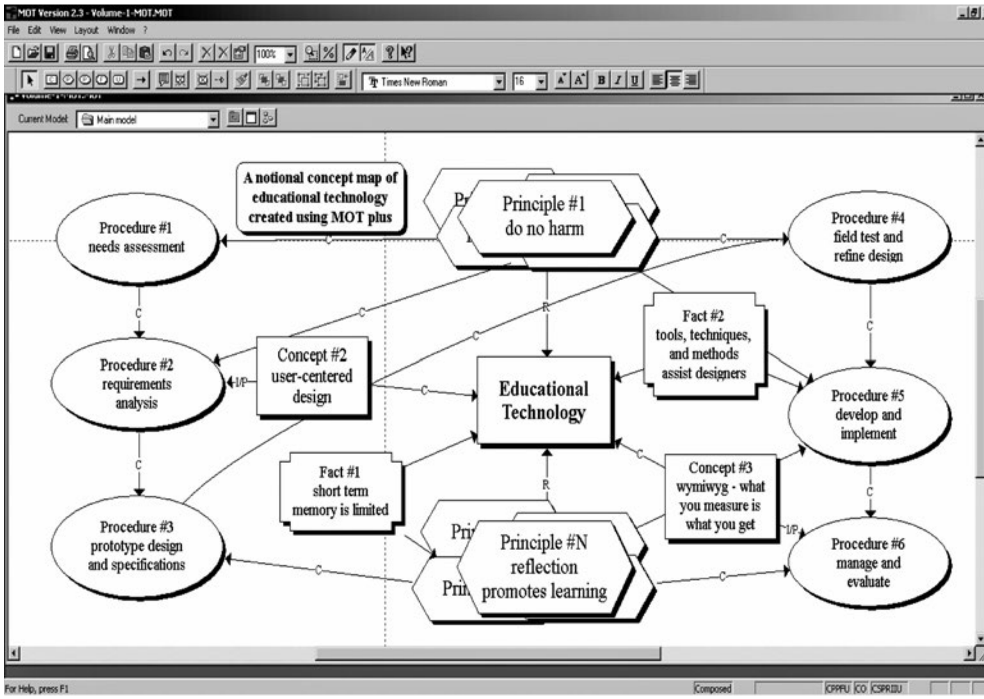


FIGURE 1.3 A notional concept map created with MOT plus

principles that influence concepts and categorizing decisions, and concepts and facts that affect procedures and other concepts. This obviously incomplete representation of educational technology is focused on the knowledge involved rather than on those who implement that knowledge to promote learning or on how the knowledge will be acquired, mastered, and applied.

In addition to multiple disciplines and tools, educational technologists have different perspectives on the various processes and activities with which they are involved. Using technology to promote learning, instruction, and performance is far from a formulaic enterprise. There are many approaches, methods, and tools to inform good solutions for the challenging problems educational technologists confront. Figure 1.4 represents a way to view educational technology in terms of support for learning and instruction, especially with regard to instructional objects (see Spector, 2014b).

In addition to offering support for instructional objects and others aspects of learning and instruction, new forms of technology are appearing that are referred to as smart technologies (Spector, 2014a). Smart technologies are those that exhibit characteristics of intelligent human behavior (e.g., selecting an appropriate alternative among multiple choices based on past knowledge and experience). Table 1.1 reflects the characteristics that might be considered necessary, desirable, or likely for a smart technology.

We close this chapter with an illustration of a representative complex problem and suggested activities to work toward a solution. This example is used to inform two

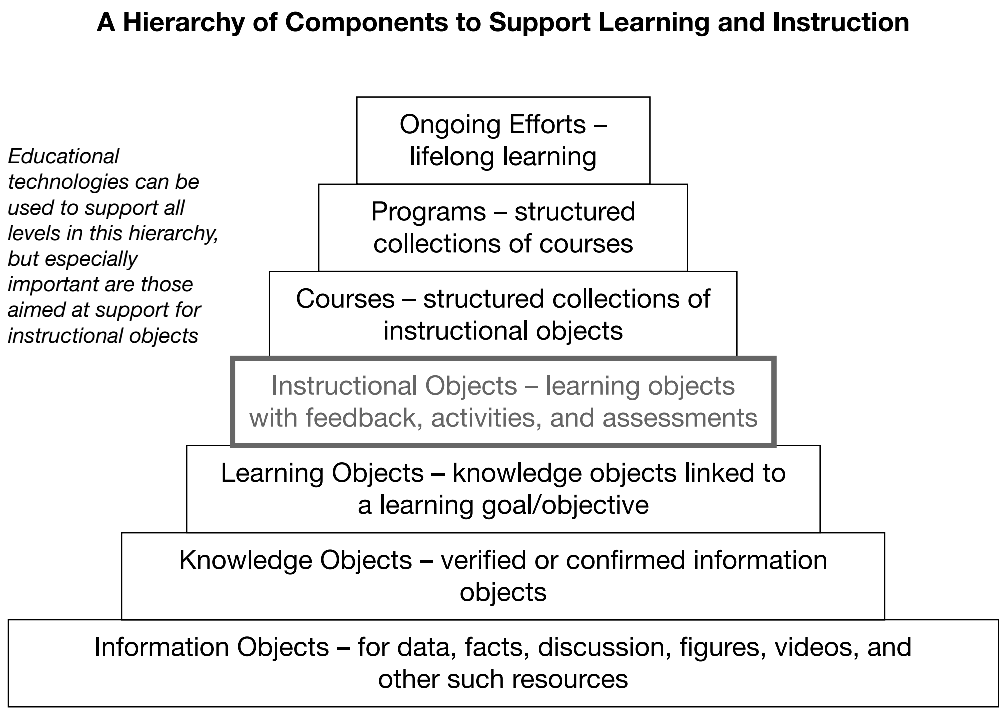


FIGURE 1.4 Educational technologies and instructional objects

TABLE 1.1

Elaboration	
Necessary characteristics	
Effectiveness	An intelligent tutoring system with evidence of improved learning
Efficiency	A tool that automatically assesses student inputs and provides feedback
Scalable	A technology that can be easily implemented on a large scale in multiple contexts
Desirable characteristics	
Engaging	An interactive game linked to a learning objective
Flexible	A tool or environment that automatically reconfigures itself to accommodate the current situation
Adaptive	A technology that automatically adapts itself to a specific learner and that learner's profile
Personal[izable]	A technology that responds to an individual with an awareness of that particular individual's history or situation
Likely characteristics	
Conversational	A system that interprets and responds with natural language
Reflective	A technology that prompts the learner to reflect on a particular aspect of a responsive
Innovative	A system that effectively integrates a new technology to support learning and instruction

activities associated with this chapter: (1) discussing the example in small groups and collaboratively developing a more elaborated solution approach; and (2) initiating a portfolio which may be used for future activities in this and subsequent courses.

A Representative Educational Technology Challenge

A large educational organization that offers online courses and provides online support for courses and projects is considering changing its learning management system (LMS). Questions to consider include the following:

1. Which LMS is the best for the organization and its constituency in terms of learning effectiveness?
2. Which LMS is the most affordable for the organization to acquire and maintain?
3. What issues exist or are likely to arise with regard to support, acceptance, and use?
4. How and when will existing courses, support materials, and projects be migrated to the new system?
5. Who will train staff (and when and how) with regard to effective and efficient use of the new system?

Learning Activities

1. Develop a plan that addresses the first three issues in the representative educational technology challenge. Share the plan with your colleagues and ask them to provide a critique; critique one or more of their plans in exchange for the feedback.
2. Develop a plan that addresses the last two issues in the representative educational technology challenge. Share the plan with your colleagues and ask them to provide a critique; critique one or more of their plans in exchange for the feedback.
3. Investigate several Internet sources pertaining to educational technology and develop a list of activities and responsibilities typically associated with instructional designers and educational technologists. Indicate the knowledge and skills associated with these activities and responsibilities. Share your findings with your colleagues and ask them to provide a critique; critique one or more of their findings in exchange for the feedback.

Links

The article entitled "Integrative Goals for Instructional Design" by Robert M. Gagné and M. David Merrill that appeared in *Educational Technology Research and Development* in 1990 was reprinted with permission in *The Legacy of Robert M. Gagné*, a volume sponsored by the International Board of Standards for Training, Performance and Instruction (www.ibstpi.org) and is freely available at the following URL: http://eric.ed.gov/?id=ED445674.

A nice example of a Web-based tool to help students learn about exponential functions in the context of the Towers of Hanoi game can be found at www.mazeworks.com/hanoi/index.htm. There are many more such examples of the Towers of Hanoi game available online. It is worthwhile to have a look at these and see how different examples might be used to teach different aspects of the Towers of Hanoi problem.

An introduction to the slide rule and its use can be found at the website for the International Slide Rule Museum: http://sliderulemuseum.com/SR_Course.htm. This website integrates history, procedures for performing calculations, and mathematical knowledge.

A powerful knowledge modeling tool is freely available from the LICEF Research Center in Montreal, Canada—www.licef.ca/Home/tabid/36/language/en-US/Default.aspx.

Another powerful concept mapping tool is called CMAPS developed by the Institute for Human and Machine Cognition (IHMC) affiliated with the University of West Florida—http://cmap.ihmc.us/conceptmap.html.

Other Resources

The Association for the Advancement of Computing in Education (AACE)—www.aace.org

The Association for Educational Communications and Technology (AECT)—www.aect.org

The International Board of Standards for Training, Performance and Instruction (ibstpi)—www.ibstpi.org

The New Media Consortium (NMC)—www.nmc.org (look for the Horizon Report)

Spector, J. M. (Ed.) (2015). *The encyclopedia of educational technology*. Thousand Oaks, CA: Sage.

Spector, J. M., Merrill, M. D., Elen, J., & Bishop, M. J. (Eds.) (2014). *Handbook of research on educational communications and technology* (4th ed.). New York: Springer.

References

Dewey, J. (1907). *The school and society*. Chicago: University of Chicago Press.

Dewey, J. (1916). *Democracy and education: An introduction to the philosophy of education*. New York: Macmillan.

Gagné, R. M. (1985). *The conditions of learning* (4th ed.). New York: Holt, Rinehart & Winston.

Gagné, R. M., & Merrill, M. D. (1990). Integrative goals for instructional design. *Educational Technology Research and Development, 38*(1), 23–30.

Spector, J. M. (2014a). Conceptualizing the emerging field of smart learning environments. *Smart Learning Environment, 1*(2), 1–10.

Spector, J. M. (2014b). Remarks on MOOCs and mini-MOOCs. *Educational Technology Research & Development, 62*(3), 385–392.

van Merriënboer, J. J. G. (1997). *Training complex cognitive skills: A four-component instructional design model for technical training*. Englewood Cliffs, NJ: Educational Technology Publications.

two
Values, Foundations, and a Framework

"Everything changes and nothing remains still"
(attributed to Heraclitus by Plato in the Cratylus*)*

Values

Given that technology changes and that what people do and can do changes, how are we to maintain a solid foundation and maintain our values? This challenge is put best, perhaps by Bob Dylan in his song "Forever Young" ("may you have a strong foundation when the winds of changes shift"), but is also evident in the writings of many, dating at least as far back as Heraclitus, a pre-Socratic philosopher. In the previous chapter, the claim was made that educational technology could be either beneficial or harmful, depending on its use. While the general intention is to use educational technologies for the good of one or more persons, unanticipated consequences can occur that are harmful. It is not logical to build the concept of ethics into the definition of educational technology, just as it would be inappropriate to build the concept of ethics into the definition of medical surgery. However, it is clear that ethics are part and parcel of medical practice, as exemplified by this portion of the classical Hippocratic Oath:

> Whatever houses I may visit, I will come for the benefit of the sick, remaining free of all intentional injustice, of all mischief and in particular of sexual relations with both female and male persons, be they free or slaves.
>
> (Edelstein, 1943: 1)

Just as practitioners of medical technology are and should be guided by ethical principles, practitioners of educational technology are and should be guided by ethical principles. An *Educratic Oath* inspired by the Hippocratic Oath was proposed by Spector (2005) for educational technologists:

1. Do nothing to impair learning, performance, and instruction.
2. Do what you can to improve learning, performance, and instruction.
3. Base your actions on evidence that you and others have gathered and analyzed.
4. Share the principles of learning, performance, and instruction that you have learned with others.
5. Respect the individual rights of all those with whom you interact.

The classical version of the Hippocratic Oath was selected rather than the modern version so as to introduce the notion of culture into the discussion. Ethical principles and values are closely connected with culture. Our culture is generally free from slavery, but there are many disadvantaged persons in our society. One of the unfortunate aspects of educational technology is that it can be unwittingly used in a way that creates additional disadvantages for those already being left behind economically and educationally. The first principle of this *Educratic Oath* implies that contributing to the widening of the so-called digital divide would be wrong. *Do not create disadvantages for one population while creating advantages for another population*. This is a difficult ethical principle to uphold, but it is our obligation to do so.

The practice of educational technology does not occur without consideration of all sorts of values, including ethical principles. Some communities place particular value on the esthetics of learning spaces and environments. Others emphasize the openness of the learning community to alternative points of view. Some put economic considerations first while others put learning outcomes first. One cannot say that one group or one values perspective is right or wrong. One should be able to identify the values perspectives of all those involved and do one's best to respect those values—or decide to go elsewhere.

For additional information on ethics in educational technology, visit the Websites of the Association for Educational Communications and Technology (www.aect.org) and the International Board of Standards for Training, Performance and Instruction (www.ibstpi.org).

Skepticism

Within the context of values pertaining to educational technology, it is perhaps worth mentioning the value of a skeptical predisposition with regard to the application of educational technology to improve learning and performance. There is a substantial history of educational technologists promising that the introduction and use of a particular technology will yield dramatic improvements in learning and instruction (Spector & Anderson, 2000). That has not happened, yet the promises of dramatic improvements on account of technology continue to be put forward. One ought to have a skeptical attitude with regard to such promises and predictions. A skeptical attitude is

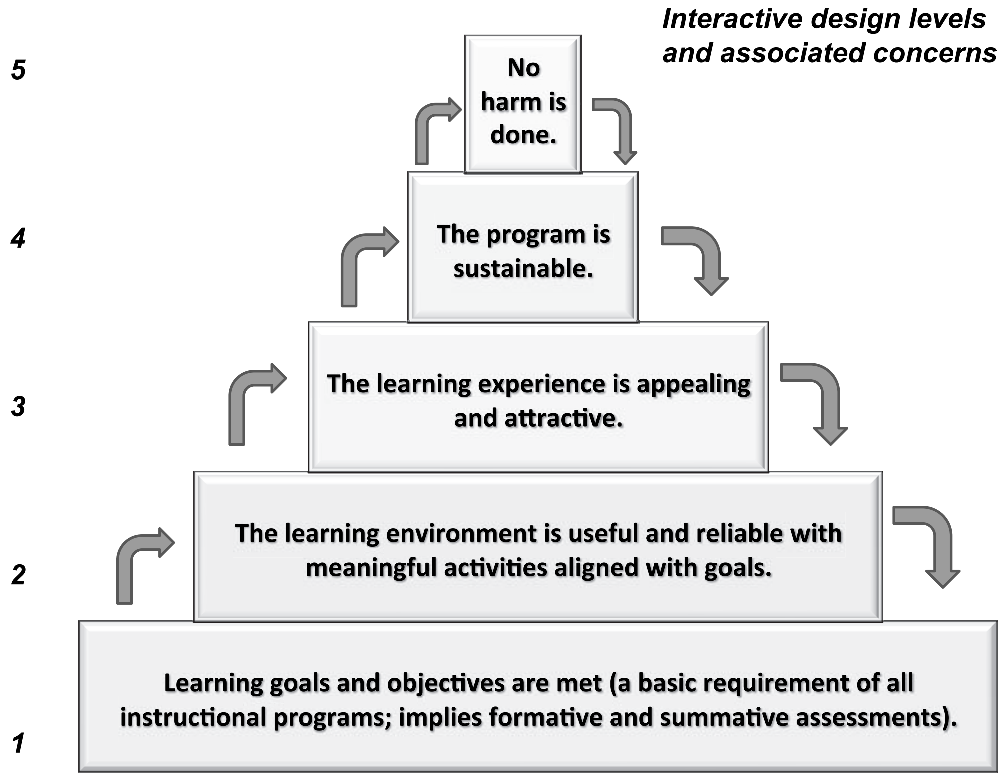


FIGURE 2.1 Design levels and association concerns

essentially a questioning attitude, which is to say that one is engaged in trying to find out and willing to consider alternatives. *Skepticism implies doubt along with a desire to know*. Admitting that one does not know but wants to understand and is willing to investigate various explanations of something is the hallmark of skepticism, and it is also an important value to keep in mind for educational technologists.

Another way to emphasize this point about skepticism is to say that one role of an educator and one use of educational technologies is to encourage students to *have questions* and to support activities resulting from having those questions. To have a question is to (a) admit to not knowing or understanding something, (b) commit time and effort to find out and understand, and (c) be open to explore and consider alternative explanations. That is to say, an educator is someone who gets others to have questions; an educational technology is something that supports finding answers. Of course, both characterizations are too narrow, but they can serve as useful guideposts.

Levels of Design

Figure 2.1 emphasizes the position of values in this educational technology framework and serves as a transition to the discussion of foundations. This figure also introduces the notion of design levels, which will be discussed later.

The emphasis in the current discussion is on the top part of this pyramid—do no harm. Additional components and the notion of levels of design depicted in Figure 2.1 will be introduced in subsequent chapters in this volume.

Test Your Understanding

Identify potential harmful outcomes of each of the following scenarios.

1. Students are introduced to the graphing calculator and taught how to use it to reason about the relationships of variables in an algebraic expression. Calculators are available for all students at the school, and students are encouraged but not required to purchase their own calculators.
2. An update to the ejection procedure in a fighter aircraft has been introduced. Formerly, this aircraft ejected the pilot out the bottom of the aircraft, requiring the pilot to invert the aircraft when ejecting at low altitude. The new version of this aircraft now ejects the pilot out the top, like most other fighter planes. Pilots had received extensive training in the former procedure. The new procedure is announced and each pilot is sent a paper copy of the new procedure with no additional training.
3. A school has decided to give teachers merit pay based on the aggregated average performance of their students on state-mandated, standards-based tests. The school is supporting this effort by making available to all teachers new software that can be used to test students to see how likely they are to perform well on those tests and to identify particular trouble spots in terms of standards-based topics causing many students problems.
4. A massive open online course (MOOC) developed for graduate computer science students in the area of artificial intelligence offered at a top university is made a requirement for all graduate computer science students enrolled in a new artificial intelligence course offered at a small, regional university. Evidence of completing the MOOC is a requirement for attaining a grade of B in the new course. Additional tasks are required to attain an A. All those failing to complete the MOOC will receive a C, which is considered a failing grade for a graduate course at the small, regional university.

Foundations

Recognizing that values permeate and inform what educational technologists (and others) do, it is now appropriate to look at the underlying disciplines upon which educational technology rests. The traditional treatment of foundations is to show pillars upon which something rests, as in Figure 2.2.

Various authors have depicted a variety of foundation pillars for educational technology. The six pillars in Figure 2.2 represent a composite summary of what others have identified (for example, see Richey, Klein, & Tracey, 2011). These particular pillars

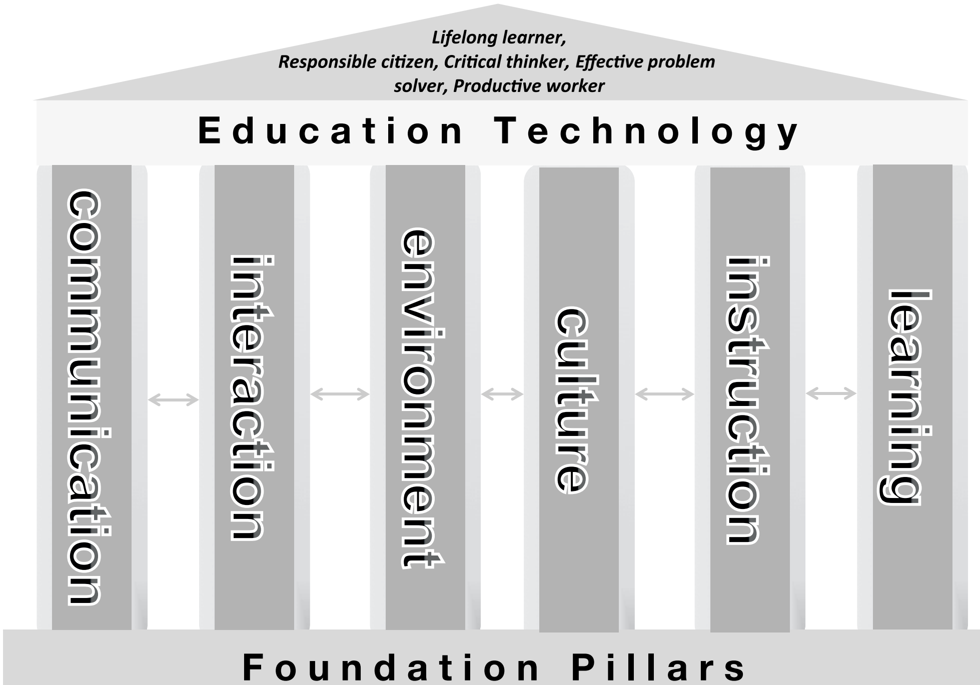


FIGURE 2.2 Foundation pillars of educational technology

were selected because they also represent clusters of things that people do or that strongly influence what people do when in instructional situations. The six foundation clusters (pillars) are: communication, interaction, environment, culture, instruction, and learning. Each of these six pillars will be briefly discussed prior to offering an alternative view of foundations.

Communication

Communication skills are important to everyone in almost every profession. Educational technologists, whether they are developers, designers, instructors, or technology specialists, have a need to communicate clearly and effectively with others, and particularly with persons having different backgrounds and training than their own. The International Board of Standards for Training, Performance and Instruction (ibstpi; see www.ibstpi.org) found that the most critical skills for instructors as well as instructional designers were communication skills (see Klein et al., 2008) rather than skills in using or integrating technology. Communication skills include writing, speaking, and listening skills, in the context of the ibstpi studies.

Communication skills are especially important in the world of educational technology as persons with different backgrounds and interests are involved (learners, managers, sponsors, technical specialists, designers, etc.). In addition, many communications occur in a digital form not involving face-to-face interaction (design specifications, instructional messages, learning content, etc.). Being clear, precise, coherent, and focused are crucial for success. Avoiding unfamiliar terminology, defining key terms, and providing meaningful context and rationale are at a premium in the world of educational technology.

From a foundations perspective, communication theories and principles form key aspects of the effective use of educational technology. For the purpose of this discussion, communication theory is broadly defined to cover theories, models, principles, and formats for representing, transmitting, receiving, and processing information.

An example of a communication theory with implications for education is Paivio's (1991) dual coding theory. Although it is often considered a cognitive processing theory, Paivio argues that the human mind has evolved in such a way that it can simultaneously process and interrelate verbal (e.g., text) and nonverbal (e.g., images) information. For a person designing a representation of something complex and desiring to minimize the cognitive load on the learner, a graphical representation along with text might be effective, according to dual coding theory. This notion is further reinforced by cognitive flexibility theory (Spiro & Jehng, 1990), which is also generally considered a cognitive theory rather than a communication theory. Given the definition of communication suggested above, both can be considered communication theories, and both have strong implications for the effective planning and implementation of materials to support learning and instruction.

Two additional comments round out this brief discussion of communication as a foundation pillar of educational technology. First, all of us are by nature language users and message designers. When we talk with our neighbors about politics or the weather, we are constructing messages for a particular purpose. Sometimes the purpose is to present simple information, in which case we might construct a purely descriptive message. On other occasions, the purpose might be to persuade, in which case we might make use of metaphor and hyperbole. Those who construct and deliver messages to support learning and performance need to think carefully about the purpose and the intended audience in order to design effective instructional messages.

Second, while the ability to share information and exchange ideas with others is a characteristically human trait, a more fundamental but related characteristic is the ability to create internal representations of things we experience. Every human is a constructor of these internal representations, called mental models by cognitive psychologists (Johnson-Laird, 1983). The ability to create these internal representations is the essence of a constructivist epistemology. While most cognitive scientists and educational technologists accept epistemological constructivism as a common point of departure, there is a great deal of misunderstanding surrounding mental models and constructivism. People are naturally and continually constructing these internal representations, which are completely hidden from view. One never sees a mental model—not even one's own. What one can see is a representation of a mental model, and these representations come