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Educational Technology: Media for Inquiry, Communication, Construction, and Expression

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Abstract

We describe a new way of classifying uses of educational technologies, based on a four-part division suggested years ago by John Dewey: inquiry, communication, construction, and expression. This taxonomy is compared to previous taxonomies of educational technologies, and is found to cover a wider range of uses, including many of the cutting-edge uses of educational technologies. We have tested the utility of this taxonomy by using it to classify a set of "advanced applications" of educational technologies supported by the National Science Foundation, and we use the taxonomy to point to new potential uses of technologies to support learning.

Introduction

Discussions in the field of educational technology concern a host of issues, including pedagogical theory, choice of hardware or software, methods of use, and evaluation of effectiveness. But in many cases these debates leave unexamined some fundamental assumptions about what counts as educational technology, or how we might think about innovative applications. Experts often disagree about what constitutes the objects of their study but avoid addressing their disagreements directly. It is no surprise that discourse in the field appears disjointed and inconclusive.

Becoming more explicit about fundamental assumptions will not ensure that the discourse achieves a higher plane, much less that a new consensus will emerge. It could even do the opposite. But we believe that laying out these assumptions could clarify what the debates are about and is conducive to progress in the field. To illustrate how different assumptions lead to fundamentally different conceptions of educational technology and consequently of research in the area, this paper proposes a new taxonomy of educational technology applications.

The taxonomy is organized in terms of the ways applications support integrated, inquiry-based learning. The taxonomy is far from a finished conception and should be read more as a work-in-progress.[1] What we have tried to do is to lay out a framework for thinking about the broad array of applications of educational technology. The framework suggests ways that computers and other new information technologies can be used to support the full range of learning. Like all such taxonomies, the boundaries between the categories are fuzzy and some applications fit in more than one slot.

There are other valid frameworks one might adopt. Some choose to emphasize hardware differences; others software. Some might focus on the content or grade level of application. Many choose to focus on function. Our point is not to preempt all other views, but rather to suggest that there are many legitimate ways to conceive of educational technology. This observation, which some might say is obvious, often goes unrecognized. As a result, many authors argue points that presuppose one perspective, without an apparent realization of how much their case relies upon that presuppostion.

Taxonomies of Educational Technology

When Carolus Linnaeus[2] published his *Systema naturae* in 1735, he established the modern scientific classification system for plants and animals. Although the specifics of his classifications have been revised many times, the idea of an orderly, international naming system was a key ingredient in the birth of modern biology. A taxonomy could guide biologists in making comparisons, looking for new creatures, and asking about the origins and transformations of life.

A taxonomy can be a productive step in the process of understanding and explaining what we see by organizing perceptions into categories if we are able to see the familiar in new ways or if we are able to cope with a confusing array of phenomena. Of course, a taxonomy always reduces the complexity and richness of whatever is being categorized. Its usefulness needs to be judged in relation to some purpose.

Schiebinger (1996) shows how Linnaeus "classified plants according to their reporoductive parts, endowing them as well with sex lives reflecting 18th-century values and controversies." She argues that when Linnaeus wrote there was a shift underway from arranged marriages to marriages based on love and affection. This was reflected in his classification scheme when he distinguished between public and clandestine marriages of plants. Thus, his categorization of plants grew out of a particular view of the world.

Many articles on the application of educational technology likewise lay out a system of types. An obvious reason for this is that there are so many different kinds of software and hardware, and so many different uses to which these have been applied, that it is simply overwhelming without some way of talking about kinds or groups. But the system presented is often treated as universally valid, rather than as a statement about a particular set of values and beliefs about technology, teaching, and learning. But any categorization of forms of technology expresses a view of the world that has significant ontological, epistemological, and pedagogical implications.

From World Models to Taxonomies

The relationship between a view of the world (or model) and a taxonomy can be seen in a book by Alessi & Trollip (1991), authors who view the educational use of computers as a set of instructional methodologies:

> According to the model we have just described, the process of instruction includes the instructor presenting the information to students, guiding the students' first interaction with the material, the student practicing the material to enhance fluency and retention, and finally, assessment of students to determine if they have learned the material and what they should do next. (Alessi & Trollip, 1991, p. 9)

Building upon this model, Alessi and Trollip organize various forms of "computer-based instruction" into five categories: tutorials, drills, simulations, games, and tests. They place tutorials first in their taxonomy, and have no explicit place for general software tools, such as spreadsheets, mail readers, or drawing programs. Thus their categories correspond to their general instructional model and can be used as a lens with which to see how various applications support instructors in carrying out aspects of the model.

A striking alternative to this approach is that of Olds, Schwartz, and Willie (1974). They report a study of teachers who examined a wide range of educational software, including drill-and-practice software focused on specific skills and software designed to encourage and support students in asking their own questions. The teachers found that different approaches to software design implied radically different models of learning and teaching. In the process of examining software critically they became more aware of their own values. As their report says, "teachers saw the enormous pedagogical difference between solving problems and formulating them, between answering someone else's question and generating your own" (p. 40). Thus, the distinction between computer control and student control assumed primary importance.

Taylor (1980) has a related, but still distinct, position. He suggests that there are three main categories. In the *tutor* role, the computer functions as a substitute or supplemental teacher. As a *tool*, the computer can be used to carry out tasks assigned by the student. This tutor/tool distinction is similar to that of Olds, et al. Taylor then adds a third role, the *tutee*, in which the student learns by teaching the computer. This is the situation with *Logo,* when students think of the computer as their pupil, who/which needs to be taught every step in a procedure.

It is easy to see that each of these taxonomies reflects more than just prevailing natural categories of technology types. Alessi and Trollip categorize software in terms of the support it affords for explicit instruction. Web browsers were not around when they wrote their book, but if they had been, it is safe to say that browsers would not have been considered instructional. There is no control over presentation of material; interactions are not guided; there is no provision for practice to "enhance fluency and retention," and there is no explicit assessment. Thus, the web per se could not be considered part of computer-based instruction. In contrast, other educators might argue for either a broader conception of "instruction," or for more attention to forms of learning that do not fit within the instructional model. Similar points could be made about the taxonomies proposed by Taylor and Olds, et al.

More recently, Means (1994) described four different categories of educational technologies based on their use: "used as a tutor", "used to explore", "used as a tool", and "used to communicate". This categorization reflects a growing awareness that features of hardware and software alone do not determine educational practices or potentials. Thus, "use" assumes a more central role than a priori technology characteristics.

The notion that conceptions of education override any sense of natural categories of technology is developed in an interesting historical analysis of software for literacy instruction carried out by Hawisher (1994). She shows how Taylor's taxonomy reflects then-current views about the potential for technology in education, drawing obviously from the early work with Logo. Then, Helen Schwartz's (1982) taxonomy reveals insights from then-current research in science education, just as Thomas Barker and Fred Kemp's (1990) shows the influence of thinking about the social construction of knowledge and social aspects of learning. In each case, pedagogical philosophy becomes the guiding focus, rather than technology features abstracted from actual use.

Media for Inquiry, Communication, Construction, and Expression

A quite reasonable question to ask is why we need another taxonomy if several already exist. For us, the motivation arose in the midst of a debate concerning future directions for educational technology within our university. The authors were struck by the fact that forms of technology use that we considered to have excellent pedagogical potential did not fit within prevailing categories that other participants in the debate were using. Some of participants appeared to adopt a technocentric model of technology use, one that seems natural, but can in fact be quite limiting. Moreover, we sensed an implicit, but powerful behaviorist bias, even among some of those eager to embrace innovative uses of technology. This bias seemed to limit the student's role in learning with the new technologies. We also felt that in foregrounding the technology, the debate obscured the students' activities and learning, which ought to have been the central issue.

The "Interests of the Child"

In response to this debate, we began to search for a way to organize the tools, techniques, and applications to accommodate better to a constructivist and integrated view of learning.[3] We assumed that the ideal learning environment would, as Peter Marin once said, satisfy children's curiosity by presenting them with new things to be curious about. It would engage children in exploring, thinking, reading, writing, researching, inventing, problem-solving, and experiencing the world.

Thus, the basis for learning would be what John Dewey (1943) identified nearly a century ago as the greatest educational resource--the natural impulses to inquire or to find out things; to use language and thereby to enter into the social world; to build or make things; and to express one's feelings and ideas. Dewey saw these impulses, rather than the traditional disciplines, as the foundation for the curriculum. The educational challenge is to nurture these impulses for lifelong learning.

Dewey's four categories, developed long before the electronic age, matched surprisingly well to the ways the first author was beginning to organize his list of educational technology applications. It appeared that a taxonomy could be built, not on a formal instructional model, nor on hardware and software features, but rather, on the "impulses" to learn and grow.

Technology as Media

In addition, we wanted to emphasize the mediative aspect of technologies. That is, we view the effects of technologies as operating to a large extent through the ways that they alter the environments for thinking, communicating, and acting in the world. Thus, they provide new media for learning, in the sense that one might say land provided new media for creatures to evolve. This view of media encompasees, but extends, the familiar idea of media as a place to put information. Today, interactive, multimedia technology provides us with a new way to draw upon children's natural impulses. These new media hold an abundance of materials including text, voice, music, graphics, photos, animation, and video. But they provide more than abundance. Bringing all these media together means that we can vastly expand the range of learning experiences, opening up the social and natural worlds. Students can explore the relations among ideas and thus experience a more connected form of learning. Perhaps most importantly, these new media are interactive, and conducive to active, engaged learning. Students can choose what to see and do, and they have media to record and extend what they learn. Learning is thus driven by the individual needs and interests of the learner.

We chose the term "media," rather than "tool," "program," or "application," for several reasons. We wanted to shift the focus from the features of hardware or software per se to the user or learner. "Media" suggests the mediational function of technologies, which link the student to other learners, teachers, other technologies, ideas, and the physical world. Moreover, as technologies become embedded in social practices, they tend to become invisible; we focus less on the fact that they may be consciously employed as a tool to do a task, and come to see the task itself as central, with the technology as substrate. Finally, it is only a small stretch to extend the familiar notion of media for expression, construction, and communication to media for inquiry.

There is an additional reason for considering technologies as media. Learning in almost any subject today means not only learning the concepts within that area, but also, how to use technologies in that endeavor. Thus, the traditional lines between learning *about* technology and learning *through* technology are beginning to blur. For example, learning science entails learning how to use computers as media for collecting and analyzing data, for modeling phenomena, and for communicating results. For these activities, science students need experience with the technological media scientists use; they need to learn how *to think through* new media. At the same time, there is a growing body of research evidence showing that these media uses are effective at supporting learning of concepts, attitudes, and processes. Thus, it is not mere coincidence that the categories of media for learning listed within the taxonomy below reflect the uses of computers by professionals in various fields.

The Taxonomy

Combining this focus on the interests of the child with the view of technology as media, we devised the following taxonomy. For each subcategory, we list several examples of existing applications that fit best in that position.

A. Media for Inquiry

1. Theory building--technology as media for thinking.

- Model exploration and simulation toolkits
- Visualization software
- Virtual reality environments
- Data modeling--defining categories, relations, representations
- Procedural models
- Mathematical models
- Knowledge representation: semantic network, outline tools, etc.
- Knowledge integration

2. Data access--connecting to the world of texts, video, data

- Hypertext and hypermedia environments
- Library access and ordering
- Digital libraries
- Databases
- Music, voice, images, graphics, video, data tables, graphs, text

3. Data collection--using technology to extend the senses

- Remote scientific instruments accessible via networks
- Microcomputer-based laboratories, with sensors for temperature, motion, heart rate, etc.
- Survey makers for student-run surveys and interviews
- Video and sound recording

4. Data analysis

- Exploratory data analysis
- Statistical analysis
- Environments for inquiry
- Image processing
- Spreadsheets
- Programs to make tables and graphs
- Problem-solving programs

B. Media for Communication

1. Document preparation

- Word processing
- Outlining
- Graphics
- Spelling, grammar, usage, and style aids
- Symbolic expressions
- Desktop publishing
- Presentation graphics

2. Communication--with other students, teachers, experts in various fields, and people around the world

- Electronic mail
- Asynchronous computer conferencing
- Synchronous computer conferencing (text, audio, video, etc.)
- Distributed information servers like the World-wide Web
- Student-created hypertext environments

3. Collaborative Media

- Collaborative data environments
- Group decision support systems
- Shared document preparation
- Social spreadsheets

4. Teaching Media

- Tutoring systems
- Instructional simulations
- Drill and practice systems

- Telementoring

C. Media for Construction

- Control systems--using technology to affect the physical world
- Robotics
- Control of equipment
- Computer-aided design
- Construction of graphs and charts

D. Media for Expression

- Drawing and painting programs
- Music making and accompaniment
- Music composing and editing
- Interactive video and hypermedia
- Animation software
- Multimedia composition

Here are some examples of what we mean by these categories and subcategories.

A Systematic Test of the Taxonomy

In order to test this taxonomy, the authors looked for a set of current efforts to conduct research and development of educational technologies which to classify according to this taxonomy. The second author had a research project funded by the National Science Foundation's program in Applications of Advanced Technologies (AAT) in its Directorate for Education and Human Resources. At a meeting of the Principal Investigators of all those projects in June 1996, he received a short description of each of the funded projects, along with a longer presentation by most of the PIs. The short descriptions are also now on the World-Wide web <http://red.www.nsf.gov/EHR/RED/AAT/AATABS96.htm>, as well as in Appendix A of this paper. The two authors independently classified each project according to the taxonomy presented here and met to reconcile minor differences in their classification of the projects. We then sent the URL for a web-based draft of this paper to each of the Principal Investigators of the NSF-funded projects in Appendix A and invited their comments both on our classification of their individual projects and on the taxonomy as a whole. Many of them made helpful comments and several suggested minor modifications in the assignment of their project to categories. Usually, such comments were of the form, ?itŒs also in ...? or a shift within one of the four major categories. Here is the taxonomy filled in with the names of the Principal Investigators of the projects that exemplify the different categories.[4]

Taxonomy with Exemplars

A. Media for Inquiry

1. Theory building

- Model exploration and simulation toolkits

  Forbus, Garik, Guzdial, Horwitz, Kaput, Lewis, Resnick, Soloway, Stephanopoulos, Wilensky
- Visualization software

Edelson, Greenberg, Kaput, Pea, Soloway, Stanley

- Virtual reality environments

  Loftin
- Data modeling

  Soloway
- Procedural models
- Mathematical models
- Knowledge representation

  Papert
- Knowledge integration

  Jacobson, Linn

2. Data access

- Hypertext and hypermedia environments

  Jacobson
- Library access and ordering
- Digital libraries

  Atkins
- Databases

  Garik, Loftin, Soloway
- Music, voice, images, graphics, video, data tables, graphs, text

3. Data collection

- Remote scientific instruments accessible via networks

  Barstow, Songer, Sadler
- Microcomputer-based laboratories

  Kaput, Nemirovsky, Nolet, Soloway, Tinker
- Survey makers
- Video and sound recording
- Real-time data access

  Pearlman, Soloway

4. Data analysis

- Exploratory data analysis

Nolet, Pearlman
- Statistical analysis
- Environments for inquiry

  Linn, Pea
- Image processing

  Barstow, Bamberger
- Spreadsheets
- Programs to make tables and graphs

  Nolet
- Problem-solving programs

B. Media for Communication

1. Document preparation

- Word processing
- Outlining
- Graphics
- Spelling, grammar, usage, and style aids
- Symbolic expressions
- Desktop publishing
- Presentation graphics

2. Communication

- Electronic mail

  Klotz, Levin, Verona
- Asynchronous computer conferencing

  Levin, Rowe, Verona
- Synchronous computer conferencing

  Bamberger, Means
- Distributed information servers

  Klotz, Levin, Linn
- Student-created hypertext environments

  Levin

3. Collaborative Media

- Collaborative data environments

  Bamberger, Pea, Tinker

- Group decision support systems

  Soloway
- Shared document preparation
- Social spreadsheets

4. Teaching Media

- Tutoring systems

  Anderson, Baker
- Instructional simulations

  Forbus, Greenberg, Guzdial, Horwitz, Kaput, Lewis, Stephanopoulos, Wilensky
- Drill and practice systems
- Telementoring

  Means

C. Media for Construction

- Control systems
- Robotics

  Resnick, Nemirovsky
- Control of equipment
- Computer-aided design

  Fischer
- Construction of graphs and charts

D. Media for Expression

- Drawing and painting programs
- Music making and accompaniment
- Music composing and editing
- Interactive video and hypermedia
- Animation software
- Multimedia composition media

Discussion

Many projects appear in more than one place in the taxonomy. Often this is due to the complexity of the projects, each consisting of different elements, which fit into different parts of the taxonomy. Some projects even have as a goal the integration of different aspects of learning represented by different parts of this taxonomy. In some cases, the authors had to add new subcategories of the four major categories, since these projects are developing innovative uses of technologies for learning that did not exist when the taxonomy was first developed.

It is interesting to look both at where these projects cluster in this taxonomy, and also at the areas that are left vacant. Below is a table providing a count of the number of AAT projects in each of the four major categories.

Table 1
Number of Entries in Each Taxonomy Category

Category	AAT projects
Inquiry	43
Communication	27
Construction	3
Expression	0

Note: Several projects appear in more than one category and subcategory.

The first two categories (inquiry and communication) are heavily represented by the AAT projects, while the latter two are much less so. This pattern may be entirely appropriate, given the emphasis on mathematics and science learning. It would be interesting to compare a comparable set of projects in other curricular areas.

None of the AAT projects were classified as being examples of the "educational media for expression" category, even though multimedia figures prominently in many of the projects. But personal expression in the sense Dewey meant is not emphasized in these projects. This may be a new area for research and development with educational technology.

Summary

We have outlined a new way of classifying uses of educational technologies, based on a four-part division suggested by Dewey: inquiry, communication, construction, and expression. This taxonomy covers more of the current uses of educational media than previous taxonomies, including many of the cutting-edge uses of educational technologies. We have tested the utility of this taxonomy by using it to classify the set of "advanced applications of technologies" supported by the National Science Foundation. And we have used the taxonomy to point to new possible uses of technologies to support learning. We hope that this taxonomy can serve as a starting point for further explorations of innovative powerful uses of technologies to support learning and teaching.

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Appendix A

Descriptions of the AAT projects

We classified those that were funded as of June 23, 1996.

Footnotes

[1]This is a good time to suggest additions, better examples, criticisms, questions, and more!

[2]Also known as Karl Linné.

[3]As this taxonomy grew, Michael Waugh, Kathleen Devaney, and many others contributed to its development and helped to refine and shape it.

[4]We sent the URL for this paper to each of the Principal Investigators of the NSF-funded projects classified here and invited their comments on our classification of their projects.

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