6 Ten Common but Questionable Principles of Multimedia Learning

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Abstract

The chapter begins with a brief summary and extension of our earlier list of 5 questionable multimedia principles (Clark & Feldon, 2005). We then add 5 more principles that have gained traction in recent years. The goal of the chapter is to provide evidence-based explanations of why each of the 10 principles is problematic and to suggest alternative generalizations that are more firmly based on evidence. The updated 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 media; (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. The more recent additions and the focus of this discussion are expectations that multimedia instruction benefits learning by providing: (6) autonomy and control over the sequencing of instruction; (7) higher-order thinking skills; (8) incidental learning of enriching information; (9) interactivity; and (10) an authentic learning environment and activities.

Introduction

Multimedia offers significant benefits for education when it is used to provide cost-effective access to high-quality, evidence-based instruction. After years of experience with multimedia, a number of beliefs about its uses have gained the status of a principle, or "a basic truth that explains or controls how something happens or works" (Cambridge Dictionaries Online). Yet it appears that many commonly held multimedia principles are mistaken – when used to guide instruction, some may have no impact and a few may have negative effects on motivation and/or learning.

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This chapter is a cautionary description of 10 of the questionable principles that have developed and seem to be widely shared about multimedia learning. Our goal is not to point out the errors in anyone's reasoning about an important and exciting innovation. In the past, both of us have advocated some of the 10 questionable principles discussed here. We hope instead to join readers in marveling at how careful research occasionally produces counterintuitive findings that help us all avoid mistakes and adjust practice so that it is compatible with the best available evidence.

Multimedia Defined

When we use the term *multimedia* in this chapter, we are referring to the capacity of computers to provide both realistic and constructed audio and visual presentations in a desired combination of text, audio, still images, video or animation. Multimedia programs designed to teach most often also permit learners to interact with the computer and influence the pace, sequence, and content of the presentations they receive. Multimedia provides visual and aural information but generally is not yet able to provide smell, taste, or touch sensory modes.

Update on Past Questionable Principles

We begin the chapter with a brief review and update of the five principles described in more detail in Clark and Feldon (2005). Our goal here is to give a status report on the evidence for each principle that has been published in the years since the first report was given. After this review we will describe five new questionable principles. We begin with a questionable principle based on the confusion about the role of media in learning and motivation.

Questionable Principle 1: Multimedia Produces More Learning Than Do Live Teachers or Older Media Such as Textbooks or Television

Earlier we claimed that there is no credible evidence of learning benefits from any medium or combination of media, including multimedia, that cannot be explained by other, nonmedia factors. Nothing has changed since that chapter was published to modify our claim. When media (or multimedia) are used for instruction, the choice of medium does not influence learning.

Research Comparing Multimedia with Other Media

In poorly designed experiments comparing multimedia with older forms of media (including teachers in classrooms), instructional methods that influence learning are present in one condition (often the multimedia condition) and not in a comparison condition.

Examples of instructional methods are worked examples or demonstration scenarios, practice exercises, corrective feedback and/or test-relevant information content. When, for example, a worked example of a strategy being learned is embedded in a multimedia presentation but not in a comparison presentation, learning differences are likely to be due to the presence of the worked example rather than its presentation in multimedia. It is also sometimes the case that the information one must learn in order to pass learning tests is available in the multimedia condition but not in a comparison media. Clark (2012) describes many of these experiments and other research design problems that lead to confusion about the impact of media on learning. The one statement we must withdraw from our earlier chapter is that "Robert Kozma (1994) [has] acknowledged that no evidence exists to support the argument that media has influenced learning in past research" (Clark & Feldon, 2005, p. 98). Kozma recently contacted the first author to protest that he had not agreed and stands by the conclusions of his review (Kozma, 1994a). Our understanding of the key point in Kozma's view is that instructional media cannot be separated from instructional methods (Kozma, 1994b). We respectfully disagree, because – as noted in the preceding paragraph – instructional devices (e.g., worked examples, practice exercises, feedback) can be easily separated from the many different media that can present them (for a discussion of instructional methods see Clark, 2009). We continue to challenge Kozma or any other colleague to describe and provide evidence for a unique aspect of multimedia that cannot be duplicated in another medium with equal learning benefits.

Future Media Research

While studies comparing the learning benefits of different media are a waste of resources, we do need many more research and evaluation studies focused on the use of media to improve student access to instructional programs and to reduce the cost of learning. These two outcome variables deserve more attention from researchers. One must wonder whether it makes sense to invest in the development of an expensive multimedia instructional program when less expensive media would have equal learning benefits. Foundational work by Levin (Levin & McEwan, 2000) has described a useful approach to cost-effectiveness studies of different media that can address this concern if more widely incorporated into studies of multimedia.

We therefore see no reason to modify our claim that the belief that multimedia produces more learning than other instructional media is based on a questionable principle.

Questionable Principle 2: Multimedia Instruction Is More Motivating Than Other Instructional Media

We also suggested that all claims for the motivating properties of multimedia used questionable principles. We stated: "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 [yet] ... 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" (Clark & Feldon, 2005, p. 99). Subsequent reviews of the research on motivation (e.g., Clark, Howard & Early, 2006; Schunk, Pintrich & Meese, 2008) have provided motivational models and added evidence for this claim.

Research on Multimedia Motivation

A recent well-designed study examining the learning and motivational benefits of online multimedia learning by Sung and Mayer (2013) is an excellent example. Their multimedia lesson on how a solar cell works was provided in two different media platforms: a desktop computer used in a laboratory setting and a mobile iPad device. Results of their brief experiment (about 12 minutes) indicated no learning differences between the two media formats, but study participants reported liking the mobile device more than the computer. It is apparent that, in this experiment at least, "liking" did not improve learning. Although it is possible that the time period of the study was too brief to produce motivational impact, the outcome is consistent with numerous studies, including Clark's (1982) meta-analysis of studies assessing the (null) impact of enjoyment on learning.

It is equally possible that "liking" might have led to less learning with the mobile devices had the instruction extended for a longer period of time. An often cited and replicated study by Salomon (1984; see replications described by Rieh, Kim, & Markey, 2012) found that when student self-reports of preferences for a medium were compared with their actual persistence at learning, it appeared that they invested less mental effort and eventually learned less as a result. Salomon hypothesized that, for many students, preference and interest indicate that they believe a medium provides an easier path to achievement. Therefore, they tend to invest less effort and time, resulting in less learning.

We therefore see no reason to modify our claim that the belief that multimedia instruction is more motivating than other instructional media is based on a questionable principle.

Questionable Principle 3: Multimedia Instruction Provides Animated Pedagogical Agents That Aid Learning

Multimedia allows for the use of animated figures that can interact with learners during instruction. These figures continue to be advocated as one of the benefits of multimedia (e.g., Kramer & Bente, 2010; Wei, 2010). It has been proposed that animated agents personalize the instructional experience and serve as beneficial pedagogical guides for learners by interacting with them and, for example, pointing out key concepts, answering questions, giving hints, or providing feedback.

Animated Pedagogical Agents Defined

Atkinson (2002) describes these agents as residing "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" (pp. 416–417). The goal of these pedagogical agents is to increase student learning and motivation.

Research on Animated Multimedia Agents

Since our first review of animated agents was published, studies of animated agents appear to have been published less frequently, though well-designed studies continue to indicate no learning benefits from agents. For example, a review by Kramer and Bente (2010) concluded that beneficial effects to learning from agents had not been demonstrated in studies. Consistent with the first principle discussed earlier, we would add that this outcome is due to the effectiveness of instructional strategies that can be implemented using an animated agent or any other form of media. Thus, well-designed studies find that when the effects of instructional methods provided by the agents are separated from the effects of the presence of the agents, no learning benefits are found. For example, if an agent gives feedback during practice or emphasizes important information in one condition, then a comparison condition should also provide feedback and alternative ways to point out important information (for a discussion of the design of agent experiments see Choi & Clark, 2004). Since agents add expense to instructional programs, they should also add learning benefits to warrant the expense.

Frechette and Marino (2010) provide a welcome example of a well-designed study on the use of agents in a college lesson on astronomy. They compared the learning impact of both agent and no-agent instructional programs. This permitted a test of the impact of the agent figure when compared with the instructional method being provided by the agent. They reported no learning benefit when the agent lesson was compared with an equivalent lesson with no agent.

Wei's (2010) dissertation provides an interesting twist on agent studies. Wei attempted to use a humanlike agent to help ninth-grade students reduce their math anxiety and therefore increase their learning. Pre-test and post-test math knowledge and math anxiety were measured and gender was also examined. A treatment with a math anxiety-reducing agent was compared with a treatment containing an agent that did not support anxiety reduction. The study did not provide a condition without an agent. The results indicated that there were no gender or learning differences (or interactions) between the conditions. While some of the most anxious students reduced their anxiety a bit, others felt greater anxiety as a result of the agent. While it would have been a more interesting experiment if a no-agent condition had been included, this study is yet another example of the problems researchers have experienced conducting multimedia pedagogical agent studies.

We therefore see no reason to modify our claim that the belief that multimedia instruction providing animated pedagogical agents aids learning is based on a questionable principle. We see no reason to continue this line of research. Yet if researchers wish to examine agents in future studies, we urge the addition of a no-agent condition in which all instructional methods provided by the agent are implemented in a no-agent comparison group.

Questionable Principle 4: Multimedia Instruction Accommodates Different Learning Styles and So Maximizes Learning for More Students

Individual and group traits that lead to differences in learning from instruction have interested educators for at least a century. In the past half-century, many attempts have been made to identify ways that we could tailor instruction so that it benefits learners who share the same individual difference (see the historical review provided by Clark & Feldon, 2005). Learning styles are a more recent addition to this long-standing effort to make instruction fit students rather than require students to accommodate one kind of instruction. Multimedia permits us to assess learner differences and present different versions of an instructional program to different students based on the assessment of their learning styles. It has therefore been hoped that tailoring multimedia instruction would increase the learning of diverse groups of students – particularly those who are underserved.

Learning Styles Defined

Gardner (1995) defines learning styles as "an individual's natural or habitual pattern of acquiring and processing information in learning situations. A core concept is that individuals differ in how they learn" (p. 19). Many varieties of learners have been proposed, including visual, verbal, and kinesthetic, or tactile, learners; convergent, divergent, assimilating, and accommodating learners; and field-dependent or field-independent learners; in addition, a number of learning style inventories have been developed, such as that of Dunn and Dunn (1978).

Research on Learning Styles and Multimedia

All recent peer-reviewed and published analyses of learning styles research have concluded that when presented via multimedia (or in any other media), learners attempts to accommodate learners' styles do not aid learning. In a review focused on K–12, Dembo and Howard (2007) concluded that "there is no benefit to matching instruction to preferred learning style, and there is no evidence that understanding one's learning style improves learning and its related outcomes" (p. 107). A very careful and complete review by Pashler, McDaniel, Rohrer, and Bjork (2009) was even more devastating in its assessment of the learning styles research. The authors concluded:

> Although the literature on learning styles is enormous, very few studies have even used an experimental methodology capable of testing the validity of learning styles applied to education. Moreover, of those that did use an appropriate method, several found results that flatly contradict the popular meshing hypothesis.... We conclude therefore, that at present, there is no adequate evidence base to justify incorporating learning styles assessments into general educational practice.... Thus, limited education resources would better be devoted to adopting other educational practices that have a strong evidence base, of which there are an increasing number. (p. 105)

On the basis of these and other reviews, we see no reason to modify our earlier claim that it is questionable to expect multimedia instruction that accommodates different learning styles to maximize learning for more students. While individual differences such as prior knowledge have been found to interact with different instructional methods (for a discussion see Clark & Feldon, 2005), learning styles do not aid learning despite the huge interest in their use.

Questionable Principle 5: Multimedia Instruction Facilitates Student-Managed Constructivist and Discovery Approaches That Are Beneficial to Learning

Since multimedia permits students to have control over the sequencing and content of instruction, constructivist-learning advocates (e.g., Savery & Duffy, 2001) have encouraged its use to support discovery learning. In Clark and Feldon (2005) we claimed that it was not beneficial for multimedia instruction to provide constructivist or discovery instruction to students. This area has been hotly debated in the past few years, and as a result of a discussion about the impact of variations in guidance and discovery on student prior knowledge, we must modify our earlier claim.

A Definition of Constructivist and Discovery Multimedia

Discovery multimedia programs ask students to navigate a rich and relatively unstructured learning environment and to learn with minimal instructional support. In extreme versions of constructivist frameworks (Mayer, 2004), students are expected to discover or construct what they learn without being guided (Savery & Duffy, 2001). Authentic and engaging problems are often presented at the beginning of a multimedia program to help focus, motivate, and encourage learners to connect with their prior knowledge about the problems and then search for information that will help them solve a problem or accomplish a task. Savery and Duffy (2001) explain that in the constructivist view of how students should learn science, "we do not want the learner to … execute a scientific procedure as dictated – but rather to engage in scientific problem solving" (p. 4). They suggest that the instructional system's role "should be to challenge the learner's thinking – not to dictate or attempt to proceduralize that thinking" (p. 5).

The approach that competes with discovery learning has been called "direct" or "fully guided" instruction (Kirschner, Sweller, & Clark, 2006). The argument here is that "ideal learning environments for experts and novices differ: while experts often thrive without much guidance, nearly everyone else thrives when provided with full, explicit instructional guidance (and should not be asked to discover any essential content or skills)" (Clark, Kirschner, & Sweller, 2012, p. 6).

Research on Multimedia-Based Discovery or Fully Guided Learning

Tobias and Duffy (2009) have provided an edited book with chapters describing different points of view about the research supporting either discovery or guided instruction. While there are many subtle and important elements to arguments about the issue, some agreement has evolved about the conditions under which more or less guided instruction is beneficial for student learning. It appears that a relatively small number of students with high levels of prior knowledge about topics to be learned not only benefit from receiving modified constructivist or discovery multimedia instruction but may learn less with fully guided instruction. For example, an experiment by Oksa, Kalyuga, and Chandler (2010) asked college students and Shakespearian experts to provide interpretations of Shakespearean play extracts using either guided expository notes or unguided materials in three different experiments. All students, regardless of their prior knowledge, benefited most from the explanatory notes. However, these same notes were somewhat detrimental to the experts, who performed better without them. Experts constantly achieved more by being allowed to solve problems on their own without guidance.

Kalyuga, Rikers, and Paas (2012) provide a very complete review of the research in which experts perform poorly with guidance and describe the results of many studies conducted in different fields. They conclude that studies of "complex skill acquisition in technical and academic domains demonstrated that more experienced technical trainees or students may learn less than expected from instructions that are very effective for novices" (p. 313).

They do not suggest that guided approaches result in failures for experts or students with higher prior knowledge, only that they do not learn as much as when they are encouraged to learn without guidance.

We therefore need to modify our claim that multimedia-based discovery learning benefits are based on a questionable principle. Discovery-based multimedia programs seem to benefit experts or students with higher levels of prior knowledge about the topic being learned. Students with novice to intermediate levels of prior knowledge learn best from fully guided instruction. Prior knowledge is therefore an individual difference that leads to learning benefits from more guidance at low to moderate levels but not at higher levels, regardless of the media used to deliver instruction (see also Chapter 24).

Questionable Principle 6: Multimedia Instruction Provides Students with Autonomy and Control over the Sequencing of Instruction

Student control of instruction is another contentious issue in educational research (Merrill, 2006). A number of prominent multimedia advocates have argued that the decision to provide linear, autocratic, and controlling instruction has demotivated students and ignored the constructivist nature of learning (e.g., Duffy & Jonassen, 1992; Shepherd, 2003). The solution they offer is to provide students with multimedia that permits and encourages learner control of content, sequencing, and pacing. When sequencing is under the control of students, they may skip or revisit topics, practice exercises, examples, and demonstrations. In essence, control of sequence permits learners to determine the order and, to some extent, the content of their instruction.

Research on Sequencing Control

We have evidence that at least one form of learner control is beneficial. For some time now we've had good evidence that learning increases when students have control over the pacing of instruction (e.g., Mayer & Chandler, 2001). Pacing control permits students to stop, pause, or slow down multimedia or other instructional presentations, presumably so that they have the opportunity to elaborate and remember what they have seen and/or heard before continuing.

Yet the results of studies where students were allowed to select the order of lessons, learning tasks, and learning support have been mostly negative. Student control over sequence generally results in significantly less learning and transfer than sequencing student prior knowledge (Merrill, 2006; Niemiec, Sikorski, & Wallberg, 1996; Ross & Rakow, 1981). The best evidence seems to support using pre-test scores to sequence lessons and examples by presenting easier-to-learn lessons, tasks, and examples about which students already have some knowledge before those that are more challenging. There is also evidence that when students are learning how to implement strategies or solve problems, sequencing of lessons and learning tasks so that they represent the way that tasks are performed by accomplished experts results in more effective transfer of learning than student control of sequencing (Clark, Feldon, van Merriënboer, Yates, & Early, 2008). Finally, there is evidence that the sequencing and fading of practice exercises are more effective when they are fixed rather than decided by students (Sweller, 2011; Merrill, 2006).

There is one exception to the generalization. There is evidence (Ayres & Kalyuga, 2011) that students who have exceptionally high prior learning of the tasks or content being taught do not necessarily benefit from external sequencing and sometimes benefit from being given sequence control. This is another instance of the principle on guidance and discovery discussed earlier. These are students who may not need instruction, since their scores on well-designed knowledge pre-tests indicate that they have already learned most of what is being taught. One might wonder why students with such high levels of prior knowledge would be assigned to instruction that they may not need in educational practice.

Explanations of the Learner Control Evidence

Cognitive load theory (Ayres & Kalyuga, 2011; see also Chapter 2) is the best current explanation for why pacing control works and sequencing control does not for most students. The theory they describe suggests that we have very limited ability to hold information in consciousness. Our minds simply will not permit us to think about more than about three to four new things at once. This information-processing limit is a major constraint, since all learning has novel elements and is thus subject to this limitation. This new estimate of a mental-processing limit by Cowan (2001) reduces by more than 50% our former estimate (Miller, 1956) of a seven- to nine-chunk processing capacity. This much lower capacity estimate is further reduced by learner anxiety, as well as the irrelevant (to learning objectives) information that attracts learner's attention during instruction. Not only do these limitations slow down learning, but they can introduce unintended reversion to older, less effective strategies when we are cognitively overloaded (Clark, 1999; Feldon, 2007). Thus, when students have control over the pacing of instruction, they have a greater ability to control the amount of cognitive load they are experiencing and can commit more information to memory. Yet when they take control of sequencing and ignore lessons or instructional supports such as examples, demonstrations, practice, and feedback, their learning suffers. The only students who appear to be an exception to this generalization are a relatively small number who are assigned to instruction they apparently do not need because of their prior learning (de Jong & van Joolingen, 1998).

Questionable Principle 7: Multimedia Instruction Allows Students the Opportunity to Practice Critical and Higher-Order Thinking

Most of us value the learning of critical, higher-order thinking skills. This value may have led some to claim that multimedia instruction increases these skills (e.g., Fontana, Dede, White & Cates, 1993; Scheibe & Rogow, 2012). Although some studies have offered tentative evidence in favor of this claim (e.g., Stoney & Oliver, 1999), research design issues limit the strength of evidence indicating that the use of multimedia itself contributed to the development of higher order skills.

Higher-Order Thinking Defined

In a very careful review of the issue, Perkins (1995) defines higher-order thinking as a predisposition toward thoughts that are "clear, broad, deep, sound, curious, strategic and aware" (p. 283) and contrasts it with lower-order thinking predispositions that are "hasty, narrow, fuzzy, and sprawling" (p. 276). When a person buys a product in part because of an advertisement stating that "no other brand was superior" in tests without asking if all brands were equally effective, that person is engaging in lower-order, non-critical thinking.

Research on Higher-Order Thinking

In a meta-analysis of more than 100 studies involving more than 20,000 students, Abrami et al. (2008) complained about the lack of consistent operational definitions of higher-order thinking skills. Yet when they grouped the different kinds of definitions and analyzed many studies, they found that while it is possible to teach thinking skills, there were no studies where multimedia contributed to learning outcomes. Instead they concluded that critical thinking tends to result when pedagogy involves specific learning objectives focused on clearly defined thinking skills and effective demonstration of the skills being taught by well-trained instructors.

Explanations of the Critical Thinking Evidence

The belief that multimedia leads to better thinking skills is a special case of the first questionable principle listed – that media produced a learning outcome rather than that some instructional program and pedagogy presented by the media was responsible. The Abrami et al. (2008) review of these studies indicated that the pedagogy and information content responsible for fostering critical and higher-order thinking could be presented by a variety of media, including teachers in a classroom, with the same learning outcomes. Multimedia is not required for or necessarily instrumental in learning to think critically.

Questionable Principle 8: Multimedia Instruction Encourages Incidental Learning of Enriching Information

Incidental learning occurs when students are exposed to an instructional presentation and learn more than the program was designed to teach. An example of effective incidental learning occurs when children watch the interactions of people around them or in movies or television programs and gradually learn social interaction rules without being specifically taught these rules (Shank, 2004).

Research on Incidental Learning

Verbal learning scholars who are interested in the number of new, unintentionally acquired words students have learned in print-based instructional programs have conducted research in this area for many decades (e.g., Klauer, 1984). The best summary of these earlier studies is that when instruction provides learning objectives, suggestions, and/or advance study questions, incidental learning is minimal or absent. Another way to interpret this finding from Klauer's meta-analysis is that when text-based instruction is well designed, incidental learning does not occur. Yet because multimedia offers a potentially great variety of aural and visual depictions, advocates expect that it should increase the opportunity for the incidental learning of potentially useful information. However, this has not turned out to be the case in the studies that have been performed by advocates of incidental learning.

In a study of multimedia language learning programs, Brett (1998) found that when learning task descriptions (similar to learning objectives) or "hotspots" are present in the program, little or no incidental learning occurs. A hotspot in multimedia lessons is a special graphic object or underlined text related to the task description that, when selected by a student, opens an application that may display a picture, run a video, or open a new window of information. For example, a graphic representation of an atomic model in a multimedia science lesson, when selected, might open up a narrated animation about the atom. This finding appears to mirror the earlier research in reading, as attempts made to direct students' attention to the goals of an instructional program during incidental learning is minimal. Baylor (2001) examined a number of multimedia pedagogical strategies in a study of example generation and learning of main points in Web navigation instruction. Her results mirrored Brett's in that when visual pointers or links to intended learning goals were offered, incidental learning decreased. However, in the absence of goal-directed pointers and links, incidental learning increased. Boechler and Shaddock (2004) reported similar results in a multimedia hypermedia search task experiment. As expected, multimedia content that was highlighted with visual links and attended to by students tended to be remembered.

Explanations of the Incidental Learning Evidence

The long history of studies in this area indicate that incidental learning is not a function of media or multimedia but is instead fostered by a lack of learning objectives and/or attention-directing devices such as hotspots and other kinds of hyperlinks related to intended outcomes. When attention-directing devices are inserted in multimedia programs, it seems reasonable to expect learning related to the information accessed by these devices. Since these devices must be intentionally inserted in a multimedia program, it seems unlikely that the learning that results from them is "incidental."

As Shank (2004) reminds us, children learn to walk, talk, and navigate around their environment without constant guided instruction. Yet Sweller (see Chapter 2) counters that while evolution has prepared us to learn walking and talking (he calls this "primary learning"), it has not prepared us to learn mathematics, physics, history, or other complex problems (secondary learning). Primary learning of walking and talking is to some extent "incidental," but all other kinds of learning are likely to be secondary learning and therefore require guided instruction. Neither primary nor secondary learning requires multimedia, however.

Thus, incidental learning is not a benefit of multimedia. One must wonder whether it is a benefit at all, since it tends to occur only when instructional design ignores learning objectives and/or fails to direct student attention to any specific instructional content.

Questionable Principle 9: Multimedia Instruction Promotes Interactivity

The expectation and goal supporting this principle is that multimedia will help learners become less passive recipients of instruction and instead act as more enthusiastically active participants in their learning experiences. The concern of many who advocate multimedia for its potential to promote interactivity is that the culture of the classroom and the way that many instructional media have unintentionally been applied in education have forced students into the role of passive recipients of instruction and not therefore actively engaged in and actively supporting their own learning.

Interactivity Defined

Essentially, multimedia interactivity involves mutual actions and reactions between a learner and a multimedia-based instructional program. Most definitions of interactivity begin with the capacity of multimedia to provide information and permit students to interact with it in both predetermined and unexpected ways. So, for example, a student can be presented with "hotspots" (see principle 8) and have the opportunity to click on them and get information that would not become available without the student's "request."

Research on Interactivity

Scholars who have tackled the issue of interactivity (see, e.g., Chou, 2003; Koedinger & Aleven, 2007; Reeves & Hedberg, 2003) have complained about the lack of specificity and rigor in definitions of interactivity. While some multimedia advocates continue to define interactivity as mutual actions and reactions during learning, most now realize that this generalization is questionable. This definition obviously begs the question "what *kind* of interaction is required to increase learning?" Some interactions obviously have a positive impact on learning, and other types may have a negligible or even negative impact. If students who had already learned the alphabet were asked to strike specific letter keys on their keyboard and were given feedback by a multimedia program when they were correct, interactivity would have occurred but what learning would have taken place?

It is also the case that a number of different media, including human teachers, permit interactivity. Thus, interactivity is not an exclusive benefit of multimedia. Furthermore, interactivity is not required for multimedia to be used in instruction or for learning to occur.

Mayer and colleagues have conducted a number of well-designed studies on various forms of interactivity (see, e.g., Mayer, Dow, & Mayer, 2003). Readers interested in the various forms of productive interactions will also benefit from an excellent discussion, including evidence-based suggestions and examples, by Koedinger and Aleven (2007). In their discussion of interactivity in cognitive tutors, they describe a number of very clear kinds of "assistance" interactions that are supported by research. Among these are the following:

1. Immediate yes/no feedback when students are practicing learning tasks or solving problems online. These authors have examined many varieties of feedback (including no feedback) and found that immediate feedback

is the most efficient (reduced learning time) and effective (resulted in more learning).

2. Explanations of errors that help students remember the goal of the exercise and/or why what they have done is in error. In general, giving more information after students have made a problem-solving error (rather than simple yes/no feedback) is helpful.
3. Providing principle-based hints about next steps when students appear to be floundering. These authors have examined the relative benefits of asking students to request helpful hints or providing them without a request and have found that "[t]he evidence is mounting … that students are not good at seeking assistance or information at the right time" (p. 253). This kind of generalization is in direct opposition to the recommendations made in the multimedia approach to the constructivism and discovery learning principle discussed earlier.

It appears, then, that all forms of interactivity are not necessarily a benefit to learning. While multimedia may be able to present most or all of the productive forms of interactivity, other media can also provide necessary interactivity. Thus, interactivity is not an exclusive benefit of multimedia and the principle is therefore questionable.

Questionable Principle 10: Multimedia Instruction Permits Students to Experience an Authentic Learning Environment and Activities

Authentic learning environments are defined as contexts or settings for instruction that reflect the critical features of the environments when learning is expected to be transferred and applied (Herrington & Kervin, 2007). Thus, when student lawyers participate in mock trials and air traffic controllers learn their jobs in simulations that duplicate displays and settings, they are experiencing authentic learning environments. It is expected that transfer will be enhanced when learning and application environments are similar.

Research on Authentic Learning Environments

Studies of the instructional conditions that support the transfer and application of skills extend back over a century to the beginning of educational research. Thorndike and Woodworth (1901) argued persuasively that knowledge of a "dead" language (e.g., Latin) was not transferrable or helpful when people were learning another language (e.g., English). They instead presented evidence to support their theory of "identical elements" and argued that when learning materials and/or environments contained important elements found in the application environment, transfer of learning was increased. Tests of the theory over time met with very mixed results, largely because of the difficulty of determining exactly what elements of a transfer environment were important or "identical."

In a recent review of instructional elements that appear to enhance transfer, Perkins and Salomon (2012) do not mention the identical-elements theory or studies. Problems determining what is "identical" may be why Gulikers, Bastiaens, and Martens (2005) found no motivation, learning, or transfer benefits associated with the use of a simulated business environment for learning business consulting skills when compared to the use of a traditional instructional environment. While Herrington and Kervin (2007) and Herrington and Herrington (2006) have attempted to describe the studies that support authentic multimedia environments, the citations they list do not provide any insight about the features of the multimedia environments that help learning. Instead they focus on pedagogical elements that can be presented using a great variety of media, including live instruction, such as in the work of Brown, Collins, and Duguid (1989).

Explanations of the Authentic Learning Environments Evidence

Research on the instructional conditions that promote transfer has been complex and contentious. Over the past century we have made progress, but the issue is not resolved in any way. What we appear to have learned is that the identical-elements theory originally proposed by Thorndike and Woodward (1901) has changed over time. In a review of the changes in transfer research, Clark and Blake (1997) argued that most identical-elements studies selected irrelevant "surface" features of transfer environments such as obvious visual or observable but arbitrary behaviors, speech, and dress. They argued that transfer is enhanced when the two environments share less obvious "structural or criterial" features such as implicit goals, cognitive demands, theoretical constructs, incentives, or stressors. They also recommended avoiding the identical-elements theory in favor of an analogical approach to cognitive transfer.

It is likely that the claims made for the capacity of multimedia to provide learning benefits in the form of visual and aural elements of transfer environments are questionable. All available, well-designed studies have found no learning or motivational benefits for students that are attributable to the depiction of the transfer environment during learning.

Discussion

Each new communication technology or mix of technologies seems to lead to enthusiastic predictions about its possible impact on motivation and learning. Looking back over the evolution of media, it seems that very similar advantages have been offered for each new device and some of those advantages reach the level of proposed principles when repeated often enough (Clark, 2012). For the past century, similar claims have been made for the learning advantages of media, ranging from illustrated textbooks (Thorndike, 1912) to multimedia (Herrington & Kervin, 2007) and nearly all media that were developed between those two historical markers, including radio, movies, television, smartphones, computers, and multimedia. It also appears that the questionable principles and the reasons they are questionable have not changed appreciably over the past century (see, e.g., historical reviews by Clark, 2012; Cuban, 1986; Reiser, 2001). It seems that each new educational technology attracts a vocal group of advocates who are not aware of past mistakes and so are vulnerable to the same errors. This unfortunate pattern puts us at risk of wasting limited resources by pursuing failed applications rather than solving long-standing, complex learning and motivation problems or implementing evidence-based instructional methods. It also should lead us to question the university programs that train educational media professionals and the editorial policies of journals that publish articles and studies based on questionable principles without offering contrasting views.

The root of many of these questionable principles is the confusion between medium, individual differences, information or instructional content, and instructional method (Clark, 2012). Each of these aspects of instruction has somewhat separate research traditions that must be examined separately. Each apparently has a different role to play in learning and motivation.

Media such as video, computers, multimedia, and teachers are "vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition" (Clark, 1983, p. 249). Media influence both access to and the cost of learning but not learning or motivation. So the question to be addressed is how multimedia (or any educational technology) influences access to and the cost of instruction, learning, and motivation. Individual differences such as learning styles and level of motivation are characteristics of students that may interact with different instructional methods and media to influence learning and motivation.

While learning styles have been found to be failed attempts to reflect important individual differences, there are other individual differences (e.g., prior knowledge and general ability) that have been found to be powerful predictors of learning under different types of instructional methods but not different media.

Instructional methods are defined as "any way to shape information (for learning) that compensates or supplants the cognitive processes necessary for achievement or motivation" (Clark, 2012, p. 127). Examples of methods contained in the questionable principles discussed in this chapter are autonomy and control over sequence and pacing of instruction; constructivist support for requiring students to discover what needs to be learned, pedagogical agent behaviors, and authentic learning environments that represent the conditions, support, and settings where student are expected to learn and use what they are learning. Of the methods emphasized in the multimedia literature, student control over pacing seems to aid learning, particularly among students with lower prior knowledge. However, other methods – typically grounded in the questionable principles reviewed in this chapter –fail to enhance learning. In specific cases, such as the case of discovery learning environments or the learner control of instructional sequence, the evidence suggests that learning may be hindered.

Finally, multimedia is confounded with the content of instruction, such as critical and higher-order thinking skills. Nearly all media can present most instructional content, although some media permit much easier access and more economical learning for more students.

We are not alone in cautioning against the application of questionable principles. Toyama (2011) offers a compelling review focused on the impact of enthusiastic but hollow technology expectations in resource-starved schools in developing countries. He also offers intelligent suggestions about the possible benefits of new technologies – but none of the benefits he discusses involve learning or motivation advantages. Most are appropriately focused on how we can increase the access to education for much of the world in economies where resources are severely limited. This is the kind of issue that media advocates should emphasize by avoiding claims about learning and motivation benefits and instead helping to solve problems that will increase the fair access of diverse learners to high-quality, evidence-based instruction in a way that makes the best use of all educational resources.

Glossary

Animated/multimedia pedagogical agents: Described by Atkinson (2002, pp. 416–417) as agents residing "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."

Authentic learning environments: Contexts or settings for instruction that reflect the critical features of the environments when learning is expected to be transferred and applied (Herrington & Kervin, 2007).

Cognitive tutors: Instructional multimedia programs that provide feedback based on a diagnosis of learners' errors using rule-based models of cognition.

Discovery learning: Instruction that asks students to navigate a rich but relatively unstructured learning environment and to learn with minimal instructional support by discovering or constructing some or all of the essential information and skills that must be learned.

Guided/direct instruction: Instruction that provides explicit step-by-step guidance to learners, including all essential elements of decisions and actions required to perform skills.

Hotspot: A special graphic object or underlined text in multimedia text that, when selected, opens an application that may display a picture, run a video, or open a new window of information; hyperlinks are common examples of these multimedia instructional features.

Incidental learning: Learning that occurs when students are exposed to an instructional presentation and learn more and/or different information than the program was designed to teach.

Interactivity: The capacity of multimedia to enable learners to input information into the computer controlling the multimedia in a variety of formats and then utilize the input to modify the information subsequently presented by the computer to the learner.

Learning style: Defined by Gardner (1995, p. 19) as "an individual's natural or habitual pattern of acquiring and processing information in learning situations. A core concept is that individuals differ in how they learn." Learning styles often focus on preferred sensory modalities of instruction such as preferences for "visual" or "aural" modes of information.

Pacing control: Multimedia or other instructional presentations in which students are permitted to stop, pause, or slow down material in order to process it at a preferred rate.

Sequencing control: Multimedia or other instructional presentations in which students are permitted to select the order of content, lessons, learning tasks, and learning support.

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