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CHAPTER 1

INSTRUCTIONAL TECHNOLOGY

Promise and Pitfalls

Roxana Moreno
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ABSTRACT

When does instructional technology promote learning? The goal of this chapter is to offer one answer to this question by examining the classic distinction between the roles of media versus method in promoting learning. To this end, I first propose a cognitive-affective theory of learning with media from which a set of instructional design principles are derived. Then, for three different media (i.e., multimedia explanations, animated pedagogical agents, and virtual reality), I review a set of experiments where two such design principles were tested: modality and personalization. Lastly, after summarizing the findings of the reviewed studies, I offer final reflections for future instructional technology research.
INSTRUCTIONAL TECHNOLOGY: PROMISE AND PITFALLS

When does instructional technology promote learning? Before answering this question, it is useful to begin by providing a unified definition of instructional technology. *Technology*, in general, may be defined as "the totality of the means employed to provide objects necessary for human sustenance and comfort" (Webster, 2003). Prevailing definitions of *instructional technology* share a common interest in improving the effectiveness and efficiency of learning in educational contexts, regardless of the nature or content of that learning (Association for Educational Communications and Technology, 1977; Commission on Instructional Technology, 1970; Heinich, Molenda, & Russell, 1993; Seels & Richey, 1994). Drawing from these definitions, I will use the term instructional technology to refer to the totality of means employed to provide the conditions necessary to promote learning.

Although "technology" means computers in the minds of many, several other technological innovations in the past have been considered promising media to promote learning. For example, when the motion picture was invented in the early 20th century, Thomas Edison predicted that this new technology was destined to revolutionize our educational system (as cited in Cuban, 1986, p. 9). Later, in the 1930s, Benjamin Darrow, founder of the Ohio School of the Air, proclaimed that radio would give universal access to the services of the finest teachers (Cuban, 1986, p. 19). Similarly, by the 1950s, television was believed to impact education by providing access to richer learning experiences at lower costs (Cuban, 1986, p. 33), and the use of computer-aided instruction in the 1970s was predicted to eventually replace teachers. In sum, a review of educational technologies of the 20th century reveals the same grand promises made over and over, about how each new technology would revolutionize education. Unfortunately, just a few decades after the implementation of these cutting edge technologies in schools, it became clear that the hopes and expectations were largely unmet (Cuban, 1986; Mayer, 2001).

There is much that can be learned from the disappointing history of educational technology. In particular, the classic distinction between the role of media and method in learning provides a useful framework to answer this question (Clark, R. E., 1983; Clark, R. C., 1999; Salomon, 1979/1994). According to the *media-affects-learning hypothesis*, more powerful, state-of-the-art instructional technologies promote deeper learning (Clark, 1999; Jamison, Suppes, & Welles, 1974). This hypothesis, persistent among many people, has been claimed to originate from the advertising budgets of the respective technology industry, "which has a vested interest in selling these machines for instruction" (Clark, 1983, p. 456). On the other hand, according to the *method-affects-learning hypothesis*, it is not the technology per se that promotes learning but rather how the technology is used (Clark, 1999; Moreno & Mayer, 2002a). As long as instructional methods promote appropriate cognitive processing during learning, then media does not seem to matter. Thus, as long as each medium allows for the full implementation of the instructional method, then instructional methods will have the same effects across media. In other words, whereas the media-affects-learning hypothesis focuses on what can be done with cutting-edge technology, the method-affects-learning hypothesis focuses on what should be done to foster student learning with technology based on cognitive science theory and research (Mayer, 2001; Moreno & Mayer, 2002a).

In this paper, I offer a cognitive-affective theory of learning with media that takes into account the contrasting hypotheses described above, and from which instructional design principles can be derived and tested (Mayer & Moreno, 2003; Moreno, in press). My goal is to provide a theoretical framework to distinguish between the role of instructional methods and media in instructional technology. Following the theoretical explanation, I review a series of experiments that tested two of these instructional design principles in three different media (multimedia explanations, agent-based multimedia, and virtual reality). Finally I offer some reflections for future instructional technology research.

THEORETICAL FRAMEWORK

A Cognitive-Affective Theory of Learning with Media (CTLM)

The cognitive-affective theory of learning with media (CTLM) proposed, represents an expansion of the popular cognitive theory of multimedia learning (CTLM, Mayer, 2001). The following assumptions or ideas underlie a CTLM suggested by cognitive research: (a) independent information processing channels—the idea that humans have separate channels for processing different information modalities (such as visual, auditory, and tactile; Baddeley, 1992); (b) limited working-memory capacity—the idea that only a few pieces of information can be actively processed at any one time (Baddeley, 1992; Sweller, 1999); (c) virtually unlimited capacity long-term memory—the idea that long-term memory consists of a vast number of hierarchically organized schemas (Paas, Renkl, & Sweller, 2005); (d) dual-coding—the idea that knowledge may be represented and organized in two representation codes, verbal and nonverbal (Paivio, 1986); (e) automatic processing—the idea that, after being sufficiently practiced, schemas can operate under automatic processing and therefore require minimal working memory resources (Kalyuga, Ayres, Chandler, &
Sweller, 2003); (f) active processing—the idea that meaningful learning occurs when the learner spends conscious effort in cognitive processes such as selecting relevant new verbal and nonverbal information, organizing it into coherent representations, making referential connections between the representations, and integrating them with existing knowledge (Mayer & Moreno, 2003); (g) affective mediation—the idea that motivational factors mediate learning by increasing or decreasing cognitive engagement (Gottfried, 1990; Moreno, Mayer, Spires, & Lester, 2001; Reed, Burton, & Kelly, 1985); (h) metacognitive mediation—the idea that metacognitive factors mediate learning by regulating cognitive processing and affect (McGinnis, 1990); and (i) individual differences—the idea that differences in learners’ prior knowledge (Kalyuga et al., 2003; Moreno, 2004; Tuovinen & Sweller, 1999) and traits such as cognitive styles and abilities (Moreno & Durán, 2004; Plass, Chun, Mayer, & Leutner, 1998) may affect how much is learned with specific media (see Shute, et al., this volume, for additional discussion of individual x treatment interactions).

Figure 1.1 presents a model for learning science with media according to a CTLM. As can be seen in the figure, the instructional media may consist of explanations entering via the learner’s ears or the eyes, depending on whether the explanations are presented with spoken or written words, respectively. Learners then need to select some of the words for further processing, organize the words into a model, and integrate this verbal model with their prior knowledge. In addition, the instructional media may include nonverbal representations of information such as tactile, acoustic, or visual representation of content. Similar to the case of verbal information, learners select some of the nonverbal information for further processing, organize the information into a model, and integrate this nonverbal model with their prior knowledge. Corresponding verbal and nonverbal models are associated with referential connections (Paivio, 1986). The process depicted so far, assumes that learners are motivated enough to devote the necessary attentional resources to actively process the new information delivered by the media. However, learning can be hindered if the learner fails to engage in the learning task due to lack of motivation. Thus, the model includes motivational factors as learning mediators. For example, some media may be perceived as more interesting than others, therefore producing positive learning effects by influencing students to spend more effort on the task (Lester, Towns, & Fitzgerald, 1999; Tang & Isaacs, 1998). Similarly, some methods embedded in the media may be perceived to be more supportive than others, therefore producing positive learning effects by reducing students’ fear of failure or increasing their self-efficacy (Cennamo, 1993). Finally, as can be seen from the model, learners may use their metacognitive skills to regulate their motivation and cognitive processing. When students are aware of the strengths and limitations of their
knowledge, strategies, and motivation, they are better able to regulate their own learning by planning and monitoring the cognitive processes needed for understanding (Bruning, Schraw, & Ronning, 1999).

Two Derived Design Principles: Modality and Personalization

From the assumptions underlying CTLM, it is possible to derive cognitive principles of instructional design. Mayer, Moreno, and colleagues have identified a set of principles for the design of multimedia learning environments that are consistent with a CTLM and can be applied to new instructional technologies (Mayer, 2001; Mayer & Moreno, 1998, 2003; Moreno & Durán, 2004; Moreno & Mayer, 1999, 2000a, 2000b, 2002a, 2002b, 2004; Moreno et al., 2001). Table 1.1 summarizes 10 principles of multimedia design, along with their corresponding theoretical rationales and underlying assumptions: multimedia, modality, redundancy, temporal contiguity, spatial contiguity, coherence, personalization, guidance, interactivity, and reflection. The presented table is not intended to be exhaustive but rather to illustrate theoretically driven principles that have found empirical support in past research studies.

Due to the focus of this chapter, I now describe in more detail two of these principles: modality and personalization. According to the modality principle, instructional technologies that include nonverbal visual information and verbal explanations in spoken words are more likely to lead to meaningful learning than those that present nonverbal visual information and verbal explanations via on-screen text (Mayer & Moreno, 1998; Moreno & Mayer, 1999). This principle is derived from the previously described CTLM assumptions a, b, and d. The rationale underlying this principle is that, by using the auditory channel to process the verbal information, effective working memory capacity is expanded because students are not forced to split their limited visual working memories between the on-screen text, and computer graphics (Mayer & Moreno, 1999).

According to the personalization principle, instructional technologies that include personalized student messages are more likely to lead to meaningful learning than those that use nonpersonalized student messages (Mayer & Moreno, 2000b). Personalized instructional messages consist of explanations given in a dialogue-style—spoken or written explanations in the first and second person; whereas nonpersonalized messages consist of explanations given in a monologue-style—spoken or written explanations in the third person. The personalization principle is based on two CTLM assumptions. First, we assume that the use of self-referential language promotes the active processing of the instructional materials by having stu-

<table>
<thead>
<tr>
<th>Principle and Description</th>
<th>Theoretical Rationale</th>
<th>CTLM Assumptions</th>
</tr>
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<tbody>
<tr>
<td>Multimedia</td>
<td>Students learn better from words and pictures than from words alone.</td>
<td>According to dual coding theory, when words and pictures are both presented, students have an opportunity to construct verbal and visual mental models and to build connections between them (Mayer, 2001).</td>
</tr>
<tr>
<td>Modality</td>
<td>Students learn better from words and pictures when words are spoken rather than printed.</td>
<td>When words are presented auditorily they can be processed in the auditory channel, thereby leaving the visual channel to process only the pictures and expanding effective working memory capacity (Moreno &amp; Mayer, 1999, 2002a).</td>
</tr>
<tr>
<td>Redundancy</td>
<td>Students learn better from pictures and narration than from pictures, narrative, and text.</td>
<td>When words and pictures are both presented visually, the visual channel can become overloaded (Mayer &amp; Moreno, 2002b).</td>
</tr>
<tr>
<td>Temporal Contiguity</td>
<td>Students learn better when spoken words and pictures are presented concurrently and spatially than successively.</td>
<td>When corresponding spoken words and pictures are presented concurrently, learners are more likely to be able to hold mental representations of both in working memory at the same time and thus, they are more likely to build mental connections between verbal and visual representations (Moreno &amp; Mayer, 1999).</td>
</tr>
<tr>
<td>Spatial Contiguity/Split Attention</td>
<td>Students learn better when multiple sources of information are integrated rather than separated.</td>
<td>When multiple sources of information are not integrated, learners are required to hold one source of the materials in working memory while attending to the other and thus, they are less likely to build mental connections between them (Mayer &amp; Moreno, 1998).</td>
</tr>
<tr>
<td>Coherence</td>
<td>Students learn better when extraneous material is excluded rather than included in a lesson.</td>
<td>Extraneous material competes for cognitive resources in working memory and can disrupt the processing of relevant instructional materials, disrupt the process of organizing the material, and prime learners to organize the material around inappropriate schemas (Mayer, 2001; Moreno &amp; Mayer, 2000a).</td>
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Table 1.1. Ten Design Principles Derived from a CTLM, Corresponding Theoretical Rationales, and Underlying CTLM Assumptions (Cont.)

<table>
<thead>
<tr>
<th>Principle and Description</th>
<th>Theoretical Rationale</th>
<th>CTLM Assumptions*</th>
</tr>
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<tbody>
<tr>
<td><strong>Personalization</strong></td>
<td></td>
<td></td>
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<tr>
<td>Students learn better</td>
<td>By presenting messages in conversational style students benefit from encoding the materials as a personal experience and spend less cognitive effort to process the message (Mayer &amp; Moreno, 2004).</td>
<td>b, f</td>
</tr>
<tr>
<td>when words are presented in conversational rather than monologue style.</td>
<td></td>
<td></td>
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<tr>
<td><strong>Guidance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Novice students learn</td>
<td>Novice learners lack proper schemas to guide them in the selection and organization of relevant new information, thus, explanatory feedback helps reduce students’ cognitive load (Moreno, 2004; Moreno &amp; Mayer, in press).</td>
<td>b, f, i</td>
</tr>
<tr>
<td>better with explanatory feedback rather than corrective feedback alone.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Interactivity</strong></td>
<td></td>
<td></td>
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<tr>
<td>Students learn better</td>
<td>Interactivity encourages the processing of new information by engaging students in an active search for meaning (Moreno, 2004; Moreno &amp; Mayer, in press; Moreno et al., 2001).</td>
<td>f</td>
</tr>
<tr>
<td>when allowed to interact by manipulating the learning materials rather than by receiving direct instruction.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Reflection</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students learn better</td>
<td>Reflection promotes learning by encouraging more active organization and integration of new information (Mayer &amp; Moreno, 2000b, in press).</td>
<td>f</td>
</tr>
<tr>
<td>when given opportunities to reflect while engaged in the process of meaning making.</td>
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</table>

*Underlying assumptions correspond to letters and descriptions described in the text.

While the modality and personalization principles were derived from a theory based on sound cognitive research, it is important to empirically consider: (a) To what extent do the modality and personalization principles generally apply to different media? (b) To what extent do specific media characteristics affect learning?

To answer the first question, I will review a set of studies where the effectiveness of the modality and personalization methods is investigated in three different computer-based learning technologies: multimedia explanations (Experiments 1 and 2), agent-based multimedia games (Experiments 3 and 4), and virtual reality environments (Experiments 5 and 6). If the same methods help student learning across the three media, then the method-affects-learning hypothesis is supported. Conversely, if it were found that different methods are needed for specific media, then the findings would be evidence for the existence of method x media interactions.

To answer the second question concerning media effects, I will examine the role that the image of an animated pedagogical agent plays in learning from a multimedia game (Experiment 3) and the role that immersion plays in learning from a virtual reality environment (Experiment 5). If the presence of the on-screen agent and/or the immersion of the virtual reality environment help/helps student learning regardless of the instructional methods used, support is garnered for the media-affects-learning hypothesis. In all six studies, to assess method and media learning effects, we used two types of tests: (a) retention—in which we asked students to recall the basic factual information that was presented, and (b) problem-solving transfer—in which we asked students to solve new problems based on the principles learned in the respective computer program. For all studies, effect sizes were calculated as the standardized mean difference or Cohen’s $d$.

**Experiments 1 and 2: A Multimedia Explanation Scenario**

Many human–computer interactions involve a one-on-one learning scenario, consisting of a student interacting with a computer. An example of a one-on-one learning scenario is that of a multimedia explanation, a combination of a visual representation of a complex scientific system and a corresponding explanation in words of the principles underlying the system. The purpose of Experiment 1 was to test the modality principle and determine whether the words included in the multimedia explanation should be presented auditorily or visually to promote deep learning (Mayer & Moreno, 1998). To this end, 78 college students viewed a computer anima-
tion depicting the process of lightning formation. Forty participants were presented with on-screen text explanations of the scientific system and 38 participants listened to a narrated explanation consisting of identical words. Immediately after viewing the presentation, participants were given retention and transfer tests. The results revealed a modality effect on both learning measures: students who learned with narrated explanations outperformed those who learned with on-screen text on both types of tests (p < .001 for both, retention and transfer tests). The effect sizes were .49 for the retention test and .94 for the transfer test (Mayer & Moreno, 1998). These results support the modality principle derived from a CTLM as an effective instructional method within the context of multimedia explanations (Moreno & Mayer, 1999).

Using the same multimedia explanation, we conducted a second experiment to test the personalization principle and determine whether the words included in the multimedia explanation should be personalized or nonpersonalized to promote deep learning (Moreno & Mayer, 2000b). Experiment 2 compared students’ learning from a multimedia explanation of lightning formation in which an animation was accompanied by either a personalized, dialogue-style speech, or a nonpersonalized, monologue-style speech. There were 17 participants in the personalized group and 17 participants in the nonpersonalized group. Similar to the case of Experiment 1, after viewing the presentation, participants were given retention and transfer tests. The results from Experiment 2 failed to demonstrate a personalization effect on our retention measure. However, there was a personalization effect on the dependent measure that is most sensitive to learning: problem-solving transfer. Students who learned with personalized explanations generated more correct solutions on tests of problem-solving transfer than those who learned with nonpersonalized explanations (p < .01). The effect sizes were 1.69 and .18, for transfer and retention, respectively. The enhanced transfer findings support the personalization principle derived from a CTLM as an effective instructional method within the context of multimedia explanations.

**Experiments 3 and 4: An Animated Pedagogical Agent Scenario**

Although multimedia explanations have been shown to be effective in fostering student understanding as indicated by performance on solving problem-solving transfer questions (Mayer & Moreno, 2003), it is more and more frequent that concise, coherent, effective multimedia lessons are combined with the presence of highly visible animated pedagogical agents (APAs). APAs are animated, life-like characters designed to facilitate learning in computer-based environments (Bradshaw, 1997; Craig, Cholson, & Driscoll, 2002; Johnson, Rickel, & Lester, 2000; Moreno, in press). In previous research we have investigated the effectiveness of various features of a science simulation game called Design-A-Plant, where an on-screen agent named Herman-the-Bug interacts with the learner by posing questions and providing guidance. In this game, students fly to a remote planet that has certain environmental conditions and must design the roots, stem, and leaves of a plant that would survive (Moreno et al., 2001). The next two experiments that I will review investigated whether the modality and personalization principles would apply to the Design-a-Plant game, and what distinctive characteristics of the Herman-the-Bug APA might help student learning.

In Experiment 3, we taught 64 college students how to design the roots, stem, and leaves of plants to survive in eight different environments through the agent-based botany game. We varied whether the agent’s words were presented as speech or on-screen text, and whether or not the agent’s image appeared on the screen. Each participant served in one cell of a 2 x 2 between-subjects factorial design, with the first factor being modality of the verbal information (narration or text) and the second factor being whether or not the agent’s image was displayed on the computer screen. There were 15 participants in the image and text group, 17 participants in the no-image and text group, and 16 participants in the no-image and narration group. Students performed better on tests of retention and problem-solving transfer when words were presented as speech rather than on-screen text, therefore, producing a modality effect (p < .005 and p < .0005, for retention and transfer, respectively). The effect sizes were .69 and .89 for retention and transfer, respectively. On the other hand, the visual presence of the agent did not affect learning performance (producing no significant media effect, respective effect sizes = .41 and .06), and there were no modality x media interactions.

In Experiment 4, a total of 39 college students learned about botany with the same agent-based botany game used in Experiment 3. In this experiment, all participants saw an on-screen APA image, but 18 participants learned with personalized agent messages and 21 participants learned with nonpersonalized agent messages. Once again, the group receiving personalized messages recalled significantly more information and produced significantly more correct solutions on problem-solving transfer problems than the group receiving nonpersonalized messages (p < .05 and p < .0001, for retention and transfer, respectively). The effect size was 0.83 for retention and 1.55 for transfer. Taken together, the findings from Experiments 3 and 4 lend support to the method-affects-learning hypothesis. Similar to the case when multimedia explanations were exam-
ined, both modality and personalization principles were supported in the agent-based learning environment. In addition, the results did not support the media-affects-learning hypothesis: There was no APA image effect on student learning. It is noteworthy that a recent review of empirical work on APAs has revealed an identical pattern of results. Although many instructional methods embedded in agentless learning environments are found to be equally effective in agent-based learning environments, there is no compelling evidence yet that the presence of an APA on the screen promotes learning (Moreno, in press).

**Experiments 5 and 6: A Virtual Reality Scenario**

Virtual reality environments (VREs) have been claimed to offer great potential for promoting science learning (Psotka, 1995; Sheridan, 1992). The last two experiments that I will review sought to examine characteristics of this new media that may help student learning. A distinctive feature of VREs is that they can be used to immerse students in the learning environment. For example, rather than learning via a desktop computer display, students might learn via a head-mounted display. Therefore, an important research issue regarding the media-affects-learning hypothesis is whether media that support more immersive VREs result in different learning outcomes than those that support less immersive VREs.

*Immersion* is usually defined as the extent to which computer displays are capable of delivering an inclusive, extensive, surrounding, and vivid illusion of reality to the senses of a human participant (Slater & Wilbur, 1997). In Experiment 5, we varied the degree of immersion by having 89 college students learn about botany with the Design-a-Plant game used in Experiments 3 and 4 under three delivery conditions (Moreno & Mayer, 2002a). In the lowest immersion condition, students interacted with a desktop display and navigated the environment using the computer mouse. In the second condition, students were seated at a computer station and used a head-mounted display to navigate the environment with head movements. Finally, in the high-immersion condition, students wore a head-mounted display and could walk in an empty room to navigate the environment. In addition, to test the modality principle in VREs, we divided the three conditions in two groups. One group of students learned with narrated explanations and another group learned with textual explanations. Each one of the 87 participants served in one cell of a 2 x 3 between-subjects factorial design, with the first factor being modality of the verbal information (narration or text) and the second factor being the level of immersion during the computer interaction (desktop, head-mounted display, or head-mounted display plus walking). There were 17 participants in the narration and desktop group, 17 participants in the text and desktop group, 13 participants in the narration and head-mounted display group, 13 participants in the text and head-mounted display group, 13 participants in the narration and head-mounted display plus walking group, and 14 participants in the text and head-mounted display plus walking group.

Once the instructional program was over, we asked students to indicate their perceived sense of presence in each learning condition with a presence questionnaire (Witmer & Singer, 1998). This measure was important because the perceived sense of presence in a virtual environment is an increasing function of immersion in all its aspects (Barfield & Hendrix, 1995). After the presence questionnaire, all participants were given retention and transfer tests.

The results of this experiment revealed a significant modality effect for both learning measures (p = .0003 and .0001, for retention and transfer, respectively). Students who learned with narrated explanations outperformed those who learned with on-screen text explanations on retention and transfer tests. The effect sizes were .70 and 1.20, respectively. On the other hand, although students who learned in the two head-mounted display conditions reported a higher sense of presence than those who learned in the desktop display condition, there was no immersion effect on learning (effect sizes = .08 and .05 for retention and transfer, respectively), and there were no modality x media interactions.

Using the same botany game, Experiment 6 examined the effectiveness of the personalization method and the role of immersion in learning from VREs (Moreno & Mayer, 2004). College students learned about botany with personalized messages speech or nonpersonalized messages, and the game was presented via desktop computer (low immersion) or head-mounted display (high immersion). Forty-eight college students were distributed randomly across the four learning conditions: desktop delivery with personalized messages, desktop delivery with nonpersonalized messages, head-mounted display with personalized messages, and head-mounted display with nonpersonalized messages. Similar to the case of Experiment 5, once the botany game was over, students were given the presence questionnaire and then asked to complete the retention and transfer tests.

As before, the results revealed that, across both levels of immersion, students who received personalized agent messages performed better on retention and problem-solving transfer tests (p = .002 and .0001, for retention and transfer, respectively). The effect size was .77 for retention and 1.64 for transfer. Similar to the pattern found in Experiment 5, although students reported higher levels of presence with high rather than low immersion conditions, higher immersion did not lead to better performance on tests of retention or transfer. Taken together, the findings from
Experiments 5 and 6 lend support to the method-affects-learning hypothesis. Similar to the case of the multimedia explanation and APA learning scenarios, we found that both modality and personalization methods promoted learning; however, there was no support for the media-affects-learning hypothesis.

**FINAL REFLECTIONS**

Any technological innovation is fraught with promises and challenges. The most straightforward conclusion from this chapter is to caution against focusing too narrowly on the “power” of state-of-the-art technologies apart from their relation to cognitive theory. Instead, instructional designers should focus on applying cognitive theories of learning in order to better understand when and why a particular technology may help learning. The reviewed studies lend support for a method-affects-learning hypothesis according to which instructional methods, not media, impact learning (Clark, 1999, p. 1). More specifically, two instructional methods (modality and personalization) that proved to have learning benefits in a lower technology (multimedia explanations), also proved to help learning from higher technologies (agent-based games and immersive virtual reality environments). Despite the promising benefits of including highly visible APAs in multimedia games and those of making learning environments more immersive, we found no evidence that these new media features promote enhanced learning.

Based on these results and on the disappointing history of educational technology, I propose to break down the chapter's opening question “When does instructional technology help learning?” into two separate inquiries. First, it is necessary to identify the distinctive characteristics of the technology at stake and to describe how such characteristics may be relevant to the learning process. For example, the lack of image effects found in past APA research may be explained as due to the fact that the agent image had no specific learning function (Moreno, in press). However, if the agent image were central to the instructional objective of the lesson, media effects may arise. For example, if the agent were to model procedural knowledge, then it may be important to carefully design the image to provide all the visual information necessary for observational learning to occur. Physical education, dance, and technical training are promising domains to explore this thesis. Similarly, it is possible that the immersive quality of our VREs did not promote learning because immersion was not relevant to the educational focus of the science lesson. Had we used a learning environment where immersion had a specific learning function, such as adding psychomotor feedback to the learning experience, we may have found a media effect (Thurnman & Russo, 2000). More research is needed to explore the conditions under which the distinctive characteristics of various media may enhance learning.

A second important inquiry, especially for the case where the new technology has no distinctive characteristics that may be relevant to learning per se, is to examine whether the new technology might present an advantage relevant to a specific instructional method. For example, there are many approaches to assessing the cost and time efficiency of technology-based instructional innovations (Levin & McEwan, 2001). These approaches provide a reasonable set of criteria for determining if the new technology helps learning by increasing the delivery or accessibility of good instructional methods.

In sum, interest in new educational technologies is so widespread that it has often taken priority over finding empirically-based principles for meaningful instructional design (Clark, 2001). Additionally, a common pitfall of media research and development is the failure to adequately distinguish between the instructional methods embedded in the technology and the specific properties of the media. Taken together, these tendencies have helped create a history of 100 years of instructional technology failure (Mayer, 2001). However, enthusiasm and cautious research are not necessarily antagonistic. Therefore, a recommendation for instructional technology research is to design studies where learning benefits or drawbacks can be clearly attributed to either method or media and as a result, to conduct more research where the two factors are manipulated separately with adequate control conditions.

In this chapter, I offered CTLM as a useful framework to help advance our understanding of the role of method and media in instructional technology. Only by focusing on the relation between design features and the human information processing system can we truly discover the promise and pitfalls of instructional technologies. Nevertheless, it is important to note some theoretical and practical limitations of the present chapter. First, the conclusions that I have drawn are theoretically limited because although the presented findings are supportive of the modality and personalization principles, they only indirectly support the CTLM assumptions from which the principles were derived. It is possible that the modality and personalization principles rely on reasons other than the assumptions presented in Table 1.1. Second, my conclusions are practically limited because the reviewed research deals with only three different media (i.e., multimedia explanations, agent-based games, and virtual reality environments), two methods (i.e., modality and personalization), and one kind of learner (i.e., college students who were unfamiliar with the content domain). More research is needed to generalize these preliminary results to other media, methods, and learners.
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