The future of multimedia learning: Essential issues for research

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Abstract
Research into teaching and learning with new technologies is currently a very dynamic, high-profile and relevant area of educational enquiry. Educational institutions are increasingly engaged with integrating technology into the delivery of course materials and in the provision of alternate methods for learning. The extent to which these efforts are based on sound principles established through research and experience is a matter for debate. Research findings validating educational outcomes in the use of new technology are often contradictory, as research approaches tend to lag behind the capabilities of technology. Many studies in educational technology studies show a lack of an appropriate theoretical grounding and regard for scientific empirical testing. This paper examines some historical approaches to researching educational technology, highlighting the weaknesses inherent in these research programs. Some contemporary research strategies are discussed and recommendations for future investigations are made: 1) Evaluations should be performed on already implemented interventions including craft technologies to generate valid hypotheses; 2) The relevant array of theoretical foundations should ground all studies and intervention developments; 3) Alongside technological principles, motivational issues should be considered; and 4) Aspects of the media debate should be reconsidered in light of new research.

Introduction
Technology and education have long been intertwined (Cuban, 1986), but never has the movement to merge the two proceeded with more vigor. Over the past twenty years, the prevalence of computers in the home and workplace has increased exponentially matching the astronomical trends in technological manufacture (Schaller, 1997). The development of the Internet has revolutionized how people communicate and introduced a new genre of entertainment. Currently, technology development is undergoing an expansive overhaul; memory capacities and processor speeds are ballooning, instigating corresponding growth in the content and bandwidth of the Internet (Schaller, 1997; Heyneman, 2001). Educators recognize the significance of this global trend and are eager to bring education up to speed (Fluck, 2001). Authoring software is increasingly available and easy to use, enabling disciplinary experts to digitize their lessons. Along with this trend come the growing repositories of learning objects, educational resources that range in complexity from text or graphics to dynamic simulations (Conole, 2002; Friesen, Roberts and Fisher, 2002).

The potential for improved learning does not easily translate into practice, however. Technology’s record of failing to deliver on expectations has been well documented (Cuban, 1986; Clark, 1983), and has promoted a general skepticism among educational administrators and practitioners. On the whole, research in the field of educational technology when compared with other sciences is inconsistent, fragmented, and struggling to keep up with developments in technology itself. This is remarkable given the incredible amount of effort and money invested in this field. Some advances have been made in developing new instructional technologies and in understanding how learners interact with media; however, a holistic view of educational technology research and its future remains elusive. In a series of papers, Clark and Estes (Clark and Estes, 1998; Estes and Clark, 1999; Clark and Estes, 1999) assert that the “gradual eroding and splintering of [their] field,” (1998, p.6) is a crisis created by a lack of substantial research, aggravated by a reliance on intuition and enthusiasm for new technology. Other researchers acknowledge that the rapid advancements in technology have developed ahead of the research required to support them (Mayer, 1997; Rieber, 1990). Despite some promising current research programs, the overwhelming consensus is that “with few exceptions there is NOT a body of research on the design, use, and value of multimedia systems,” (Moore, Burton, and Myers, 2004;
emphasis in original). There are two major issues here: the problem of technology development and the problem of implementation. Although these issues are related, they are not inseparable. This paper focuses on the development of technology-enhanced instruction and the research supporting it, with the underlying assumption that when technology has been proven effective, its implementation should proceed effortlessly. The reasons for the failings of previous research are first outlined, followed by a set of specific recommendations for future research.

**Research on Educational Technology**

In the research literature on learning with technology, history has certainly repeated itself. After the introduction of each new commercial media technology, inventors and marketers have made outlandish forecasts about the technology’s impact on education. A famous example is Thomas Edison’s prophesy for the motion picture: “I believe that the motion picture is destined to revolutionize our educational system and that in a few years it will supplant largely, if not entirely, the use of textbooks,” (Thomas Edison, 1922). Similar statements were made about radio, television, video, interactive video, the computer, and the Internet. These technologies have clearly not lived up to expectations (Cuban, 1986). Although this is due in part to practical constraints, researchers have had difficulty establishing the learning advantages of technology in theory (Clark, 1994; Kozma, 1994a).

Three main obstacles have hindered the progress of educational technology research. First of all, proponents of technology have used the enthusiasm, assumptions, and excitement surrounding technology as substitutes and sometimes rebuttals for empirical evidence. Secondly, until recently studies sought to uncover the advantage of one medium over another without considering how learning occurs and how the media concerned differ in this respect. Finally, although technological interventions are frequently developed and used, they are rarely based on or employ well-structured research. The combination of these factors has created a crisis whose only resolution lies in authentic, theoretically based research.

**Assumptions and enthusiasm: the technology centred approach**

Shouldn’t moving images be more effective for learning than static ones? Shouldn’t interactive multimedia be far superior to linear presentations? These questions seem simple and imply intuitive answers, but they have plagued educational researchers and practitioners for decades.

Since the industrial revolution, technology has transformed nearly all aspects of life, from agriculture and transportation to modern culture. It seems only reasonable that one would expect technology to have an analogous impact on education. Science and technology have achieved great successes, increasing productivity, lowering costs and improving the quality of life for many. In doing so, they have become a goal in themselves, a hallmark of progress and advancement and a recipe for resolution to societies’ ails (Jonassen, 1988). It is in this context that many educational technologists have directed their research, to expand the applications of technology to new realms.

The novel capabilities of educational technology are incredibly exciting, fuelling an enthusiasm for their application to educational problems. Computer storage and processor speeds are growing exponentially, accompanied by similar growth in software development (Schaller, 1997). This enables 3-D systems (Dalgarno, 2004), microworlds, and other inspiring visual environments. It also enables a wider range of developers to create and tune multimedia presentations. The novel capabilities of technology have become its merits and excite growing interest in the field of educational technology.
It seems intuitively obvious that a dynamic presentation should be more effective for teaching than a static one. If one is trying to explain the workings of a dynamic system, a grandfather clock for example, it seems obvious that a dynamic representation can best describe the system (Lowe, 2004). Since means to display and even interact with such systems have never been available before, there is an underlying assumption that technology will facilitate learning better than traditional instruction. It can be easily demonstrated, however, that this oversimplifies the interactions between the learner and the medium. Contextual parameters must be specified scientifically to establish the best learning environment (Lowe, 2004). Intuition overlooks the important details of confounding factors, which technology promoters can gloss over.

Developers and marketers have used the interest and enthusiasm surrounding technology and the assumptions that increased functionality leads to increased learning to promote educational products. For Edison, the emphasis was on efficiency:

On the average we get about two percent efficiency out of schoolbooks as they are written today. The education of the future, as I see it, will be conducted through the medium of the motion picture ... where it should be possible to obtain one hundred percent efficiency. (Thomas Edison, 1922)

Similar claims are not restricted to a bygone era. Even after widespread publicity of the patterned failings of technological interventions (Clark, 1983; Cuban, 1986), promoters continued to predict incredible futures for new innovations (for example, see Semrau, 1994). This cycle continues even today, with technophiles often emphasizing the unique attributes of a new medium to explain how it will succeed where so many others have failed. These claims perpetuate the myth that functionality is equivalent to learning and foster enthusiasm for applying new technology.

**Practice of educational technology**

Educational technology is constantly being created, tested and implemented throughout the world at an amazing rate with incredible cost. This production is spurred by the rhetoric of technologists and the enthusiasm of interested individuals who believe that technology will revolutionize the practice of education. The fact that educational technology is produced everyday gives the field the appearance of maturity in terms of its research.

It would be a frustrating paradox, for a new researcher, to be confronted with established practices of instructional design on the one hand and little concrete research evidence validating these approaches on the other. Routinely, practitioners are producing multimedia and students are being trained in the discipline of instructional design despite the fact that the research to support these activities is distinctly incomplete. “It is also very troubling that most university-based educational technology programs have continued to abdicate their responsibility to confront these problems (Clark, 1978, 1989). The recent glut of students rushing to Internet-based, multimedia, distance education has not served to discipline our academic programs,” (Clark and Estes, 1999, p.5). The difficulty is that administrators and educators demand technological solutions immediately and technology is available to fulfill this demand. Therefore educational technologists must make due with what little reliable literature is published and use intuition or industry rules of thumb to make the balance of decisions. Blinn (1989) outlined a number of design criteria for educational animation, based on his work as an animator for a physics education video series. Although very useful, these guidelines are a starting point for investigation rather than established principles of best practice. Clark and Estes (Clark and Estes, 1998; Estes and Clark, 1999; Clark and Estes, 1999) have classified educational technology
produced in this way as “craft” solutions, uninformed by scientific research. They claim that it is this lack of concrete foundation that has led to the unreliability of technological solutions.

These craft solutions are the most common type of educational technology, and, since they are not developed scientifically, are unable to directly inform the body of research on learning with technology. This perpetuates the cycle of craft educational technology, further inhibiting progress in the field.

Research programs

For almost a century, the question that dominated educational technology research was which medium most effectively delivered information. Despite numerous studies and meta-analyses that yielded no significant difference results (for an overview, see Clark, 1983), researchers proceeded with this line of investigation. In fact, it has only been in the last decade that researchers in the field have moved to a constructivist paradigm. “It is time to shift the focus of our research from media as conveyors of methods to media and methods as facilitators of knowledge-construction and meaning-making on the part of learners,” (Kozma, 1994b, p.13).

Without the focus on learner cognition, early studies viewed the medium-learner system as a black box and experimented ad hoc without a clear understanding of the controlled and uncontrolled variables. For example, Baggot (as cited in Wetzel et al, 1994) conducted a study in which the audio and visual tracks of an instructional film were misaligned by 7, 14, or 21 seconds. Students were then tested for retention and were found to perform best when the tracks were most closely synched. Although this result seems obvious, it is better understood from the empirical studies of Mayer (1997) who based his hypotheses on Paivio’s (1971, 1986) dual coding theory and cognitive load (Sweller, 1994).

Summary

The common factor among the weaknesses of many previous educational technology studies is a lack of appropriate theoretical grounding and regard for scientific empirical testing. The perception of learners as passive absorbers of information and the practice of “craft” educational technology has led to unproductive research and ultimately to the separation of intervention development and supporting research. In the attempt to synthesize these two aspects of educational technology and forge new research foundations, researchers must learn from their mistakes.

Recommendations

The following are a series of recommendations that attempt to overcome the inadequacies in research created by historical methodological weaknesses, synthesizing studies suggested by Clark and Estes, Kozma, and Mayer. These recommendations are not intended to be comprehensive but serve to highlight a set of important, specific areas that require research and consideration.

Evaluation of Implemented Interventions

The ability to definitively say that one instructional technique is more effective than another on the basis of several pre-determined criteria is the ultimate goal of educational research. As such, evaluation is the most important aspect of any research program. Many educational technology
studies employ evaluations, both formative and upon completion of the project, but they are often qualitative and address attitudes only. Although this is a necessary and important area for evaluation, it is insufficient to determine whether the intervention is a better holistic educational solution than that which was previously in place. In addition, evaluations on newly developed interventions often show improved attitudes simply due to novelty (Clark, 1983) rather than actual educational advantages.

Evaluations are rarely carried out on already implemented interventions. This reflects researchers’ interests in exploring new educational technology, which, though understandable, does a disservice to the progress of research. Reliable evaluation must first exist before experimental intervention studies can be meaningful. For example, in physics education, before new teaching methods could be tested, a reliable measure of learning with traditional means was required. For Newtonian mechanics, the Force Concept Inventory (FCI) was developed (Hestenes, 1992). This is now used as a benchmark to determine conceptual gains of students in physics programs (Hake, 1998).

Evaluations of current interventions can provide the most relevant and accessible information required to develop new interventions of a similar type. “Often craft-based knowledge is the best and most useful knowledge we have in a particular area, at any given point in time,” (Clark and Estes, 1999, p.7).

This researcher was involved in conducting focus groups on a popular science video that is shown to first year students every year during lectures (Muller and Sharma, 2005). The aim of this study was to determine the aspects of the video that contributed most strongly to students’ perceptions of the video and the content. Findings showed that students appreciated many of the aspects of the video that were in line with Mayer’s (1997, 2001) principles, however students also commented strongly on the context. This is an area in which Mayer believes interesting but unrelated material must be excised. However, from the comments arising from the focus group, it appears that this would negate the affective impact of the video. The role of context and its integration with instructional material is therefore a topic of future investigation for this researcher.

Theoretical Foundations for Research and Intervention Development

There is a large array of theoretical perspectives to consider when researching or developing educational technology. Clark and Estes (1999) suggest three criteria for selecting relevant theoretical bases.

First, we need to choose the most comprehensive, experimentally verified theory that predicts the outcomes (problems to be solved) of interest to the new technology. Second, the independent variables and interventions described in the theory must be morally, ethically, and practically acceptable in the target application environments. Third, the theory and related experimental studies that provide evidence for the theory must permit a description of the “active ingredient” that causes or alleviates the problems being solved in a way that permits “no plausible alternative explanation.” (p.8)

These theories must be selected from a series of domains including discipline specific areas. Typically, multimedia interventions are developed without in depth research into the topic area since funding for such projects is allotted only after a detailed proposal has been made. While this system caters to the practical constraints for intervention development, it does little to advance
the cause of effective multimedia solutions. Fortunately, on some occasions a proposal arises out of previous research into learning difficulties, but most often this is not the case. Clark and Estes (1998) point out the need for more pre-planning for intervention development. It typically requires “much more ‘front end’ analysis of problems, but impulsive problem solvers are not inclined to wait,” (p.9). There is a strong argument for developing multimedia tools from within a disciplinary area to ensure appropriate treatment of the material and, more importantly, correct identification of the teaching and learning difficulties and their potential solutions (Kozma, 2000; Ridd, 2005). Kozma goes so far as to suggest all researchers or developers of educational technology should have a substantive degree in a discipline like chemistry or physics to better understand the problems to be addressed. At the very least, there is a need for interdisciplinary collaboration on projects.

Discipline specific learning theories are vital to intervention development, but so too is an effective working model of how students learn in general. The shift from conveyance to constructivist metaphors in educational technology has been evident in the literature for the past decade (Kozma, 1994b), yet new learning environments often reflect traditional knowledge delivery paradigms. “The designers of these applications themselves sometimes acknowledge these shortcomings and refer to e-learning as computer supported page turning,” (Kirschner, 2005). McLuhan (1964) showed that the content of any new media, at least at the outset, takes the form of the medium or process it’s replacing. It would seem that educational technology is still working through this stage.

It should also be acknowledged that theoretical perspectives on learning do not necessarily dictate instructional strategy. For example, ongoing debates about the merits of direct versus discovery instruction are not solved simply by taking a theoretical stance. Acknowledging that students are active participants in the learning process and constructors of their own knowledge does not necessitate direct or discovery instructional approaches. Perhaps the two methods can be used complimentarily, but this is a difficult topic to investigate as most researchers are either on one side or the other.

Fundamentally, all studies and interventions must be based on clearly defined theories to ensure research and development contributes to the overall body of knowledge rather than being independent of it.

**Motivation and Educational Technology**

No one denies the importance of motivation for learning, but exactly how to quantify such a concept in relation to the use of multimedia is a complex challenge. Motivation can range from intrinsic to extrinsic to amotivation. Intrinsically motivated learners tend to behaviorally and cognitively engage with learning tasks and their contexts whereas amotivated learners do not (Ryan and Deci, 2000). Extrinsicly motivated students, on the other hand, engage if the learning task or context appeals to them or has some perceived value, leading to situated motivation (see for example Paris and Turner, 1994).

Ryan and Deci (2000) focus on the nature of the three motivational types and try to determine whether it is possible to shift learners towards intrinsic motivation. Their model associates increased and more sophisticated regulation and reflection with increased levels of intrinsic motivation. Multimedia and computers have the capacity to allow for external regulation and autonomy support (Stefanou, Perencevich, DiCintio, and Turner, 2004). Technology also provides for context and variety in learning tasks that theoretically could be exploited to situate motivation.
The difficulty in measuring motivation due to its multiple facets (Weiner, 1990) has led researchers to depend upon self reports, assumptions or eschew the idea altogether when evaluating an intervention. Lowe (2004) divorces the motivational aspects of animation from its instructive power, reproaching technology enthusiasts whose “conviction is based upon the naïve view of the power of animation’s affective characteristics,” (p.558). Clark and Estes (1999), too, criticize motivation studies for impeding the progress of educational technology research. Mayer’s coherence principle (1997, 2001) states that instructional interventions must be stripped of all extraneous information that does not directly contribute to the learning task. This includes information that promotes interest in the instructional material. Mayer (2003) has however begun to investigate motivation effects as suggested by Reimann (2003), but this pertains only to phrasing of verbal material within an intervention rather than additional content.

Since motivation is difficult to define, measure, and control, research on the topic carries the stigma of being unproductive or highly subjective. It is vital, though, that this aspect of learning be considered in the design of educational technology or the range of potential instructional possibilities is artificially and likely critically impaired.

Future studies must not search for a motivational effect for the use of technology in education, as has been proven futile in the past (Clark, 1994; Clark and Estes, 1999). Rather, studies must seek to identify the methods employed in various media that can demonstrably and repeatedly enhance motivation. Furthermore, the range of applicability and other contextual contributors must be identified.

Media Effects

The question of whether one medium should be more effective than another for teaching has a long history in the literature on educational technology. Mayer (1997. p.7) calls it “a persistent, if somewhat unproductive question,” since the effectiveness of an instructional message depends not on the medium but the methods employed within it. “It is possible to produce effective and ineffective instruction in both computer-based and book-based media; moreover, in both media, ineffective instruction can be changed into effective instruction by applying the same basic principles,” (p.7; see also: Mayer, 2003). For this reason, Clark (1983) declared that no further research into the effectiveness inherent in different media be undertaken “unless a novel theory is suggested,” (p.457).

Since Clark’s review, some important paradigmatic shifts and theoretical advancements have occurred. First of all, educational researchers have embraced a constructivist view of learning as mentioned above. This is in stark contrast to Clark’s instructional delivery metaphors. Researchers such as Kozma (1991, 1994a) have furthered the notion that the attributes of a medium make possible different instructional methods (Kirschner, 2005), like multiple dynamic representations, for example (Ainsworth, 1999; Ainsworth and VanLabeke 2004; Kozma and Russell, 1997). A medium, then, is intrinsically neither better nor worse than any other but it possesses a potential set of attributes that can be exploited to greater or lesser degrees by an instructional designer. Clark (1994) argues that methods employed in any one medium, could be employed by another; whereas Kozma (1994a,b) believes certain media have unique attributes that cater to particular methods better than any other. Kirschner (2005) also recognizes these two common standpoints on this issue and views the media effectiveness question as open-ended.

Mayer (1997, 2001) has shown that using multi-modal instruction is more effective than using any single mode. In a way, this finding supports Kozma’s position and demonstrates that media
do impact learning, by the instructional possibilities they enable. For example, based on Mayer’s research, one could state that when used appropriately, the video medium should be more effective than radio since the latter cannot provide visual information.

Another principle of Mayer’s is the modality principle: verbal information is better presented as narration than as onscreen text when accompanying a visual presentation. This is because text causes the learner to split his attention between the animation and the verbal information, thus increasing extraneous cognitive load. For book-based media, Mayer’s contiguity principle states that words must be placed around the visual representations to which they refer to minimize a similar split attention effect. It should stand to reason then that providing the verbal information orally could eliminate this split attention effect altogether. Mayer stops short of this recommendation, however, presumably since this is beyond the capabilities of book-based media.

Mayer’s results show no evidence of this split attention effect, either. Learners often perform as well, if not better, when learning from static text media than from animations and narrations. Mayer uses these results in conjunction with the stigma associated with media comparison research to argue that no media is capable of facilitating knowledge construction better than any other.

This ignores the fact that the cognitive theory of multimedia learning, as put forth by Mayer (1997, 2001) predicts such an effect. There are many reasons why this effect may not be visible in Mayer’s studies. The pace of the animation may be too quick, increasing the extraneous cognitive load especially when learners have low prior knowledge. Since the verbal information does not cue the learners’ attention to particular aspects of an animation, they may not know where to look at all times (i.e. what exactly the narration is talking about). If it is equally likely that learners cognitively engage or not with any media, the transient nature of the animation means they cannot look back and fill in gaps in their understanding. If the information were not intrinsically engaging, it would also be more likely for learners to “tune out” of the animation since reading requires a certain threshold level of cognitive engagement.

The above variables could be controlled in experiments to obtain a more complete picture of contextual factors influencing multimedia learning. One must approach the question of media effectiveness carefully since results can easily be misconstrued to support the causes of technology sales. However, since theory exists that predicts lower extraneous cognitive load with elimination of the attention splitting effect, experiments should be performed to determine whether the theory is correct or if it requires alteration.

**Conclusion**

In some ways, technology has seamlessly integrated itself with education. Electronic databases and search engines have replaced card catalogues and PowerPoint is commonly used in lectures. These innovations have eased the mechanical labour of traditional processes, digging through filing cards, and writing every lesson on the blackboard. Learning is not such a mechanical process however, and therefore more care must be taken in designing and implementing technological teaching tools. The dominant feature of the vast majority of educational technology research is a lack of appropriate theoretical foundations. Researchers believed that students were receptacles for knowledge rather than active learners. This led to studies that searched for a better vehicle for conveying knowledge, ignoring the cognitive processes of the learner and using enthusiasm and assumptions above or in place of empirical evidence. The typical practice of educational technology confounded the research deficit by often disregarding and failing to contribute to literature. In light of these fallacies, research is turning a corner. Researchers are
examining learning with technology from the ground up, seeking to understand the fundamental “active ingredients” to proceed scientifically to “authentic educational technologies,” (Clark and Estes, 1999). What must not be overlooked is the information that can be gleaned from successful, already-implemented interventions. These can be used to generate hypotheses that can be tested in theoretically based experiments, taking into account the experience of the learner. Motivational issues must also be investigated as they may hold the key to explaining the success or otherwise of interventions. Finally, given current theories of multimedia learning (Mayer, 2001), aspects of the media debate should be reconsidered. In physics, experiments have sometimes yielded apparent contradictory results. These occasions have resulted not in skepticism and dismissal of observations, but in unique clarity of new insight realized through careful experimentation and specification of parameters.

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