CURRENT TRENDS IN EDUCATIONAL TECHNOLOGY RESEARCH

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ABSTRACT

Educational technology research has moved through several stages or “ages”, focusing at the beginning on the content to be learned, then on the format of instructional messages and, finally on the interaction between computers and students. The present paper reviews the research in technology-based learning environments in order to give both a historical perspective on educational technology research and a view of the current state of this discipline. We conclude that: 1) trends in educational technology research were forged by the evolution of learning theories and the technological changes, 2) a clear shift from the design of instruction to the design of learning environments can be noticed; 3) there is a positive effect of educational technology on learning, but the size of the effect varies considerably; 4) learning is much more dependent on the activity of the learner than on the quantity of information and processing opportunities provided by the environment.

KEYWORDS: educational technology, computer-based learning, learning environments, research methods, virtual reality.

Computer technology and the tremendous development of information technologies over the last few years have transformed the way education is conducted nowadays (Lou et al., 2001). Although computer technology has the potential of a powerful and flexible tool (Scardamalia & Bereiter, 1996), the previous experiences with the integration of early technologies in schools (e.g., radio, television, early computer-assisted instruction) underline the fact that the mere installing of hardware does not lead to desired results (Clark, 1983). Thus, the main question, research tried to find an answer for, was and still remains whether computer technology is benefic for the learning process and if yes, in which conditions?

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The “proper research of educational technology” has represented the subject of a debate for more than a decade (Lagemann, 2000; Levin & O’Donnell, 1999; Shavelson & Towne, 2002; Slavin, 2002). Despite the accumulated experience in conducting research and publishing results in specialized journals, there is no consensus regarding methods that are used, or results and interpretations that are given to them (Hannafin, 2006). Reeves (1993) claimed that an important part of the research in the educational technology field is “pseudoscience”, because it fails in meeting the high level of theoretical, conceptual, methodological and/or analytical requests of the paradigm that it is based upon.

The purpose of this article is to review the research performed in the educational technology field in order to understand the nature of questions and problems that researchers had to face in this field over the years, and also to place the current research in the context of educational technology research.

THE EVOLUTION OF RESEARCH IN EDUCATIONAL TECHNOLOGY

The field of educational technology found its origins in the discovery made by researchers and practitioners of the fact that the instruction can be planned, projected, evaluated and revised before being applied on students. In other words it can be treated as an object on which a set of procedures, (i.e., technologies) can be applied (Winn, 2002).

Educational technology is, according to the definition of the Association for Educational Communications and Technology (AECT), “…the theory and practice of design, development, utilization, management and evaluation of processes and resources for learning” (Seels & Richey, 1994, p. 231). Another definition is the one offered by Reisser (1987), who states that educational technology is the systematic way of designing, utilization and evaluation of the teaching/learning process, in terms of specific objectives, based on research in human learning and communication fields and on combining human and technical resources.

The research made in the educational technology field, according to Winn (2002) has moved through four stages or “ages”, each being built on the previous one and each of them being characterized by a specific focus, specific theoretical assumptions and practical implications.

In what follows, we will review the “ages” of educational technology research, discussing the key theoretical issues, the research directions and the weakness associated with each of these stages.

The age of instructional design - a focus on content

The main topic of the research during this period, starting from the ‘50s was related to what content should be taught by using technology and how it should be organized. The performance criterion was related to teacher performance.
In other words, an educational technology is effective if it can be used to teach the same contents with the same learning outcomes as teachers do.

Robert Gagné had an important contribution, by this time to the instructional design research, stating that knowledge acquisition could be facilitated by hierarchical sequencing of instruction, from subordinated knowledge to more complex abilities (Gagné, 1962; White & Gagné, 1978). The main idea of this theory was that former learning of some prerequisite knowledge facilitates later acquisition of higher-order skills, but this doesn’t happen when the prerequisites are learned out of the learning sequences (Gagné, 1962; White & Gagné, 1978). Also, Gagné (1968) proposed a descriptive theory of the instructive strategy that includes nine events, which, in his opinion, are critical for an efficient instruction. The sequence of events are: (1) gaining attention, (2) informing the learner about the objective, (3) stimulating recall of prerequisite learning, (4) presenting the stimulus material, (5) providing learning guidance, (6) eliciting the performance, (7) providing feedback about performance correctness, (8) assessing performance, (9) enhancing retention and transfer.

Capitalizing on these ideas, educational technologies have tried to create tools aiming to maximize learning outcomes of the students. Gagné and Briggs (1979) provided prescriptions for each of these instructional events, based on the type of learning - intellectual abilities, cognitive strategy, verbal information, attitudes, motor abilities (according to the descriptive theory of knowledge, elaborated by Gagné) - combining them in a matrix with five different models of instruction. The work of the two authors had at least two major consequences for the instructional designers (Reigeluth & Curtis, 1987):

1) it provided a comprehensive and useful framework integrating several prescriptions about specific components of the instructional strategy;
2) it emphasised the idea that different models of instruction are needed for different learning situations and the idea that the most important factor for a learning situation is the nature of the content that has to be learned.

In this period, the task analysis becomes the main tool of organizing the teaching content. Probably the most widely accepted approach to the analysis of tasks was proposed by Gagné (1985) and is referred to as hierarchical task-analysis. This approach entails the identification of a hierarchy of subskills such that lower-ordered skills or behaviors generate positive transfer to skills at a higher level. Thus, the purpose of hierarchical task-analysis is to reveal prerequisite skills, and not to describe the steps of a task or procedure (Merrill, 1987).

According to Winn (2002) the main purpose of educational technology in that period was to make the computer assisted instruction as good as the one delivered by the teacher and so, the early educational software tried to teach the same content the teachers teach and in the same way. Therefore, the main research method used in that time was the so-called comparison of media, i.e., comparing the computer-assisted teaching (as a substitute of teachers) with the traditional instruction delivered by the teacher.
Kulik et al. (Kulik, 1992; Kulik et al., 1980; Kulik et al., 1983; Bangert-Drowns, Kulik, & Kulik, 1985) conducted some metaanalyses concerning the effect of computer-assisted instruction on learning performance at several educational levels: primary, secondary and college. The magnitude of the effects varies across elementary, secondary, and college samples. Studies with elementary school students found that the average improvement at school performance was .47 standard deviations or a "medium" effect (Kulik, Kulik, & Bangert-Drowns, 1985). Studies with secondary school students found that the average improvement was .40 standard deviations, another "medium" effect (Kulik et al., 1985), whereas with college students the average improvement was the smallest, with .25 standard deviations (Kulik et al., 1980). Later, Kulik (1994) revised the results of 12 metaanalyses concerning the effectiveness of computer-based instruction and he found an average effect size, varying from .22 to .57 depending on the type of instruction and the instructional level of the recipients. He concluded that although all the metaanalyses indicate that computer-based instruction improves on average academic achievement, they differ in the size of desired benefits, which leads to a more detailed analysis of the factors that determine the variation of results.

The studies of media comparison, were plagued by a series of criticisms addressed by some researchers (Clark, 1985; Hagler & Knowlton, 1987; Shlechter, 1986; Salomon & Gardner, 1986). The main argument is that in this kind of studies the researchers fail to control variables such as: content, methods of teaching, the novelty brought by computers. For example, Clark (1985) concluded in his article that 75% of the examined studies had serious design problems, 50% failed in controlling the timing of the task and only 50% controlled the instructional method.

The main concern of this period was not what to teach and how to organize the content, but rather which format is the most appropriate in order to improve learning.

In this period, a special attention was given to the way the information should be constructed or to the “message design” (Fleming & Levie, 1993), especially that several studies were showing that students with different abilities and skills learn in a different way, according to the format in which the content is presented. The researches emphasized that individual differences in aptitudes not only predict individual differences in learning from instruction, but they also interact with alternative instructional treatments. This kind of interaction between individual differences and instructional treatment conditions is called “aptitude-treatment interaction” (ATI), where the aptitude is defined as any individual difference measure related to instructional results, and the treatment is any variation in introducing instructional content to students.

The main idea of this approach is that there is no optimal instructional method for all the students, some being more appropriate for students with
particular characteristics, and others for students with other characteristics. The conclusion extracted after revising the ATI literature was that “no Aptitude x Treatment interactions is so well confirmed that they can be used directly as guides to instruction” (Cronbach & Snow, 1977, p. 492).

Therefore, one of the major problems in the field of ATI has been the inconsistency of research findings, Cronbach and Snow (1977, see also Tobias, 1987) stating that the number of significant results was almost equal to the non-significant ones. But, even more intriguing has been the fact that, when significant effects of the aptitude-treatment interaction were reported, they were difficult to replicate. All these problems determine the authors to assert that results from ATI research have to be limited to a particular location and population (those proposed for research) and they should not be generalized. In other words, the impact of any format of teaching material is contextually determined.

The ATI approach helps however instructional designers to understand, evaluate and improve the instruction so that all students benefit from a particular educational situation. They learned that there is not instructional format generally useful. They should calibrate the format to particular constrains of the learner and his/her context. Educational technology researchers continued (and they still continue today) to respond to some questions that were left without answer: how much aptitude for learning should be built into the instructional treatment and how much should be required from the student, in any given instance (e.g., see Salomon, 1993).

Another topic of concern for educational technologists in this period is related to the “message design”. According to Fleming (1987) the design of displays, that transmit information, is not a stand-alone part of the instructional development process, but develops from previous analyses of the learner’s characteristics, tasks, and learning situations.

The principles regarding the “message design”, that Fleming considered to be the most important have been selected from four cognitive domains: 1. attention (influence on attention comes both from the display and from the learner, and the designer has some control of both), 2. perception, 3. learning (learning is limited by what the learner perceives, and that can be influenced directly by the designer) and 4. concept formation (because a concept is more than its label, concept formation requires a higher cognitive process, a generalization across a varied set of examples, so designers have to be assisted in moving learners from memorization to conceptualization processes).

In order to summarize these principles, Fleming (1980) used a four-components model of the learner. In Fleming’s view, the learner actively seeks stimulation (information) in the environment, is attentive to order (regularities) there, requires some strategy for dealing with those stimulations and regularities, and as a general consequence of this ongoing process derives meaning from the environment.

The following principles could be grouped under stimulation cluster:

- the attention principles: selectivity and novelty
the learning principles: concreteness, prior knowledge, and salient criterial attributes;
the concept formation principles: varied examples, and close-in nonexamples.

The following principles could be grouped under the order cluster:
- the perception principles: organization, similarity, and proximity contiguity;
- the learning principles: limited capacity, similarity, and primacy-recency;
- the concept-formation principle: simultaneous display of examples.

The following principles could be grouped under the strategy cluster:
- the perception principle: expectancy;
- the learning principles: activity, strategy, mental imagery, and elaboration.

Under meaning could be grouped the attention principle: uncertainty and the learning principles, meaningfulness and feedback.

According to Fleming, the principles presented as guidelines to instructional design should be stated in a language and format that translates readily to practice. These principles are expected to inform the creative processes of the designer, increasing the probability of wise decisions without guaranteeing them. Thus, he emphasized that, although the principles are based on large bodies of research, testing prototype designs is essential, followed by redesign and retesting as needed.

Winn (2002) stated that a comparison of first and second editions of Fleming and Levie’s book (Fleming & Levie, 1978, 1993) shows that not only the ability to deliver instruction in different formats has changed dramatically over time, but also the underpinning theory of message design has maintained the pace with developments in research on learning and instruction.

The age of simulation - a focus on interactions

A major conceptual shift brought by the constructivists in the 80s is a switch of attention from how the information is presented (or "message design"; Fleming & Levie, 1993), to enhancing the learner to use the medium in order to arrive at a unique and idiosyncratic understanding (i.e., how the information is assimilated).

The cognitive constructivist view of learning claims that an active, self-regulated, goal-directed and reflective learner constructs personal knowledge through discovery and exploration in a responsive learning environment. This constructivist environment can be activated by interactive technologies that can adaptively and intelligently respond to for-the-moment learning needs.

In this context a long-standing debate in the instructional design field began in the 80s between advocates of media solutions to learning improvements...
and those who continued to question the effect or influences of media on learning. The main protagonists of this debate were Richard Clark and Robert Kozma.

After reviewing a number of meta-analyses and studies regarding the influence of media on learning, Clark (1983) concluded that they often confounded the media with the content or the method. He also asserted that acquisition of knowledge is possibly due to the last factors and not to the medium itself. Thus, media per se does not influence learning, this one being caused by instructional methods that are included in the medium. In Clark’s (1994) view, an instructional method is any mean giving shape to information that activate, supply or compensate cognitive processes necessary for acquisition and motivation.

Because Clark stated that „media are mere vehicles that deliver instruction” (Clark, 1983, p. 445), he concluded that media „do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition” (Clark, 1983, p. 445). Another argument offered by Clark (1983, 1985) was that, aside from a few advantages on the efficiency of media helping students learn, they have no intrinsic properties that make them instructionally effective. In other words, there is nothing that can be done to teach through media that cannot be done by a teacher. He also asserted that research had often shown a slight advantage for learning from new media, comparing to conventional instructional vehicles, but this advantage is vulnerable to compelling rival hypotheses (e.g., confounding variables, Clark, 1983, such as instructional method or content differences and the novelty effect of newer media which tends to disappear over time).

Unfortunately, the shortcomings of the educational technology research, observed by Clark and Snow (1975) are still evident today (Bernard et al., 2004; Clark, 2001; Clark & Estes, 1998, 1999). Feldon and Yates (2006) stated that, according to Clark, much of the research in educational technology is rather the practice of a craft, than of a technology. “Whereas technology is the application of a scientific principles to solving real-world problems and the generalizability of solutions, craft is characterized more by situated trial and error and solutions that are indeterminate, non-transferable and unconnected to a systematic knowledge base. Further, the result of this confusion in practice of educational technology is reflected in research studies that report «no significant differences», that fail to isolate «the active ingredient» for effect attribution, and that are not generalizable to other contexts” (Feldon & Yates, 2006, p. 5).

Robert Kozma is opposing to Clark, his main argument being that medium and method have a integral relationship, because both of them are part of the design. He asserted that, separating media from the method, Clark created an undesired ‘schism’ between the two of them. In his opinion, method must be intricated with medium, if media are going to influence learning.

According to Kozma (1991, 1994), various aspects of the learning process are influenced by the cognitively relevant characteristics of media: technologies, symbol systems and processing capabilities. The value of this debate has been challenged by many researchers (Jonassen et al., 1994) on the grounds that the
question of whether media affects learning is not a fundamental one and that inevitably leads to a misconception. It is meaningless to determine a “super medium” that will produce an efficient learning and to expect significant academic achievements, just by coming in contact with that particular medium (Samaras et al., 2006).

Moreover, technologies, and with them the media and the symbol systems they support, have changed considerably since the acid critique of Clark in 1983. Reviewing the literature, Kozma (1991) drew attention to a shift in the instructional function of media from a didactic one to creating learning environments that allow students the freedom of exploration and encourage them to construct their own knowledge (Seel & Winn, 1997). This position reflects the recent rediscovery of “constructivism” by instructional designers (Bednar, Cunningham, Duffy, & Perry, 1991; Duffy & Jonassen, 1992), and a number of media-based instructional simulations, which emphasize active construction of knowledge by learners.

The most important feature of simulations is that of allowing students to experimentally act and discover some phenomena by doing, not only by observing them. They allow learners to construct new knowledge from the experience, using concepts and capabilities they already possess.

However, diagnostic functions are more difficult to be designed, as the degree of student control increases, and many students need additional guidance to take advantage of discovery treatments. For example, Pea and Sheingold (1987) found that many students needed more structure to think about what to do on computers; fully self-directed learning worked well for only a few (i.e. the best learners). Again, research showed that skillful students do well in discovery whereas less skillful students and those with little prior knowledge perform poorly. Guided discovery programs (for example, ThinkerTools in order to address learning difficulties that students have in Newtonian mechanics) (White 1984,1993) introduce a goal structure and various forms of assistance according to the student’s specific needs (Seel & Winn, 1997).

“The new age” of research - a focus on learning environments

In line with the evolving conception of situated cognition and computer-supported learning (see Brown, 1989), there is a clear shift nowadays toward supportive systems that are less structured and less directive, that are more focused on coaching than on tutoring, and that attempt to integrate both tools and coaching strategies in collaborative learning environments (see Kaput, 1992). A learning environment is a system that consists of interrelated components that jointly affect learning in interaction with (but separately from) relevant individual and cultural differences (Salomon, 1991).

The researchers have asserted that an artificial environment could serve to achieve some specific learning objectives through so-called cognitive...
apprenticeship (Brown et al., 1989) or professional apprenticeship (Lave & Wenger, 1991).

As Vosniadou (1996) has put it, substantial changes have occurred in the conceptualization of learning in the last decade, changes that had important implications for the construction of technology-supported learning environments. One of these changes is reflected in the analysis of knowledge as an activity that takes place among individuals in specific contexts, rather than as a substance contained in the mind of individuals independent of context (e.g., Brown, Collins, & Duguid, 1989; Cognition and Technology Group at Vanderbilt, 1990; Resnick, Levine, & Teasley, 1991). This approach, known as “situated” or “anchored” cognition points out that learning cannot be easily separated from the "act of knowing" and that "what is learned" is an integral part of "how it is learned and used". Situated approaches to cognition emphasize the need to construct learning environments that engage students in meaningful and purposeful activities. Thus, the content of cognition (what is known) and the process of cognition (how it is known) cannot be separated from the context and the act of knowing. Consequently, educational technology is seen as a major tool to create adequate learning environments where enhanced situated cognition takes place.

Another related change centers around the approach of learning as a developmental and internalizing process that occurs first in the social, interpersonal domain, and only then becomes intrapersonal. Following the writings of Vygotsky (1978), a number of researchers agree that learning is not an endogenous generated process, but is an activity that has its roots in participation in sociocultural interaction (e.g., Lave, 1988; Saxe, 1990). The implication of this view is that it is important to design learning environments that facilitate social interaction and cooperative learning in the classroom (Vosniadou, 1996) as a premise for a successful internalization of distributed learning.

A strong candidate for creating learning environments seem to be, in the last years, the technologies of virtual reality. Some aspects of the use of virtual reality in education will be presented below.

Recent research has indicated that virtual reality has the potential to immerse the learner in various situations (e.g., the surface of the Moon, the invisible physical forces), visualize information (the temperatures of a frontal system), see hidden phenomena (forces directed on an object or a tumor in a body), in other words helps the students understand concepts and processes that the virtual environment represents (see McClellan, 1996; Olson, 1998; Winn, 1995).

Virtual reality is already in use for learning astronomy (Barab et al., 2000), meteorology (Hay, 1999), physical oceanography (Winn & Windschitl, 2000), global warming (Jackson, 2000), etc. For example, using generic virtual reality construction tools, Barab et al. (2000) supported students in building a Virtual Solar System in order to develop a more realistic sense of the relative interactions of the Sun, the planets, and their moons and in the process of challenging previous astronomical misconceptions.
The Virtual Solar System (VSS) is a learner centered, project-based astronomy course in which students work in dyads and triads in order to build models of different aspects of the Solar System.

So, one of the system characteristics is that it requires students to work collaboratively with others as they negotiate goals, tasks, practices, and meanings (Blumenfeld et al., 1996; Savery & Duffy, 1996). As such, the role of group dynamics and the need for supporting positive interactions in which all members have legitimate roles become central (Johnson & Johnson, 1990, 1994; Slavin, 1995).

Because, the center of this learning environment is not the teacher’s fixed curricular objectives, but rather the learners’ emergent practices in relation to the need at hand, it should be considered an inquiry-based, participatory learning environment (Barab et al., 1998). By supporting participatory learning environments, educational technology has moved from a “teacher curriculum” to a “learner curriculum” (Lave & Wenger, 1991), or from an “acquisition” metaphor to a “participatory” metaphor (Sfard, 1998).

Another interesting characteristic of virtual reality technologies (e.g., of the Virtual Solar System project) is that it allows the students to build 3-D models of different aspects of the solar system, using CosmoWorlds, a VRML editor, on average desktop personal computers. According to Barab et al. (2000) whereas immersive virtual reality places students in the virtual world, the software being used in this project simulates a 3-D environment on a 2-D screen, providing the user with what McClellan (1996) referred to as a “window-on-the-world.” It is in fact a real achievement of the system, because some studies found that developing an understanding of an inherently 3D concept from a 2D diagram or image is a challenging task for many students (Copolo & Hounsell, 1995; Khoo & Koh, 1998). Barab et al. (2002) concluded that given the power of current technologies, educators could easily find ways of integrating 3-D technologies into learning environments in order to improve and deepen students’ understanding of the content, to empower students with the tools of scientists, and to do so in a fashion that is financially viable and sustainable.

In a second version of the Virtual Solar System project, Keating et al. (2002) used a VRML system in which the students built their own virtual representations of the Sun–Earth–Moon system. They evaluated the students’ conceptual understanding and summarized their findings by stating that 3D computer modeling provided students the possibility to visualize abstract 3D concepts such as the line of nodes, and transform them into conceptual tools, which in turn, supported the development of scientifically conceptual understandings of many essential astronomical subjects. However, there were cases where students’ conceptual understanding was incomplete and frequently hybridized with their preexisting conceptions.

To resume, there is no doubt that the technologies of virtual reality may provide the learner with much many information of “the hidden” aspects of the world. They enrich the learner with a large range of experiences. However, we
must emphasize again that learning is a phenomenon much more dependent on the processing taking place in the head of the learner than the information or processing opportunities provided by a learning environment. Much work is still needed to be done in the future to reveal the real impact of virtual reality on learning.

CONCLUSION

A number of conclusions can be drawn from the review of the educational technology research:

1. Trends in educational technology research were forged by two main factors: a) the evolution of learning theories from behaviorism to cognitivism and latter on to constructivism and b) the technological changes, from learning machines to technologies of virtual reality.

2. The evolution of educational technology use in learning was itself influenced by the dominant scientific paradigm and the affordances of the tools created.

3. A clear shift from the design of instruction to the design of learning environments can be noticed. This is not just a shift from content-focused to learner-focused instruction, but also an acknowledgement that learning outcomes are owned by the learners and the technology should empower them to reach their idiosyncratic learning goals.

4. There is a positive effect of educational technology on learning, without any doubt, but the size of the effect varies considerably. The variance is due to factors of context, aptitudes of the learner and the characteristics of technology. Therefore, if one wants to evaluate the impact of a particular educational technology, the valid question to ask is the following: what technology used in what context, interacting with what characteristics of the learner? Any evaluation is inevitably local, because learning is a local, contextual, concrete phenomenon, not an abstract process.

5. We should emphasize that learning is much more dependent on the activity of the learner than on the quantity of information and processing opportunities provided by the environment. In other words, the key of successful application of media in learning is not so much how the “message” itself is presented, but the degree to which students are motivated to exploit the environment in order to achieve their personal learning goals.

REFERENCES


