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Learning with Computer Games and Simulations

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Computer games and simulations can be defined as interactive multimedia with dynamic elements that are under user control. They range from games that require simple, repetitive actions, such as Tetris®, to complex digital worlds. Unlike much of the currently available educational multimedia, games and simulations are highly interactive, with many user-controlled features (Rieber, 2005). Although similar in many ways, games differ from simulations by including a goal or challenge (Van Horn, 2007). Most people agree that video games can promote learning, although critics suggest that what is learned may be inappropriate (Shaffer, Squire, Halverson, & Gee, 2005). Video games are highly engaging, and there is great interest in how to harness their power to support learning. Researchers have studied educational games and simulations to determine how they can effectively support learning. This Research in Brief article provides an overview of this research, emphasizing how computer games and simulations can best be used to support learning, citing research done with students with disabilities where available. The article includes four main sections: an overview of the research implications for using computer games and simulations to support learning, a guide for choosing games and simulations for the classroom, a list of resources, and a more detailed description of the research literature.

Overview of Games and Simulations

Educational games and simulations have been found to be effective in motivating students to learn (Ke, 2008; Papastergiou, 2009; Tüzün, Yilmaz-Soylu, Karakus, Inal, & Kizilkaya, 2009) and games that encourage exploration may be particularly engaging to students, especially girls (Kinzie & Joseph, 2008). An example of a game that fosters exploration is Discover Babylon, in which students travel through Mesopotamian time using math, reading and writing skills.

Some games and simulations allow students to explore and create materials that they could not work directly with in real life. For example, ChemSense provides an environment in which students can explore chemical processes and see the effects of changes. These open environments can also help students to correct errors and misconceptions in their thinking by allowing them to test out hypotheses. Simulations can enable students to develop familiarity with an activity before they engage in it. As an example, with Froguts students can use an interactive computer program to proceed fully through a frog dissection before attempting dissection of an actual frog. Students who use simulations report that they feel more confident in their skills when later working with real materials (Ronan & Elihu, 2000).

Students need guidance when using games and simulations

Computer-based games and simulations are more effective when some form of guidance is provided to students. Many games and simulations provide guidance in the form of directions at critical points and feedback on performance. Games and simulations can also guide students by highlighting critical features, ensuring that students attend to what is important. Often, particularly when working in a relatively new content area, students may be overwhelmed by the features of a game and miss important points. Well-structured games and simulations anticipate this problem in various ways, such as by limiting the choices a student can make or drawing students' attention to a specific feature. Some games and simulations use animated pedagogical agents to provide directions and offer guidance and advice. For example, in Immune Attack, the student is guided by a mentor while traveling through the body. The goal is to learn about the different cells and environments in the human body in order to figure out how to train the immune system. Providing relevant instructional advice, within the context of the game, can lower anxiety, especially in competitive games (Van Eck, 2006).

Students need to be challenged

As in any learning situation, students are usually more engaged when they face a challenge that they feel they can meet. The level of challenge should match the student's skill level. If the task is too hard, the student will give up easily, and if it is too easy, the student may become bored. Students also benefit from games that become progressively more complex and difficult. Thus, an effective game allows students to begin at different levels of challenge and gradually take on more challenge. As an example, Chucky's Chicken Stacker is a game in which players find words with a specific vowel sound. There are two levels of difficulty, and the speed of the game can be adjusted.

Students need to reflect

To effectively promote learning, games and simulations must include ways for students to reflect on and explain what is happening. In fact, learning may not occur without guidance and time for reflection. Students may become caught up in the game format and not internalize the learning. Students with disabilities, in particular, may have trouble focusing simultaneously on the rules of a game and the educational content. Several programs use animated pedagogical agents or worksheets to help students reflect on what they are learning by providing explanations and questions for them to answer. For example, the Rabbits and Wolves simulation at Project Interactivate, in which students explore how nature keeps balance, has a worksheet of guiding questions that students can answer as they use the simulation.

Choosing a Program

Games and simulations can be a valuable part of an educational curriculum. As with all learning, students need guidance and opportunities to reflect on their work. Games and simulations need to be sufficiently challenging to engage students, and the level of challenge should be flexible, changing as students become more proficient. While many games and simulations incorporate features to guide and support students, teachers should monitor students' use of these materials to make sure the structure and rules of the game do not take priority over learning.

Resources

Discover Babylon

Discover Babylon TM, a joint project of the Federation of American Scientists Learning Technologies Project, UCLA's Cuneiform Digital Library Initiative, Escape Hatch Entertainment, and the Walters Art Museum., uses sophisticated video gaming strategies and realistic digital environments to engage the learner in challenges and mysteries that can only be solved through developing an understanding of Mesopotamian society, business practices, and trade.

ChemSense

ChemSense provides software that simulates an environment in which students can explore chemical processes and see the effects of changes. Students also can collaborate on their work in this environment.

Froguts

Froguts is subscription-based software that students can use to simulate dissecting several different animals, including frogs, fetal pigs, squids, and starfish.

Immune Attack

Immune Attack is an educational video game created by the Federation of American Scientists and Brown University, in collaboration with the University of Southern California, under a grant from the National Science Foundation. The game is designed to teach immunology to high school students as well as first year college students.

Chucky's Chicken Stacker

In Chucky's Chicken Stacker, available at the PBS Kids website, students identify words that have a specific vowel sound (e.g., short a). It takes 5 correct words to win the game. Students can select the speed at which the words are shown and choose between two levels of difficulty.

Research Support

Students are motivated by a game format

Kinzie and Joseph (2008) surveyed 42 middle school students on their game activity preferences. The explorative mode of play was the most appealing for all students but particularly for girls. In a study of 487 fifth grade students, Ke (2008) found that games were more motivating than pencil and paper activities in learning math, although no difference was noted in learning outcomes. In contrast, Papastergiou, (2009) and Tüzün and his associates (Tüzün, Yilmaz-Soylu, Karakus, Inal, & Kizilkaya, 2009) noted differences in both motivation and conceptual learning. Students in the Tüzün et al. study, which included 24 fifth grade students, showed increased intrinsic motivation and less concern about grades when studying geography using a game format, compared to their traditional classroom. Additionally, their performance in geography improved significantly after using the game. Papastergiou analyzed the effect of a game format on learning in a computer science classroom. He assigned 88 high school students to either a gaming or non-gaming condition. The game format was found to be more motivational, and more effective in teaching the computer concepts that were covered. Games and simulations can provide a safe environment for exploration and experimentation.

Games and simulations can provide a safe environment for exploration and experimentation

Kinzie and Joseph (2008) surveyed 42 middle school students on their game activity preferences. The explorative mode of play was the most appealing for all students but particularly for girls. Akpan and Andre (2000), in a study of 81 seventh grade students, found that using simulated frog dissection, before or instead of an actual dissection, resulted in significantly better understanding of the anatomy than dissection alone or use of the simulation after the dissection. Similarly, Maloney (2005) showed in an experiment with 224 high school girls that a simulation of a fetal pig dissection was a viable alternative to actual dissection. Further support for the value of exploration in a simulation environment comes from a study by Ronen and Eliahu (2000) of 63 pairs of 15-year-old students. Students permitted the option of exploring an interactive simulation of electrical circuits demonstrated better knowledge of circuits and increased confidence in their skills than those who did not have this option.

Students need guidance when using games and simulations

In their review of research on computer simulations and learning, deJong and van Joolingen (1998) found the need for instructional support, including hints, suggestions, and just-in-time background knowledge, to be a consistent finding. Rieber and colleagues have conducted a series of studies of a computer game designed to simulate the relationship between velocity and acceleration. They found that although students were successful with the game, they needed guidance in the form of explanations and feedback during the game in order to explicitly describe the principles involved. However, in one study they found that with a carefully structured simulation, a tutorial in advance was unnecessary. (See Rieber, 2005, for a review of their research.) In a pilot study of 60 eighth grade students, Zydney (2005) found that students benefited from scaffolds for organization and higher-order thinking that were built into a multimedia learning environment on pollution.

However, the availability of support within the software is not always sufficient—students may not access such support if left to themselves. In a study by Lajoie and colleagues (Lajoie, Lavigne, Guerrera, & Munsie, 2001), 40 high school biology students used a hospital simulation program as a part of their curriculum. Students worked in one of three groups: one with a teacher providing guidance, one with a graduate student serving as a coach, and one working independently without the aid of a teacher or coach but with the availability of an online consultant. Although they had access to this support, this group did not use it at any time. They spent more time than the other two groups in determining how to proceed and clarifying misconceptions.

Students need to be challenged

Habgood, Ainsworth, and Benford (2005) reviewed research on fantasy and learning in digital games and noted that well designed, highly engaging games incorporate achievable challenges. Rieber's research (2005) also highlights the importance of the level of challenge in a game being proportional to a student's skill level. Rieber noted that with complex games and simulations students may benefit from starting with a subset of skills and adding additional skills as the earlier ones are mastered. In contrast, however, deJong and colleagues (1999), using a physics simulation with 46 students, found no difference between students who were initially given a subset of skills and those who had the entire simulation available to them from the start. Both of these studies used college students as subjects; younger students might be more likely to benefit from this leveled presentation of a simulation or game.

Students need time to reflect

One surprising finding from research by Rieber and Noah (as cited in Rieber, 2005) is that a game might negatively affect learning. In the velocity-acceleration game described above, students who used the game scored lower on a posttest of physics concepts than did students who did not have the game. They hypothesized that the game element took precedence for the students, and that although users became proficient at the game, they were not explicitly aware of the underlying principles that they were applying because they did not reflect on them. When the researchers engaged the students in conversation about the game's relationship to physics, the students were able to make connections to the principles. Later work by Rieber, Tzeng, and Tribble (2004) with 52 students supports the need for students to provide explanations of the concepts and principles that the game or simulation is designed to represent. Again, these studies were with college students; it would seem logical that the need for reflection would be even more critical for younger learners, particularly those with disabilities, who may have particular trouble making the connections.

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