Effect of Gaming and Visual Metaphors on Reflective Cognition Within Computer-Based Simulations

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Abstract: The purpose of this study was to investigate the influence of game-like activities on adult learning during a computer-based simulation. This research also studied the use of visual metaphors as graphic organizers to help make the underlying science principles explicit without interfering with the interactive nature of the simulation. A total of 70 university students were the participants in the quantitative phase of the study. They interacted with a simple computer simulation that modeled the relationship between acceleration and velocity using a discovery-based approach: No formal instruction on the science concepts was given. Participants had control over the acceleration of a computer animated ball. In the quantitative phase of the study, four simulation conditions were studied comprising two levels of two factors: Gaming Context (Yes, No) and Visual metaphor (Yes, No). Results from the quantitative phase showed that although participants reported greater levels of enjoyment when the game was included, the game actually interfered with participants' explicit learning of the science principles. No effect for the visual metaphor was found. However, the use of the game in tandem with the metaphor resulted in increased levels of tacit learning, as evidenced by greater scores on a special gaming task used for evaluation at the end of the session. In the qualitative phase, four additional participants were interviewed as they interacted with a version of the software which allowed each of the conditions to be switched on and off. Qualitative results demonstrated that the visual metaphor became a very important tool for participants. Also, the qualitative sessions uncovered patterns of interaction while playing the game that might explain why the game interfered with learning. These results are important given developers' infatuation with gaming strategies within commercial educational software, often referred to as "edutainment."

Games and education have enjoyed a long history together. It has long been believed that the origin of games may lie in training simulations conducted by our most remote ancestors (Groos, 1901, cited in Murray, 1978). One theory of the origin of board games holds that the earliest games were battle simulations designed to instruct the young (Murray, 1978). One of the oldest games on record is the Indian precursor to Chutes and Ladders, the goal of which was spiritual instruction (Provenzo, 1981) — moral education in general has often been the theme of games (Grunfeld, 1975). The first American-manufactured board game, "Traveller's Tour Through the United States," was based on a map, and purported to teach something about American history and geography (Whitehill, 1992). Educational games are one of the earliest forms of instructional technology.

Games are a way of knowing the world, a mediation between experience and understanding. Their existence is recorded throughout history with roots in our most fundamental practices. Games are common throughout human culture (Loy & Kenyon, 1981; Roberts, Arth & Bush, 1959). In fact, they are so intricately embedded in culture that it is difficult to separate the two. The earliest games may well have derived from religious rituals. Pennick (1989) has traced connections between ritual divination and ancient game boards. Games and play have long been closely associated. Huizinga (1950) believed that the construct of play was inseparable from what it means to be human and that we should properly be called "Homo ludens, " or "man the player." Games are the distillation of play, and thus, following Huizinga, the distillation of our humanity. Similarly, Piaget long viewed play as one of the most essential of human learning mechanisms (Piaget, 1951, 1952). (See Rieber, 1996b, for a critique of play theory in instructional technology.)

Technological advances have opened new possibilities for educational gaming. The potential complexity and flexibility of recent computer simulation capabilities allow educators to devise instructional games of increasing power and instructional precision. Contemporary digital technologies make it possible to devise ever more sophisticated and pedagogically precise educational games. Instructional designers of these games will benefit, as will the learners who use them, from being better informed of how they work.

Despite their everyday use, defining the terms *simulation* and *game* is a difficult task.[1] Many activities and events are casually called either simulations or games (or both), resulting in a muddled set of characteristics. However, there are some general characteristics upon which most designers agree. For example, Gredler (1996) describes several similarities and differences. One similarity is that both simulations and games base an activity in a totally imaginary context, usually, but not always, based on a real-world model with varying degrees. Another similarity is that both usually offer the user a great deal of control over the activity, even though random variation is almost always a part of the experience. An important difference is that all games include some level of competition, even if it involves the player against self — the object of the game is to win. In contrast, the chief aim of most simulations is to put the player into a specific role. Another important difference is that games are rule-based, often times defined in completely arbitrary ways, whereas simulations are always defined on the dynamic relationship of two or more variables upon which the simulation operates, often called the underlying model (Reigeluth & Schwartz, 1989).

Current theoretical support for gaming is dominated by Malone's theory of intrinsic motivation which contends that intrinsic motivation is a function of an optimal relationship between challenge, fantasy, curiosity and control (Malone, 1981; Malone & Lepper, 1987). Achieving such an optimal relationship results in the game being fun. Learning is viewed as a consequence of a person choosing to participate and persist at a task they find enjoyable. However, the research literature related to gains in achievement through participation in games is ambiguous. Few positive results of gaming, at least as compared to traditional classroom instruction, have been reported (Dempsey, Lucassen, Gilley & Rasmussen, 1993-1994; Gredler, 1996; Randel, Morris, Wetzel & Whitehill, 1992). Though gaming pervades all of education, the way in which its cognitive and affective characteristics contribute to learning is not well understood. It is well known that motivation is a necessary, but not sufficient, condition to learning. However, a critical assumption is that motivation can only lead to positive outcomes. Can the intense motivation triggered by some gaming environments actually pose a unique threat to learning? This question was considered in this study.

Another way of looking at this question comes from Norman (1993) who distinguishes between experiential and reflective cognition when describing the role of technology in learning. Experiential cognition is based on reactions to moment-to-moment events that we encounter, whereas reflective cognition requires careful and deliberate thought and consideration over time. Each leads to qualitatively different kinds of learning — experience leads to understanding embedded in a particular task and reflection leading to explicit understanding that can be articulated and applied to other problems. While both are important and interdependent, Norman warns of the danger of technological-based learning environments which fail to promote reflective cognition. Educational computer games seem particularly prone to this shortcoming. On one hand, games may provide an intrinsically motivating learning environment where students intensely complete the activity. However, unless steps are taken to encourage reflection, deeper levels of learning that transfer beyond the gaming context itself may not occur. Gaming also walks a fine line between enabling organization or promoting distraction. The game may help students to organize content into meaningful patterns and help them set up and monitor learning goals. On the other hand, games may serve to distract students away from learning goals if the gaming activity is particularly intense.

The purpose of this study was to explore the role of gaming on reflective cognition in a science simulation that demonstrates the relationship between acceleration and velocity. Past research in this area has demonstrated that these concepts are very difficult for people to understand, especially when the simulation uses a discovery-based approach — that is, when no externally provided instructional elements are included. For that reason, the use of a visual metaphor was also studied as a way to promote reflective cognition while people are engaged in the simulation. This use of visual metaphors constitutes a *conceptual model* as supported by theory and research on mental models (Carroll & Olson, 1987; Gentner & Stevens, 1983; Mayer, 1989). A common example of a visual metaphor used in this way is the computer represented as a person's desktop, complete with files, folders and physical space in which to organize and manage them.

Educators have long used metaphors and analogies to help learners bridge the gap between old and new knowledge (Glynn, Duit & Thiele, 1995; Mayer, 1979). The student is presented with new material in terms of older material that is already well understood. In this sense, metaphor has a limited but useful role as a device for conveying comparisons. However, others (Davidson, 1976; Petrie & Oshlag, 1993) believe that metaphors can play a unique role in the acquisition of new knowledge. Because there is a connection between vividness of presentation and learning, Davidson (1976) has argued that metaphor can transfer learning in a memorable way. Petrie and Oshlag (1993) have advanced the theory that "metaphor is one of the central ways of leaping the epistemological chasm between old knowledge and radically new knowledge" (p. 583) The metaphor accomplishes this by juxtaposing two apparently unrelated concepts in the mind of the learner, thus creating an anomaly. The learner then resolves this anomaly by bringing the two concepts together and constructing a new understanding. This is consistent with constructivist ideas about learning, since the learner makes an active contribution. In the context of a gaming/simulation environment, visual metaphors may help the learner put new concepts together with already understood ideas into a new cognitive synthesis.

A variety of data sources and methodologies were used in this research, including achievement (explicit and tacit), motivation, and metacognition involving both quantitative and qualitative assessment strategies. Given the complex nature of learning from such highly interactive and visual environments as used in this study, a combination of such a wide array of assessment strategies is believed to provide a more complete understanding than any could provide individually. This is in keeping with Salomon's admonition to view qualitative and quantitative methodologies as complementary, rather than competing, approaches (Salomon, 1991).

Method

The quantitative phase of the study involved a total of 70 participants. Participants were upperclass undergraduate students enrolled in an introductory computer education course. Participation was voluntary, though extra credit in the course was provided to students as incentive to participate.

Materials

The materials consisted of four versions of a computer-based simulation of the relationship between acceleration and velocity. In all versions, participants had direct control over the acceleration of an animated ball; the computer then calculated the resulting velocity (i.e. speed and direction) and position of the ball and reported this information back to the user in real-time, that is, the computer updated the velocity of the ball as fast as the user interacted with the simulation. The task for participants was to try to understand the relationship between acceleration and velocity through their interaction with the simulation.

Participants were given one of four versions of the simulation. The first version was a pure simulation in which no instructional or organizational elements were included. In the second version, the simulation was embedded in a game context. The object of the game was to change the ball's direction when it was inside an area on a number line indicated by a yellow box. The total number of times participants were successful in making the ball do a "flip flop" constituted their score for that round. The third version included a graphical metaphor as an aid to understanding the relationship between acceleration and velocity. Participants in this version were told to pretend that the ball was rolling on a table top that could be tilted in either direction. Tilting the table left or right was equivalent to accelerating the ball in that direction. This graphical metaphor was likewise animated as participants manipulated the ball's acceleration. The fourth version included both the game context and graphical metaphor, as illustrated in Figure 1.[2]

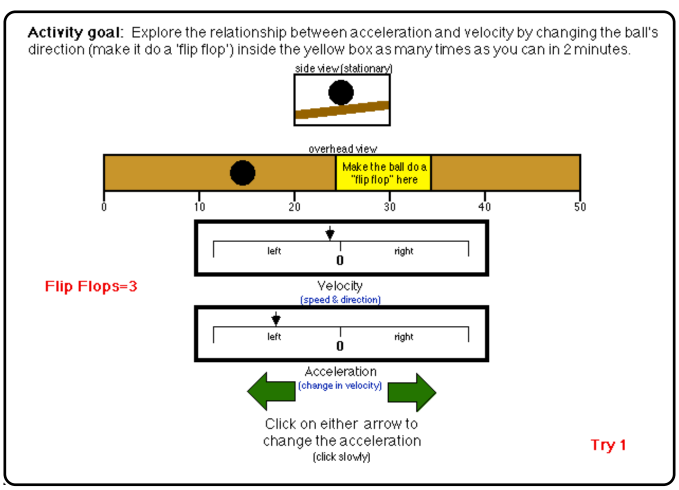

Figure 1. Snapshot of the computer screen during the simulation condition which included the game and visual metaphor. The goal of the game was to make the ball reverse directions inside the yellow box (marked "make the ball do a 'flip flop' here) as many times as possible in two minutes. The visual metaphor (marked "side view") likened the acceleration of the ball to its motion *as if* it were rolling on a board that one could tilt in either direction. As the participant manipulated the ball's acceleration (by clicking on either large arrow), the visual metaphor changed accordingly.

Dependent Measures

Explicit learning. A 12-item test was used to measure participants' explicit understanding of the relationship between acceleration and velocity. Multiple-choice questions (1 answer and 4 distractors) were used as the testing format. This measure was administered both before (pretest) and after (posttest) the simulation activity. This test was conceptual in nature, not mathematical. The purpose of the test was to demonstrate a conceptual understanding of these physical principles using everyday examples. For example, one group of questions used the context of a ball in motion and another group used the context of a car in motion, as illustrated in Figure 2.

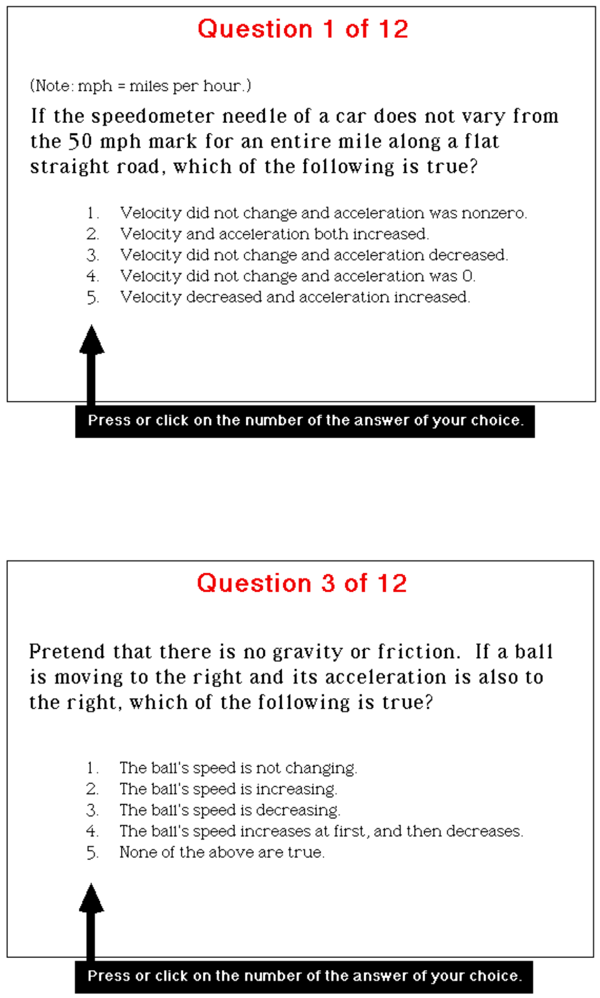

Figure 2. Two representative questions from the pretest/posttest, one using the context of a car in motion (top) and one using the context of a ball in motion (bottom).

Comprehension monitoring. Right before the posttest was administered, participants were asked to predict what their posttest score would be in multiples of 10%. The purpose of this assessment was to understand better how participants perceive and monitor their own learning in open-ended learning environments. Such environments place unusually heavy demands on people's abilities to successfully monitor and regulate their own learning, since no instructional support is given.

Response Confidence. Immediately after answering each posttest question, participants were asked to rate how confident they were in their answer on a scale from 0 to 10 where 0 was "I guessed" and 10 was "I know I'm right." This assessment was used to gauge each participant's perceived level of learning and was designed to complement the comprehension monitoring data.

Tacit learning. After the posttest, all participants completed a special game designed to measure tacit learning of the relationship between acceleration and velocity. The goal of the game was to move the ball to a certain segment of a number line and keep it there for ten seconds, as illustrated in Figure 3. The total time taken by participants to complete five tries at this game was their tacit learning score. The purpose of this assessment was to measure participants' tacit understanding of the science principles embedded in the simulation. Tacit learning remains situated in the performance activity. This type of knowledge is termed "tacit" (also often referred to as implicit) because it exists below one's awareness level and learning takes places without deliberate effort or attention (Reber, 1993).

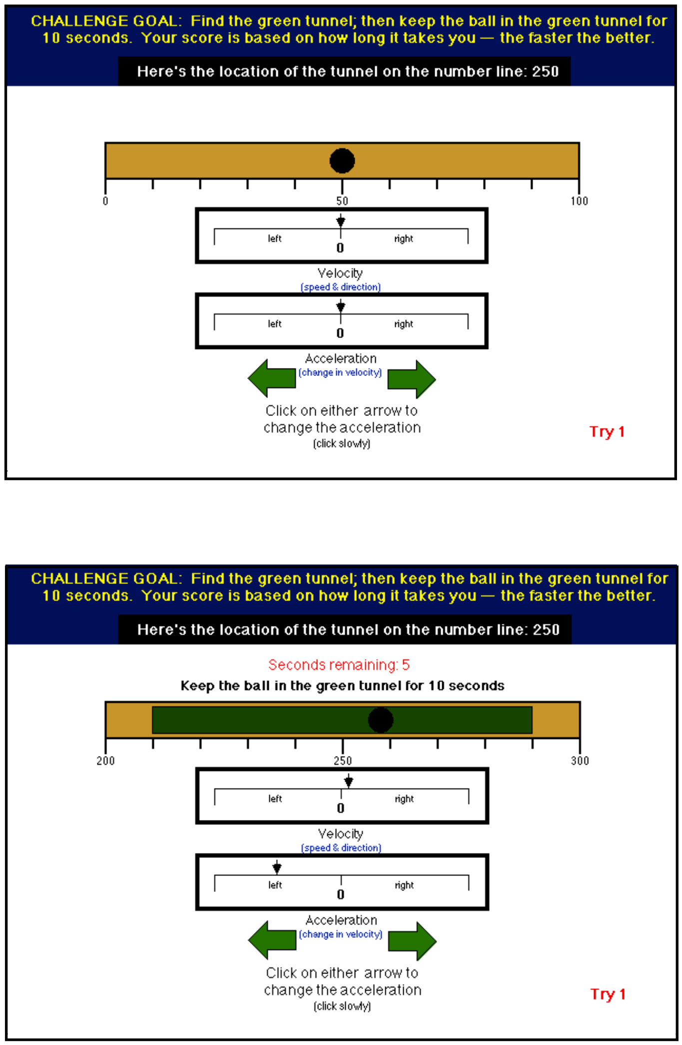

Figure 3. Two screen snapshots from a game used to assess tacit learning. The game began with the ball at the 50 mark on the number line (top). The goal of the game was to move the ball to the location indicated at the top of the screen and then keep it in this area for ten seconds (bottom).

Frustration. After each simulation trial, participants were asked to rate their level of frustration on a scale of 0 to 8 where 0 was "no frustration," 8 was "extreme frustration." These data were collected because it has been our experience that many participants are often unfamiliar with the demands placed on them during open-ended learning environments. Rather than being told what to do or learn, they must figure it out for themselves. Cognitive theories of learning emphasize the qualitative differences in learning that can take place when a person discovers or "invents" knowledge for themselves. However, such potential for deeper kinds of learning comes at the risk of not being to make sense of the learning environment. Such frustration may actually inhibit learning.

Enjoyment. After each simulation trial, participants were asked to rate their level of enjoyment on a scale of 0 to 8 where 0 was "no enjoyment," 8 was "extreme enjoyment." These data were collected in order to verify or validate the prediction that adding a game context would increase the motivational appeal of the learning task for participants, as predicted by Malone (1981, 1987).

Procedures

All of the simulations and testing were administered by the computer. Participants were randomly assigned to one of the four conditions (i.e., Game with Metaphor, Game Only, Metaphor Only, No Game/No Metaphor) as they reported to the computer lab. The computer immediately administered the pretest. Participants then were given a total of 10 attempts at the simulation — two minutes for each attempt. After each attempt, the computer surveyed participants on their level of frustration and enjoyment. Immediately upon completion of the simulation activities, the computer automatically administered the posttest. After each posttest question, participants were surveyed on their response confidence. Approximately one hour was needed to complete the experiment.

Design

This study used a 2 X 2 factorial design involving two levels of two between-subjects variables: Gaming Context (Yes, No) and Graphical Organizer (Yes, No). Statistical procedures consisted of separate Analysis of Covariance (ANOVA) tests for each of the dependent variables using the pretest as the covariate.

Results

Explicit learning. A significant effect was found for Game, $F(1,65)=3.96$, $p<.05$, $MS_{error}=255.82$. Posttest scores for participants who were given the game context (mean=52.1%) were lower than participants not given the game context (mean=65.4%). The game interfered with explicit learning. There was no effect on performance for Metaphor, $F(1,65)=.23$, $p=.63$, $MS_{error}=255.82$.

Response confidence. A significant effect was found for Game, $F(1,65)=10.13$, $p<.01$, $MS_{error}=511.35$. Participants who were given the game context were less confident in their posttest answers (mean=4.98) than participants not given the game context (mean=6.92). There was no difference in response confidence for Metaphor, $F(1,65)=.02$, $p=.88$, $MS_{error}=511.35$.

Comprehension monitoring. A significant effect was found for Game, $F(1,65)=3.51$, $p<.1$, $MS_{error}=1742.86$. Participants' predictions of their posttest scores were lower when given the game (mean=46.6%) than when not (mean=56.6%).

Tacit learning. There was a significant interaction between Game and Metaphor, $F(1,65)=4.28$, $p<.05$. Participants given both the game and the metaphor scored significantly better than all other participants.

Frustration. No significant main effects were found for Game, $F(1,65)=1.73$, $p=.193$, or Metaphor, $F(1,65)=.04$,$p=.84$, $MS_{error}=384.66$. Participants' level of frustration was not affected by the presence or absence of the game or graphical metaphor.

Enjoyment. A significant effect was found for Game, $F(1,65)=15.8$, $p<.0001$, $MS_{error}=356.32$. Participants given the game context reported much higher levels of enjoyment than participants not given the game. No significant differences were found for Metaphor, $F(1,65)=1.09$,$p=.30$, $MS_{error}=356.32$.

Qualitative Methods

Procedures

As previously stated, qualitative procedures were used in this study to complement the quantitative data in order to interpret participants' experience from a number of perspectives (often called "triangulation"). Although quantitative procedures allow for a systematic analysis of many variables across a large number of participants, they do not enable a thorough understanding of an *individual's* experiences. In contrast, qualitative procedures provide for such an in-depth analysis, though with fewer participants. The methodology we used is best described as grounded theory (Strauss & Corbin, 1994) because it is designed for the generation of theory instead of verification of theory. The goal of this analysis was to encourage participants to describe their thoughts and feelings as they interacted with the simulation. We assumed the role of participant observer by asking questions and discussing their learning of the science content as they interacted with the simulation. The participants were solicited from the same audience as those chosen for the quantitative phase of the study. One difference was that participation was solicited on the basis that each had a legitimate interest in learning science even though the actual content of the simulation was not disclosed beforehand. The purpose for this condition was to try to involve individuals who were not averse to physical science content.

An unstructured interview protocol was used. Although several general directions for the interview were prepared beforehand, we allowed ourselves to take the interview in whatever direction that seemed appropriate at the time. Each session was conducted one-on-one with one of the authors (each of us interviewed two participants). Each session began by having each participant to complete the pretest on their own with no interference. The interview began as soon as the participant finished the pretest and was about to begin the simulation. Each participant was asked to explore the simulation for the first 2 or 3 tries at the simulation without the visual metaphor or gaming features. Next, the visual metaphor was introduced, followed by the game. Each participant then negotiated with the interviewer as to when to turn on or off the metaphor or game. There were no set number of times that the participant was required to complete the simulation, though 10 was the target. Throughout the session, the participant was encouraged to use a "think aloud" protocol. After completing the simulation, the participant answered the posttest questions. Although neither the computer or interviewer gave any hints or feedback during the posttest. The computer internally kept track of which questions were missed during the posttest. Upon completion of the posttest, the participant was given their pretest and posttest scores. The participant and interviewer then reviewed in detail the questions missed during the posttest as another approach to interpreting what the participant had learned from the simulation.

The authors met several times after completing the qualitative sessions to compare, contrast, and synthesize our findings. So far, four interviews have been conducted, though more are planned.

Results

Five distinct themes emerged from the qualitative phase of the study: the usefulness of the visual metaphor; the locus of attention in the various stages of the program; the self-competitive element of the game activity; the difficulty experienced by participants in applying the visual metaphor to questions involving the car context; and the importance of the interviewer in asking questions to cue strategies and actions. All participants appeared to respond favorably to the simulation.

In contrast to the quantitative results, all four subjects found the visual metaphor to be useful and important. Most important, the metaphor became an important "anchor" when trying to articulate the motion of the ball. That is, the metaphor seemed to give participants a way to talk about what was happening to the ball. This is probably because the metaphor was concrete, almost having a tactile element. Participants would often hold out their hands, tilting them as if they were actually holding the board.

It was also interesting how participants shifted their visual attention to various places on the screen. Interestingly, few reported actually looking at the ball after the first several tries. Instead, most shifted their attention between the visual metaphor and the acceleration and velocity "gauges." One participant stated that she felt these gauges helped her the most in her learning. When the game was first introduced, the participants immediately paid close attention to the animated ball itself. However, at least two of the participants soon began to use the other visual elements as an aid to completing the game. The velocity gauge seemed particularly important in completing the game for at least two participants because they learned that the ball does the "flip flop" when this gauge crosses the zero point.

The game resulted in a complex set of outcomes. Before the game was introduced, two of the participants said that they fully understood how the simulation worked and felt confident that they could control the ball as they wished. However, when the game was introduced they clearly had great difficulty controlling the ball and this surprised them. One participant continually reported that she enjoyed the game and was not frustrated, although her best score never exceeded four "flip flops" in two minutes. The other three participants began to engage in a high level of self-competition as they gained mastery of the game. In short, they became obsessed with improving their score. Although this had the positive consequence of motivating them to play the game repeatedly, they clearly lost all awareness of the purpose of the game — that is, to learn more about acceleration and velocity. In other words, the game inhibited all reflection on the underlying science principles. One might say that these participants went into "Nintendo mode," or "twitch mode." Improving their score became an end unto itself. It took a great deal of prompting and coaxing by the interviewer to bring their attention back to the purpose of the game by questions such as "What have you learned about the relationship between acceleration and velocity as a result of playing the game?" None of the participants felt they were learning more about the content, even though their scores were improving.

During the posttest, participants clearly demonstrated their use of the simulation experiences as a way to help answer the questions so long as the questions involved the example of a ball in motion. One participant commented how the simulation "leaked in" when she tried to answer the questions. Participants also used the vocabulary of the visual metaphor — tilting board, ball going uphill and downhill, etc. — as a means to answer the questions. However, the participants were largely unable to use the simulation experience or the visual metaphor in answering the questions involving the motion of a car. Participants were not able to transfer the simulation experiences to this different context.

Finally, it was readily apparent that the interviewer served a very important role for participants as they completed the simulation, especially when the game was activated. The participants seemed to rely on the constant questioning or prompting the participant in order to consider the relevancy of the simulation on learning the science principles. When left on their own, participants had much difficulty in focusing their attention on how to manipulate the task in order to learn more about the content.

General Discussion

The purpose of this study was to investigate the influence of game-like activities and graphical organizers on adult learning during a computer-based simulation. Our previous research has indicated that adults rapidly increase their ability to successfully complete game-like activities in which physical science concepts and principles are embedded, yet have great difficulty in transforming this experiential (or tacit) knowledge into an explicit understanding of the scientific principles (as measured by traditional performance tests, such as posttests) (Rieber, 1996a; Rieber et al., 1996). One reason for this may be that the highly experiential nature of the visual representations of the simulations coupled with the game-like contexts may be inadequate for promoting reflection of the principles underlying the simulations. In this research study, the influence of game-like contexts was directly investigated.

Consistent with Malone's (1981, 1987) theory, the gaming context appeared to produce greater levels of intrinsic motivation as suggested by the participants' reports of enjoyment. Participants' enjoyment actually increased as they gained mastery of the game. Indeed, the participants' game scores increased steadily from about 2 to 8 "flip flops" during the ten tries. Such improvement suggests that participants were intensely engaged in the activity. The gaming context appeared to promote experiential cognition. The combination of game and visual metaphor appeared to be an effective strategy for promoting tacit learning of acceleration and velocity — these participants were able to transfer their understanding to another game context. Despite this, however, the gaming activity did not promote reflective cognition. In fact, it actually interfered with explicit learning. Participants were less able to answer questions that relied on explicit understanding of the physical relationships at work. Similarly, participants' self-reported levels of response confidence and perceived comprehension were lower when given the game — they did not feel as ready to answer the posttest questions, nor were as sure of their answers as compared to participants not given the game. The metaphor, by itself, had no effect on explicit learning.

The qualitative analysis revealed a more complex conclusion than simply if adding games to content is "bad" or "good." In all cases, participants were challenged by the game context when it was introduced, even those who felt strongly that they completely understood the simulation and the physical principles it was modeling. The game gave these participants a clear means to evaluate their own understanding, at least in terms of having them recognize that they did not understand the principles as well as they thought.

Although the quantitative analysis largely dismissed the graphic metaphor as nonconsequential, the qualitative analysis, on the other hand, revealed a much more positive case for its use. Participants in the qualitative phase clearly found the metaphor to be useful in helping them to understand the principle of acceleration. They continued to use this metaphor as an aid to answering the questions that dealt with the example of a moving ball. The metaphor became a way to think about acceleration, making this principle explicit in a way that the simulation was unable to do without it. The qualitative analysis also revealed the limitations of the metaphor for near transfer tasks. Participants became confused and disoriented when the context of questions changed to the motion of a car. Perhaps with more time and discussion with an expert (such as a teacher), participants would have been able to map the metaphor onto contexts requiring far transfer. This is an area for future research.

An unexpected result of the qualitative analysis was the complexity in which participants reported using the various screen elements, shifting their attention dramatically between the ball, the visual metaphor, and the acceleration/velocity gauges. Although the animation of the ball gives the most direct evidence of the ball's speed and direction, it was surprising to see that participants relied much more heavily on the gauges. These gauges were not the focus of the research, but instead were intended only as a necessary part of the graphical interface. For one participant, for example, the gauges seemed to provide the most direct mapping between the acceleration/velocity of the ball and her own mental construct of what this relationship meant.

Finally, this study illustrates the significant role played by an outside agent in helping a learner to make sense of and use the simulation/game to learn about the science content. This is consistent with Vygotky's (1978, 1986) zone of proximal development, where individuals who are on the threshold of learning are often unable to reach understanding without some kind of externally provided assistance or intervention. In the absence of such intervention, participants focused far too much on the competitive nature of the game and, as a result, their ability to monitor their own comprehension was inhibited. This is a plausible explanation as to why participants in the quantitative phase who were given the game scored worse on the posttest than those who were not. Although all participants seemed to enjoy the game (as evidenced by the enjoyment data in the quantitative phase and the verbal reports during the qualitative phase), the game, in and of itself, did a poor job in promoting any reflection on the content. However, this study indicates that given an outside agent (such as a teacher), the game context has much potential to benefit learning. An obvious conclusion is that teachers should not simply introduce “edutainment” software into the classroom without careful consideration and planning as to how to make these highly interactive (and enjoyable) experiences relevant and meaningful from the educational point of view. Rather than replacing the teacher, this software elevates the role of informed teachers and emphasizes the importance of their contribution and influence.

Proponents and opponents of educational gaming should take care in not jumping to the conclusion that this study provides evidence to support either position. In fact, this study provides at least initial evidence of the complex nature of learning from gaming environments and the need for guidance from a master teacher. Certainly, proponents of gaming should take heed of avoiding the “game ethos,” that is, believing that all games must be good for learning. If anything, this study provides some sobering reminders how a good idea can quickly sour if implemented inappropriately. The evidence reported here cautions against giving students access to a computer game without careful monitoring of student understanding.

These results should help guide designers of educational computer games to consider how to effectively balance the demands of motivation, experiential cognition, and reflective cognition. It is clear that considering the value of an educational computer game solely on one of these criteria is incomplete and potentially misleading. This study demonstrates the antagonism inherent in the use of activities hoped to both promote enjoyment and learning, similar to the class of computer software known as “edutainment.” On one hand, the use of a game may increase the level of enjoyment for participants, yet on the other hand distract their learning away from the intended instructional goals.

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Footnotes

[1]For example, Psygame, an electronic listserv dedicated to discussing the scientific study of games in education and psychology (http://weber.u.washington.edu/~chet/researchers.html), recently held a long debate, without resolution, over the definition of a game proposed by one of its subscribers.

[2]Obviously, an adequate understanding of the relationship between acceleration and velocity is prerequisite to fully understanding the nature of the task that subjects experienced in this study. An adequate explanation of the underlying physics principles is beyond the scope of this article. Here is a brief explanation of the principles upon which the simulation was modeled (modified from Rieber, 1996a).

Subjects were only able to change the acceleration of the ball by clicking on either an “acceleration left” button or “acceleration right” button, though they could click on these buttons as often as they wished. The buttons were in the shape of large left and right arrows as illustrated in Figure 1. Each time the subject clicked on either acceleration button (left or right), the computer added one unit of acceleration to the ball’s motion in that direction. For example, if the subject clicked just once on the left arrow, the simulation would record the object’s acceleration as .1 cm per second per second to the left edge of the screen. Consequently, the velocity of the object already moving at 3 cm per second from right to left would begin to increase its speed by .1 cm every second: after 1 second its speed would be 3.1 cm per second; after 2 seconds its speed would be 3.2 cm per second, etc. If the subject pressed the left arrow again, another unit of acceleration would be added to the ball. The ball would increase in speed by .2 cm per second per second — the rate of change in the ball’s speed would be doubled. In this example, the ball’s speed would continue to increase in speed unless the subject clicked on the right arrow twice to return the acceleration to 0, at which point the ball would continue to move again at a constant velocity. To make the ball slow down, the subject would need to press the right arrow which would record the object’s acceleration as .1 cm per second *to the right edge of the screen.* For example, if the object was moving at a velocity of 5 cm per second in a right to left direction, the object’s speed would decrease in speed by .1 cm every second until its speed reached zero, at which point the object would reverse direction and begin moving from left to right with its speed then *increasing* at a constant rate of .1 cm per second.