CHAPTER 6

Five Common but Questionable Principles of Multimedia Learning

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Principle: *A basic generalization that is accepted as true and that can be used as a basis for reasoning or conduct.*
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Abstract

This chapter describes five commonly held principles about multimedia learning that are not supported by research and suggests alternative generalizations that are more firmly based on existing studies.[1] The questionable beliefs include the expectations that multimedia instruction: (1) yields more learning than live instruction or older media; (2) is more motivating than other instructional delivery options; (3) provides animated pedagogical agents that aid learning; (4) accommodates different learning styles and so maximizes learning for more students; and (5) facilitates student-managed constructivist and discovery approaches that are beneficial to learning.

Introduction

Multimedia instruction is one of the current examples of a new area of instructional research and practice that has generated a considerable amount of excitement. Like other new areas, its early advocates begin with a set of assumptions about the learning and access problems it will solve and the opportunities it affords (see, e.g., a report by the American Society for Training and Development, 2001). The goal of this chapter is to examine the early expectations about multimedia benefits that seem so intuitively correct that advocates may not have carefully examined research evidence for them. If these implicit assumptions are incorrect we may unintentionally be using them as the basis for designing multimedia instruction that does not support learning or enhance motivation. Even when easily available research findings contradict widely shared beliefs about benefits, it is tempting to ignore the research by assuming, without careful analysis, that the multimedia instruction has been poorly designed.

Definition of Multimedia

So many different definitions of multimedia have been offered (see, e.g., Clark, 2001) that it is important at the start of this discussion to clearly specify what is being discussed. *Instructional media* generally refers to any vehicle for presenting or delivering instruction. Examples of these vehicles usually refer to computers, books, television, radio, newspapers, and people. *Multimedia* usually refers to the capacity of computers to provide real-time representations of nearly all existing media and sensory modes of instruction. Sensory modes are distinguished from media because they relate to the sensory format of information so that it is compatible with one of the five senses. Visual and aural forms of information can be provided by a variety of media whereas taste, smell, and texture representations in media are very limited. Multimedia instruction is most often offered at a "distance" from live teachers and so is occasionally referred to as *distance education*. One of the issues raised in this chapter is that the impressive breadth of multimedia formats for instruction and learning may invite a confounding of the specific factors that influence (or fail to influence) learning and motivation for different people and different learning tasks.

Chapter Goals

This chapter examines the research evidence for five of the implicit assumptions one finds in much of the current literature on multimedia instruction. Each of these assumptions seem to be so widely shared, that they have taken on the mantle of "principles" that guide the design of instruction and research on multimedia instruction. Yet each of these beliefs has been examined by a body of well-designed research and found either to be incorrect or only to apply in a very limited set of circumstances. The goal of this chapter is to provide a brief survey of some of the research and related analysis that challenge each of the five mistaken principles. In each case, the discussion will provide an alternative generalization that seems warranted, given the current research. The discussion begins with the most dominant and perhaps the most erroneous multimedia assumption, that learning benefits are greater from multimedia than from other instructional media.

Principle 1: Multimedia Instruction Produces More Learning than "Live" Instruction or Older Media

There is no credible evidence of learning benefits from any medium or combination of media that cannot be explained by other, nonmultimedia factors (Clark, 2001; Clark & Salomon, 1986; Mielke, 1968; Salomon, 1984; Schramm, 1977). Even the critics of this conclusion, for example, Robert Kozma (1994), have acknowledged that no evidence exists to support the argument that media has influenced learning in past research. Critics of the "no learning from media" view who are familiar with the research, hope that multimedia will provide unique forms of influence on learning in the future. Yet it appears that this optimistic hope is swimming upstream against a considerable body of evidence to the contrary extending back over 75 years (Clark, 2001; Mielke, 1968).

The capacity of multimedia is broad and inclusive. It even permits us to provide presentations by human instructors that have been "recorded" on video and presented on a computer screen as well as all instructional methods, including interactivity between instruction and learner (e.g., feedback to the learner on their progress or answering questions posed by learners as they progress through instruction), the providing of examples in the form of simulations or models, and other methods of teaching that have been found to influence learning. In order to fully understand the impact of multimedia on learning and motivation, it is important to separate it from the instructional methods multimedia can present and the sensory modality (visual, aural, olfactory, tactile, and taste information) chosen

to represent instructional methods. Research and evaluation studies that provide evidence for more learning from multimedia than from live instruction or other media have been challenged because of their failure to separate media from method and sensory mode. A number of reviews have argued that when experiments or evaluation studies report learning advantages for multimedia when compared with other media, the learning benefits attributed to multimedia are more plausibly due to the uncontrolled effects of instructional methods and/or sensory mode influences (not media) and/or different test-relevant information being given to different groups (Clark & Salomon, 1986; Mielke, 1968; Morrison, 1994; Salomon, 1984; Schramm, 1977). Clark (2001) has argued that all instructional methods, sensory modes, and information components of instruction can be presented in a variety of media with equal learning outcomes but with very different costs and access outcomes.

Method Confounding

The most promising approach to learning is to assume that it is influenced by instructional methods (Cronbach & Snow, 1977) that can be embedded in instruction and presented by a variety of media and not only by multimedia per se. Instructional methods are defined as "... any way to shape information that compensates for or supplants the cognitive processes necessary for achievement or motivation. For example, learners often need an example to connect new information in a learning task with information in their prior experience. If students cannot (or will not) give themselves an adequate example, an instructional (method) must provide it for them" (Clark, 2001, p. 208). Variations in interactivity can be provided to learners by a number of media, including live instructors. If studies provide a necessary method of instruction in a multimedia condition and do not provide an equivalent form of the method in a compared instructional treatment, the results will appear to favor multimedia when in fact, the method influenced the learning. The key issue is whether any instructional method can be presented in more than one medium. Clark (2001) has argued that all instructional methods that are necessary for any kind of learning can be presented in a variety of media. He claims therefore, that the benefits of media are economic or are to be found in the increased access to instruction by disadvantaged groups in society, but that learning benefits due to multimedia alone have not been found and cannot be claimed.

Sensory Mode and Learning

Multimedia instructional designers are tempted toward instructional presentations that, besides agents, include very active animation, motion video, colorful graphic displays, background sounds, music, and other multisensory depictions of course concepts, voice-over narration, and other visually and aurally exciting displays. While many learners seem to welcome the visual and aural entertainment, the best evidence suggests that learners are often overloaded by seductive but irrelevant distractions or the effort of processing redundant information so their learning is reduced (Mayer, 2001; Moreno & Mayer, 2000; see also chapter 12). Mayer (2001) has described a systematic program of research designed to tease out the benefits of multimedia-supported integrations of visual and aural depictions of processes that are being learned. He reports evidence that multimedia lessons where both visual and text-based explanations of processes are spatially or temporarily separated, and/or are heavily text laden seem to overload the working memory of many students and decrease their learning. He also reports instances where the presentation of spatially and temporally integrated visual and aural descriptions of the same process can enhance learning (Mayer, 2001). He suggests that providing both a visual and a narrative description of a process being learned will increase the amount of time information about the process can be held and processed in working memory. This finding suggests that formatting process information in two sensory modes results in better learning than presenting the same information in either visual or auditory form alone. Multimedia, computer-based instruction is a very efficient vehicle for presenting integrated visual and auditory information yet other media (including live instructors using silent motion films or television) could provide the same instruction. Because a number of different media will present visual and aural sensory mode information, this instructional method is not considered to be a potential learning benefit that is exclusive to multimedia.

Meta-analytic Studies of Multimedia

The most recent summary of instructional media research has been provided in an extensive meta-analysis conducted by Bernard et al. (in press) who examined over 650 empirical studies comparing live and multimedia distance learning to locate 167 studies that met their criteria for design. Their comprehensive analysis concluded that a very weak learning advantage for multimedia in empirical studies was attributable to uncontrolled instructional methods. They also reviewed four previous meta-analyses of earlier and different multimedia issues and suggested that the evidence in all of them pointed to "no differences" as the most reasonable conclusion.

A Recent Example of Methods and Multimedia

An interesting example of the difference between multimedia and instructional method can be found in a series of experiments by Corbett (2001) that focused on the impact of a variety of instructional methods used to teach Lisp programming based on Anderson's Lisp tutor (see Anderson & Gluck, 2001). Corbett describes an approximate 1.5 sigma effect size increase in learning over standard mastery learning methods due instructional methods called *model tracing* and *cognitive mastery*. The addition of scaffolding (providing more tracing and cognitive mastery support for novice students then withdrawing it slowly as they gain expertise) increased the effect size impact another 0.42. This means that Corbett's methods produce a learning benefit of approximately 60% over instruction that gave all necessary information to students but did not use the experimental methods.

Time to Learn

Equally interesting is that when the new methods were compared with mastery methods (Bloom, 1984) they produced a 40% increase in learning. The methods described were derived not from a study of multimedia but instead from recent research on cognitive architecture and its influence on the learning of complex knowledge (Anderson & Gluck, 2001). All methods were delivered by a computer but all could have been provided by human tutors although with much less efficiency. The latter point is emphasized by Corbett's (2001) finding that the computer-delivered version of the powerful methods resulted in a 40% decrease in the time required to learn when compared with human tutors.

If Not "Learning Benefits," What Are the Advantages of Multimedia Instruction?

Clark (2000) has described a number of strategies for evaluating multimedia instructional programs that separate the benefits of the media from the benefits of the instructional methods used. Multimedia benefits, he suggests, are to be found in the cost of instruction, including time savings for students and instructors (when the investment in instructional design and development are amortized across increasing numbers of students) and increased access to quality instruction by disadvantaged or rural groups of students. Evidence for cost and time savings can be found in the work of Corbett (2001) described previously and cost-benefit and cost-effectiveness studies conducted by Levin and his colleagues (Levin, Glass, & Meister, 1987; Levin & McEwan, 2001).

Evidence for access benefits is more difficult to locate and it is possible that this is a less explored area. One example is a government report of increased access to instruction by people whose educational alternatives are severely limited by geography or other handicapping conditions such as economic, physical, or social barriers (Office of Technology Assessment, 1988).

In addition to learning benefits, advocates often implicitly and explicitly (e.g., Abrahamson, 1998) claim that multimedia results in increased motivation to learn when compared with more traditional instructional media. The discussion turns next to this issue.

Principle 2: Multimedia Instruction Is More Motivating Than Traditional Instructional Media or Live Instructors

Abrahamson (1998) may represent the majority of multimedia advocates when he states that "a primary function of the use of television, computers, and telecommunications in distance learning is to motivate students rather than just to provide information to them" (p. 2). However, evidence for the motivational qualities of multimedia instruction has been elusive at best. The best conclusion at this point is that overall, multimedia courses may be more attractive to students and so they tend to choose them when offered options, but student interest does not result in more learning and overall it appears to actually result in significantly less learning than would have occurred in "instructor-led" courses (Bernard et al., in press). In order to explain this ironic twist in empirical research, the discussion turns first to a definition of motivation.

What Is Motivation?

Pintrich and Schunk (2002) in their review of research on motivation to learn suggest that the existing research focuses on one or more of three "indexes" or outcomes of motivation: (1) active choice (actively starting to do something that one formerly "intended" to do but had not started), (2) persistence (continuing to work toward a goal, despite distractions or competing goals), and (3) mental effort, defined by Salomon (1984) as "the number of non-automatic elaborations invested in learning" (p. 647).

Each of these indices play a different role in the learning process and some may not be related to learning. On one hand it is possible that active choice (e.g., the choice to engage in multimedia learning by choosing to start a multimedia lesson or to select a multimedia course alternative over a more traditional option) may be facilitated by attractive multimedia features such as ease of access, flexibility of scheduling, and the personal control students are often able to exercise when starting, pausing, or moving between different sections of a course of instruction (often called *navigation control*). Yet initially attractive features of a multimedia course might work against students when they engage in learning.

Do Motivated Students Learn Less in Multimedia Instruction?

In their comprehensive meta-analysis of 232 empirical studies reporting nearly 600 comparisons conducted between 1985 and 2002, Bernard et al. (in press) concluded that courses reporting high levels of student interest also tended to report lower levels of achievement. They also concluded that end-of-course measures of interest tended to be negatively correlated with end-of-course achievement. Thus, as achievement increased in multimedia distance studies, student interest and satisfaction decreased. They conclude that "interest satisfaction may not indicate success but the opposite, since students may spend less effort learning, especially when they choose between [multimedia distance education] and regular courses for convenience purposes (i.e., happy to have a choice and satisfied but because they wish to make less of an effort to learn . . .)" (words in brackets inserted to replace acronym, p. 43). Salomon (1984) presented compelling evidence that may explain the negative relationship between interest and satisfaction with multimedia courses and significantly lower learning by students who express a preference for multimedia. He hypothesized that student interest in newer media is based on an expectation that it will be a less demanding way to learn. This expectation results in the investment of lower levels of mental effort, and consequent lower achievement levels, when compared to instructional conditions that are perceived as more demanding. He presented compelling evidence to support his hypothesis. This finding has been replicated a number of times with different media (see, e.g., the discussion of related studies in Clark, 2001). Salomon's theory is the most compelling explanation for Bernard et al's. (in press) meta-analytic finding of an inverse relationship between interest and achievement.

Mental Effort

Apart from the Salomon (1984) studies, not much is known about the direct impact of multimedia instructional formats on mental effort but recent research is not promising. Studies by John Sweller and others (e.g., Mousavi, Low, & Sweller, 1995; Sweller & Chandler, 1994) indicate that many instructional strategies and complex screen displays risk overloading working memory and causing "automated" cognitive defaults (Clark, 2001) where mental effort is both reduced and directed to nonlearning goals. Complicating this finding is strong evidence that learners are not aware when they become overloaded and enter a default state (Gimino, 2000). Because all methods used to measure mental effort involve self report (e.g., Bandura, 1997), this finding is very distressing. Pintrich and Schunk (2002) suggest the use of various measures for ongoing assessment of motivation including self-efficacy (Bandura, 1997), value for learning goals (Eccles & Wigfield, 2000), mood or emotionality, and dual-task measures for mental effort (Gimino, 2000). In general, it seems that mental effort may be influenced in large part by the amount of perceived difficulty in a multimedia course. It is possible that when moderately challenging learning goals and tasks are presented, mental effort increases. When learning tasks are too easy or impossibly difficult, mental effort decreases radically. Students seem to be able to accurately report the amount of mental effort they are investing in easy to moderately difficult tasks. Yet there is disturbing evidence that they seem unaware when they stop investing mental effort as learning tasks become extremely difficult or impossible. Designers must exercise caution not to overwhelm multimedia students with extremely complex tasks or screen design features that overload working memory. Meanwhile, researchers should continue to study how specific tasks and design features impact mental effort.

Separating Motivation to Choose Multimedia Courses and Motivation to Learn

Many of the currently measured motivation variables in multimedia studies seem to reflect interest and enjoyment factors that influence access to instruction or choice of instructional media rather than learning. Students appear to choose multimedia courses based on expected flexibility and ease of learning, but those expectations may cause them to reduce their effort and learn less. This is Bernard et al.'s (in press) conclusion in their review of empirical work. On the other hand, persistence and mental effort seem to be very important learning-related motivation indexes for multimedia because the added control computers allow students may make it more possible for them to become distracted and avoid instruction. Imagine a scenario where students stop a multimedia lesson when they are tired or bored, intending to restart soon, and yet become distracted and allow a great deal of time pass before restarting the lesson. These gaps in time may make recall of previously learned material more difficult and/or push students so close to course or lesson completion deadlines that they must rush to finish on time. While multimedia lessons do not have to permit this kind of flexibility because it is possible to program required "milestone" completion schedules, the attractiveness of flexibility may increase the probability that students will take multimedia courses if they have choices. Thus, increases access while at the same time placing considerable stress on motivational processes that support persistence over time.

Persistence in Multimedia Courses

Multimedia courses may be chosen over other forms of instruction because students expect that they will receive more individualized instructor contact. While there appears to be no empirical work on this issue, in Kennedy's (2000) survey of a group of online students, 68% of the 40 respondents said they enrolled online rather than self-study because they wanted instructor feedback and guidance through the course. Most students also believe that the heightened instructor contact enhanced their learning in the course. The State University of New York students who reported the highest levels of instructor interaction also reported the highest levels of value for the course (Fredericksen, Pickett, Shea, Pelz, & Swan, 2000). The University of California Los Angeles has also reduced drop out with a system, in which course managers contact "missing" students to prod them into persisting (Frankola, 2001). Thus, although it seems clear that multimedia instruction *can* include (or be perceived to include) more instructor-student contact, and that this increased interaction may enhance the value of the course and student persistence, to the extent that such increased interaction is missing, motivation to persist may be lacking as well. Additional studies concerning the factors and strategies that would further enhance student persistence in multimedia courses would be useful.

One issue that has been examined for a number of years is the extent to which multimedia allows designers to accommodate learning styles and therefore enhance the learning of a broader range of students.

Principle 3: Multimedia Shapes Instruction for Different Learning Styles

Quite understandably, individual differences between people that may impact the efficacy of instruction have been a major focus of research for decades. If we were to understand all of the factors that contributed to instructional outcome differences, it could be expected that we would be able to optimally align pedagogical approaches with learner profiles, thereby narrowing achievement gaps. While this goal is an important one for the future of instructional research and multimedia design, to date researchers in this area have found no evidence that tailoring multimedia instruction to different learning styles results in learning benefits. This section briefly reviews the research on a variety of individual differences investigated in the research literature (learning preferences, cognitive styles, motivation, intelligence, and prior knowledge) and identifies those that have consistently been found to be relevant factors in the success of learning outcomes in most instructional environments, including multimedia courses, and those that have not.

Cognitive Styles and Learning Preferences

Cognitive styles and learning preferences have been advocated by some researchers for a number of years as traits that contribute to differential success in learning tasks on the basis of learners' innate approaches to learning or solving problems. By understanding these proclivities, it is argued, multimedia instruction can be optimally matched to the learner in order to maximize achievement. Unfortunately, these constructs have proven notoriously difficult to validate for both the stable assessment of learner characteristics and the customization of instruction to improve student outcomes (e.g., Duff & Duffy, 2002; Henson & Hwang, 2002; Kavale & Forness, 1987; Loo, 1997; Richardson, 2000; Stahl, 1999). In general, cognitive style theories posit one or more linear scales on which learners can score closer to one extreme or another. These descriptors typically have a global, integrative, contextualized reasoning pattern at one extreme and a highly focused, isolative, decontextualized pattern at the other (e.g., Cassidy, 2004). In similarly structured dichotomies, some theories also include a visualizer/verbalizer differentiation for sensory, rather than logical, cognition or other descriptive dimensions (e.g., Riding & Cheema, 1991).

Classifying learners in these systems entails requiring each learner to complete a self-report instrument that usually asks questions about their preferred learning modalities and typical approaches to solving problems. However, in addition to persistent problems achieving intraindividual score reliability over time and across domains, attempts to validate these styles have also failed to yield consistent differentiation between cognitive style and measures of intelligence (Richardson & Turner, 2000).

An additional problem with cognitive and learning styles lies in the self-report method of identification wherein learners are asked to report their preferences for approaches to learning and solving problems. Mayer and Massa (2003) tested 95 undergraduates using measures of visual and verbal reasoning ability and found no significant relationship between subjects' self-reported measures of style and their performance on the reasoning tests. This finding is consistent with other investigations of learners' abilities to adequately select effective learning approaches. Clark (1982) found in an extensive meta-analysis of studies that utilized learner preference or enjoyment for particular instructional media or techniques that learner enjoyment was typically uncorrelated or negatively correlated to performance outcomes. That is, subjects who reported preferring a particular instructional technique typically did not derive any instructional benefit from experiencing it. Salomon (1984) found similar results in an experimental study of sixth-grade learner preferences for learning from television or print: The subjects who learned more of the material presented in instruction were those who did not receive instruction through their preferred medium. More recently, these results were replicated with adult distance learners by Li, O'Neil, and Feldon (in press).

Motivation/Goal Orientation

Another individual difference known to impact achievement in instructional settings is goal orientation. Goal orientation refers to the source of an individual's motivation for learning. Those who are classified as having mastery goal orientations pursue the acquisition of new knowledge for their own satisfaction and are not motivated by the comparison of their performance to that of others. In contrast, performance-oriented learners invest effort in learning primarily for the purpose of attaining public or comparative recognition for their accomplishments (Pintrich & Schunk, 2002). Because mastery-oriented students engage with the material for the purpose of understanding, they have been consistently found to be more likely to expend effort to learn the concepts presented and engage with the material more strategically and at a deeper level. However, their internal focus may sometimes prove maladaptive in the context of an evaluated course, because their focus may not have been on the learning objectives on which they would be assessed (Barron & Harackiewicz, 2001). Likewise, performance-oriented learners can manifest both adaptive and maladaptive behaviors. Successful behaviors are referred to as "approach" strategies, because they entail a proactive attempt to gain recognition for success by self-regulating and scaffolding learning opportunities to ensure success. In contrast, "avoidance" behaviors are those by which performance-oriented learners seek to dissociate their performance in the learning environment from negative evaluations of their abilities through self-handicapping behaviors that prevent their

best efforts from being demonstrated (Eccles & Wigfield, 2002).

Intelligence

One of the first traits found to account for stable differences between learners is intelligence. Fluid reasoning ability has been found to reliably predict performance on novel problem-solving tasks (Cattell, 1987). However, as instruction familiarizes learners with a given set of skills and problems over time, such advantages diminish when criterion-referenced performance is evaluated (e.g., Ackerman, 1987, 1988, 1990, 1992). Indeed, studies of experts in a variety of fields have found no correlation between fluid ability and performance (e.g., Ceci & Liker, 1986; Doll & Mayr, 1987; Ericsson & Lehmann, 1996; Hulin, Henry, & Noon, 1990; Masunaga & Horn, 2001), precisely because the high levels of deliberate practice that are necessary to excel in a domain entail the development of skills that are applied to problems whose qualities are known. Although individuals can acquire new knowledge and problem-solving strategies and apply them to improve their performance within a particular domain, there is not yet any evidence that such improvements can impact the general problem-solving skills associated with fluid ability (Perkins & Grotzer, 1997).

Prior Knowledge

Learners' acquired knowledge prior to participating in a course can also account for significant individual differences in academic outcomes. Not only do discrete pieces of knowledge relevant to the course material provide a relative advantage to those learners who possess them, but having such knowledge can directly affect the efficacy of certain pedagogical strategies. When novices acquire knowledge in a domain, the learning process is slow and effortful. The requisite effort to process relevant information decreases as schemas are constructed and skills are practiced. As a result, learners with low levels of prior knowledge require more extensive instructional support to minimize the level of unnecessary cognitive load imposed by the material presented. By reducing the amount of effort required of novice learners, more attentional capacity is available for the accurate encoding of material. If excessive or unstructured information is presented to the novice learner, he will become overloaded and subsequent performance will suffer (van Merriënboer, Kirschner, & Kester, 2003). Conversely, learners with higher levels of prior knowledge in the domain benefit from less-structured instruction. Whereas the novice requires scaffolding to properly organize the information presented without overwhelming limited working memory, for a more knowledgeable learner, superfluous instructional support likely will interfere with existing schemas and consequently impose unnecessary cognitive load, resulting in performance decrements (Kalyuga, Ayres, Chandler, & Sweller, 2003).

Conclusions About Accommodating Learning Styles

Whereas cognitive and learning styles have not proven to be robust foundations on which to customize instruction to accommodate individual differences, intelligence, motivational goal orientations, and prior knowledge have demonstrated significant effects. Although there seems to be little that can be done to modify intelligence and goal orientation, the assessment of prior knowledge for the customization of multimedia instruction offers great promise. Past studies have demonstrated significant relative improvements in instruction when learner support was faded out as learners acquired more knowledge (Kalyuga, Chandler, Tuovinen, & Sweller, 2001), and new research suggests that rapid assessments of learners' knowledge states can dynamically shape the course of computer-based instruction to effectively improve overall achievement (Kalyuga & Sweller, in press-a, in press-b).

The multimedia pedagogical support used to scaffold learning for less experienced students is often provided by animated instructional figures or "agents." This chapter turns next to a review of the research on the learning impact of multimedia agents.

Principle 4: Multimedia Instruction Can Provide Active Pedagogical Agents That Increase Motivation and Aid Learning

Animated pedagogical agents are defined by Craig, Gholson, and Driscoll (2002) as "a computerized character (either humanlike or otherwise) designed to facilitate learning" (p. 428). Many multimedia instructional programs directed to both children and adults seem to provide instructional support in the form of animated agents. Atkinson (2002) suggests that agents "... reside in the learning environment by appearing as animated 'humanlike' characters, which allows them to exploit... communication typically reserved for human-human interaction... [and] can focus a learner's attention by moving around the screen, using gaze and gesture, providing... feedback and conveying emotions" (p. 416–417). Agents are a product of recent technological advances in multimedia computer animation and user interface design. Advocates suggest that they have great potential for aiding human learning (e.g., Sampson, Karagiannidis, & Kinshuk, 2002). The use of agents is a recent, welcome, and visible attempt to insert pedagogical support into multimedia instruction yet initial empirical studies suggest that they may distract and interfere with learning more than aid it.

Agent Research Results Are Mixed

In some studies, agent-based instruction results in more learning and/or more positive attitudes toward lessons (e.g., Bosseler & Massaro, 2003; Mitrovic & Suraweera, 2000; Moundridou & Virvou, 2002; Ryokai, Vaucelle, & Cassell, 2003), whereas in others agents produce no learning or motivational benefits (e.g., André, Rist, & Müller, 1999; Baylor, 2002; Craig, Driscoll, & Gholson, 2004; Mayer, Dow, & Mayer, 2002). However, in other experiments, results are mixed and somewhat confusing (e.g., Atkinson, 2002; Moreno, Mayer, Spires, & Lester, 2001) and many studies that demonstrate learning benefits from agents have been criticized for design errors (Choi & Clark, 2004). Our review of these studies suggests that positive learning results most often come from studies where the method being used by the agent to "teach" are not compared with conditions where the method is provided to students without the agent.

Design Problems

Very few agent studies control for the type of hypothesized learning and/or motivational support the agent is providing in a balanced, alternative condition where the same type of learning support is provided by a lower technology, nonagent condition. If the agent is providing a specific type of instructional support, study designs should include a "low technology" alternative method of providing the same type of support to a comparison or control group. Any pedagogical support provided by an agent can also be provided in a "lean" format. Dehn & van Mulken (2000) explain that without this type of design control, "... differences between the two conditions cannot be attributed exclusively to [the agent]" (p. 18). An adequate test requires that the nonagent or control condition provide all of the learning and motivational support available from the agent condition, otherwise a comparison will be potentially confounded by the uncontrolled effects of the instructional methods the agent provides and by the agent itself.

Confusion About the Source of Measured Benefits

For example, Atkinson (2002) compared a "voice plus agent" group with "voice only" and "text only" groups (Experiment 2). In the voice-plus-agent group, participants listened to the agent's verbal explanations and saw the agent highlighting relevant

information on the screen simultaneously by using pointing gestures. Alternatively, participants in the voice-only and text-only conditions only received explanations delivered either in voice or text, respectively. In other words, participants in the voice-only and text-only groups did not have the benefit of a visual, highlighting indicator for important information, which might have forced the participants to use their scarce cognitive resources to connect verbal explanation with related visual information on the screen. Therefore, although the voice-plus-agent group outperformed the other two groups in far-transfer performance, it is problematic to attribute the obtained learning benefit exclusively to the presence of the agent. The critical learning support provided by the agent – directing learner's attention to the key information in the screen display, was not available to the two comparison groups. A leaner version of the agent's pointing gesture would be to simply use an animated arrow and/or to underline the same information selected by the agent in the comparison conditions. Other studies that also failed to control the types of instructional and motivation supports provided in agent and alternative conditions include Moundridou & Virvou (2002) and Ryokai, et al. (2002).

Adequately Designed Studies Provide Consistent Results

André and colleagues (1999) conducted a well-controlled study that avoided this design pitfall. To find empirical support for the affective and cognitive benefits of their "PPP Persona" agent, they exposed participants to two different memory tasks – a technical description (the operation of pulley systems) and an informational presentation that included the names, pictures, and office locations of fictitious employees. Both experiment and control versions provided the same treatments except that the control groups did not have the PPP Persona agent. The control group heard a voice conveying the same explanations that the agent provided to the experimental group. The agent's pointing gesture was replaced with an arrow that pointed to important information in the control condition. Following the presentations, participants' affective reactions to the agent and control condition were measured through a questionnaire whereas the cognitive impact was measured by comprehension and recall questions. The results showed significant differences only in the affective measures. Participants interacting with the PPP Persona agent for the technical description found the presentation less difficult and more entertaining. The positive effects, however, disappeared for the informational presentation about the fictitious employees. Participants reported that the PPP Persona agent was less appropriate for employee information and less helpful as an attention direction aid. No significant achievement differences were found between the experimental and control groups for either the technical description or information presentation tasks on comprehension or recall measures. Thus, in this well-designed study, the agent did not provide learning or motivational benefits that translated to greater learning. Yet, because of the adequate design, there is the serendipitous finding that learners may believe that agents are more appropriate and likeable in some learning tasks but not in others.

Craig, et al. (2002) also employed an adequate design where participants learned the process by which lightning occurs presented through an agent and through alternative multimedia (i.e., picture, narration, or animation). An animated agent that pointed to important instructional elements on a computer screen was contrasted with a sudden onset of highlighting (i.e., color singleton or electronic flashing) and animation of the same information (without the agent) for comparison groups. The narrative information was synchronized simultaneously with the agent's pointing gestures, separated and provided prior to the agent's pointing, or in a third condition, with a sudden onset of highlighting and animation of relevant parts of an instructional picture. Craig, et al.'s results indicated that the agent made no difference in learners' performance both in cognitive load assessment and performance tests (i.e., retention, matching, and transfer). Rather, they reported a significant benefit from both a sudden onset of and animation of parts of the pictures for focusing learners' attention. This may be an example of an effect that van Merrienboer (1997) calls "just in time" learning support.

Conclusion – Animated Agents Do Not Increase Learning

These results provide evidence that in multimedia studies of agents, measured differences in student learning may not be due to the agent by itself or any increased motivation or attention caused by the agent, but rather due to the pedagogical method provided by the agent. Thus we should ask a question: Is the animated pedagogical agent the only way to deliver these types of instructional methods in a multimedia learning environment? If alternative ways can deliver the same instruction with the same learning and motivation, but with less cost, shouldn't we choose the least expensive option?

Erickson (1997) argued that the adaptive functionality of an instructional system is often enough for learners to perform a task and achieve the same outcome without the guidance of an agent. He further suggested that when including an agent, instructional designers should think about what benefits and costs the agent would bring, and far more research should be conducted on how people experience agents. Furthermore, Nass and Steuer (1993) found that simply using a human voice without the image of an agent was sufficient to induce learners to use social rules when interacting with a computer. Moreno and colleagues (2001) also noted that learners may form a social relationship with a computer without the help of an agent and thus, the image of an agent might not be necessary to invoke a social agency metaphor in a computer-based learning environment. Baylor (2002), Craig, et al. (2004), and Mayer, et al. (2003) found no effect of agent image on learning outcomes. This research is also reviewed in chapter 13 of this volume.

Principle 5: Multimedia Instruction Provides Learner Control and Discovery Pedagogy To Enhance Learning

There is a persistent belief among some segments of the education and training communities that the most effective learning experiences are those in which learners navigate unstructured multimedia learning environments or solve novel problems presented without instructional supports (Land & Hannafin, 1996). However, this assumption about pure discovery learning has been tested repeatedly over 40 years of research and found to lack empirical validation when its efficacy, efficiency, and impact on successful transfer of skills have been compared to well-structured, guided instruction (Mayer, 2004). Several factors have been found to play key roles in enactive learning environments that have significant impacts on student success, specifically cognitive load, instructional supports, and prior knowledge.

Cognitive Load Theory

Developed by John Sweller and his colleagues, cognitive load theory reliably predicts instructional learning outcomes by analyzing the pedagogical materials and features of the learning environment to determine the amounts of relevant and irrelevant load placed on working memory (Sweller, 1988, 1989, 1999; Sweller, van Merriënboer, & Paas, 1998; chapter 2). Because working memory capacity is limited, unnecessary features function as artificial constraints on the amount of mental resources that can be directed toward the necessary semantic elements for new knowledge to be successfully acquired. As novice learners develop skills and organizational schemas within the domain of instruction, the information occupies significantly less "space," which allows for the processing of more advanced (i.e., higher load) elements and complex problem solving. Because adaptive organizational schemas are difficult to acquire, resources that could otherwise be dedicated to conceptual understanding must be dedicated to imposing meaningful structure on the material presented if external supports and carefully controlled presentation of material is not utilized. If these supports are not used, fewer cognitive resources are available to be focused on the mastery of conceptual content (Chandler & Sweller, 1991; Sweller, Chandler, Tierney, & Cooper, 1990).

Instructional Support

As learners gain mastery of basic knowledge and organizational structures, their need for external supports to optimize their learning efforts decreases. Because the schemas organize the information presented effectively, it becomes redundant for those frameworks to be provided externally within the learning environment. Thus, providing more structure than is appropriate to the level of the learner can impose extraneous cognitive load and redirect working memory resources away from the target material. Known as the expertise reversal effect, it has been demonstrated that optimal instruction utilizes instructional supports that fade in proportion to the learner's level of expertise for a particular skill or concept (Kalyuga, et al., 2003).

These findings present a complex picture for the appropriate use of discovery learning environments. Because by definition, pure discovery learning does not use instructional supports, it imposes large amounts of extraneous cognitive load on novice and intermediate learners, thereby increasing the amount of time and mental effort expended on learning while decreasing postlearning performance relative to more structured approaches (Tuovinen & Sweller, 1999). However, learners with high levels of expertise in the material presented have been found to perform better after learning in unstructured environments that do not impose unnecessary scaffolding. As such, pure discovery learning is maximally beneficial only to those learners who require additional training least.

Types of Support

The specific nature of the instructional supports that have been used to guide discovery learning processes also plays a major role in the efficacy of the instruction (see also chapter 14). De Jong and van Joolingen (1998) reviewed a variety of tools that were used in computer-based discovery learning environments and concluded that providing enhanced task structure for learners consistently improved learner outcomes. For example, a number of studies found that up to four times as many students were able to grasp concepts central to a simulation-based discovery program when instructions specifying how to proceed in solving the problem were provided when compared with subjects who experienced the pure discovery mode (e.g., Gruber, Graf, Mandl, Renkl, & Stark, 1995; Linn & Songer, 1991). Even when overall results did not indicate a significant difference in subsequent student performance between guided and pure discovery learning environments, deeper analyses indicated that students with lower levels of ability in the target domain who received guidance did attain posttest scores significantly higher than their unguided counterparts, providing a replication of the expertise reversal effect discussed previously (Veenman & Elshout, 1995). Further, several studies demonstrated high correlations between intelligence and success in discovery learning environments across a number of domains, suggesting that such forms of instruction are less able to generate strong results for all learners (Veenman, 1993). Indeed, Funke (1991) reported that correlations between intelligence and achievement linked to discovery learning simulations increase as the level of guidance offered by the environment falls. Similarly, Shute and Glaser (1990) found that embedding guidance tools into the learning environment resulted in only a very low correlation between achievement and intelligence.

Thrashing

One of the problems that learners frequently encounter in pure discovery learning environments is that of "thrashing" (Lewis, Bishay, & McArthur, 1993) or "floundering" (Goodyear, Njoo, Hijne, & van Berkum, 1991), in which learners lack an effective and/or systematic approach to interacting with the learning environment and consequently are unable to draw valid or helpful inferences from simulation outcomes or events. In Lewis, et al.'s study, students were directed to engage in discovery learning tasks using a geometry software tool to identify formulas describing mathematical relationships between geometric figures. When they reached an impasse and no scaffolding or assistance was available, students generally persisted in their attempts to use a strategy that had been previously effective. After multiple attempts at using the maladaptive strategy, students were then observed to progressively attempt less and less appropriate solution strategies until they eventually quit the program or selected a new, unrelated goal to pursue. Such thrashing in pursuit of a solution did not yield a successful solution for any of the study participants but occupied as much as 25% of their total instructional time. Similarly, Goodyear, et al. found that when students engaged in this kind of behavior, they were unable to identify the causal relationships that existed between their actions and resulting events within the learning environment. The lack of a systematic approach prevented them from adequately tracking their own actions, and learners were thus unable to extract functional principles from the interactions.

Even when goals and processes are relatively clear, discovery learning environments can produce impediments to learning through uncontrolled sequencing of material. Kester, Kirschner, van Merrienboer, & Baumer (2001) found in an exploratory study that the timeliness of information presentation predicts performance in learning tasks designed to facilitate complex skill acquisition. Their just-in-time instructional model holds that abstract "supportive" information (e.g., mental model explanation) must be presented prior to learner attempts to solve authentic complex tasks, whereas prerequisite information (e.g., facts relevant to a specific problem scenario) should be presented to the learner during the execution of the tasks. Further, in a recent study, Clarke, Ayres, and Sweller (in press) found that when students were given a learning task to master mathematics concepts through the manipulation of a spreadsheet, those students who were not provided with specific instructions for using the spreadsheet program prior to attempting to learn the mathematics material performed at a much lower level than those who had acquired spreadsheet knowledge prior to attempting the learning task.

Similarly, many of the studies reviewed by de Jong and van Joolingen (1998) that required students to discover scientific principles within simulated environments found that only those students who acquired strong scientific inquiry skills prior to attempting identification of the science concepts were able to achieve at high levels. Although many such environments provided related procedural support if requested by the learner during the discovery task, meta-analyses of students' self-assessments with regard to their learning needs have found consistent evidence that students – especially novices – do not accurately determine which pedagogical formats and tools will be most beneficial for them (Clark, 1982, 1989).

General Conclusion

Multimedia instruction offers extraordinary benefits to education including a wide range of instructional options and, with adequate instructional design, considerable reductions in the time required to learn, the time required of expert teachers, and when large numbers of students are involved, the cost

of learning (Clark, 2001). Like all new and exciting educational innovations it also suffers from mistaken beliefs about its potential and achievements. This chapter reviewed five commonly held beliefs about multimedia that have not been supported by research. For example, multimedia does not increase student learning beyond any other media including live teachers.

It also appears that studies examining the motivational benefits of multimedia instruction provide good news and bad news. While multimedia may be a more attractive option for instructions by students than older media, the bad news is that their interest most often seems to lead them to reduce their effort to learn. Meta-analytic evidence from many studies suggests that as student interest in multimedia courses increases, learning tends to decrease because students may feel that learning in these courses requires less work.

If multimedia does not produce more learning than other options, and if motivation to choose multimedia courses produces an ironic reduction in course achievement, the solution seems to require increasing the focus on pedagogical support in multimedia courses. A pedagogical approach that seems very common in multimedia courses is an attempt to tailor instructional sequences for learners with different learning styles. The flexibility of multimedia permits the tailoring of instruction to a variety of learning styles by providing different versions of the same lesson to accommodate different styles. However, attempts to validate this assumption over the past 30 years have generally failed. New efforts, such as those initiated by Mayer and Massa (2003), may meet with success in the future. However given the data currently available, it appears that the two most promising individual differences that can be used to shape adaptive instructional programs are the prior knowledge and learning goal orientation of students, and nothing inherent to these factors seems to require use of multimedia for tailored accommodation.

Attempts to insert socially engaging learning support into multimedia courses with animated pedagogical agents also seem not to increase learning and sometimes appear to diminish instructional effectiveness, because agents often produce cognitive overload for students. Evidence from well-designed studies suggests that agents may be expensive and unnecessary, because appropriately designed narration and instructional methods embedded into instruction can achieve similar learning outcomes at less cost.

Finally, multimedia advocates have often embraced constructivist-based discovery and problem-based learning pedagogy. The flexibility of multimedia technology permits the design of courses where students can control not only the (beneficial) pacing of instruction, but also students' navigations between and within lessons. The latter type of control combined with unguided or minimally guided instruction seems most often to harm learning for students with less prior knowledge of course subject matter. In another ironic twist, strong instructional guidance and scaffolding seems to interfere with the learning of more advanced students. Thus, tailoring instruction to student prior knowledge does seem to be beneficial, but it does not require most of the features of multimedia instruction.

The main concern addressed in this chapter is the need to check research evidence for the presumed benefits of all instructional media and related pedagogies. Research sometimes provides counterintuitive evidence and so prevents us from unintentionally causing damage or investing scarce resources in instruction that does not support learning. It can also point in directions that can lead to dramatically increases in achievement such as Corbett's (2001) 2 sigma gain in learning accompanied by a 40% reduction in learning time.

Footnotes

1. Parts of the discussion in this chapter have been summarized from two previous manuscripts including: Choi, S. & Clark, R. E. (April 2004). Five suggestions for the design of

experiments on the effects of animated pedagogical agents. Symposium paper presented at the American Educational Research Association Annual Convention in San Diego California; and Clark, R. E. (2003). Research on web-based learning: A half-full glass. In R., Bruning, C. A., Horn, & L. M. Pytlik Zillig (Eds.), *Web-based learning: What do we know? Where do we go?* (pp. 1–22). Greenwich, CT: Information Age Publishers.

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