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Gaming as a Platform for the Development of Innovative Problem-Based Learning Opportunities

Abstract

The state of education in the United States, particularly in the areas of science, mathematics and technology, has been a consistent source of concern since at least the early 1980s when student performance on the 1986 National Assessment of Educational Progress (NAEP) revealed that science proficiency was lower than comparable measures from the 1970's (Alvarado, 1994). For many students, science education continues to be presented primarily through didactic lectures and rote memorization of information. These outdated modes of teaching create un-motivating learning contexts that can significantly impede learner development of deep conceptual understandings (Barab, Sadler, Heiselt, Hickey & Zuiker, 2007). Researchers, teachers and parents are looking for strategies and technologies that create opportunities for students to not just learn the basic principles of science but understand the relationships that govern these principles and their applications. Science is based on inquisitive, collaborative and disciplined investigation in which individuals, and the groups they form, critically analyze the nature of how and why things work. Problem-Based Learning (PBL) is an instructional strategy that supports this perspective on science education. PBL facilitates learner development of collaborative, problem solving skills and promotes scientific reasoning (Barrows, 1996). In this article, we extend the links between science education and PBL to consider computer-based gaming. We examine the use of gaming as a delivery method for PBL opportunities and suggest biotechnology applications as one area of content for game-based PBL. In the final section we introduce Mission Biotech, a game that we have recently developed, as an example of using gaming as a context for PBL.

Key words: problem-based learning, PBL, problem solving, scientific reasoning, computer-based gaming, biotechnology

Introduction

The state of education in the United States, particularly in the areas of science, mathematics and technology, has been a consistent source of concern since at least the early 1980s when student performance on the 1986 National Assessment of Educational Progress (NAEP) revealed that science proficiency was lower than comparable measures from the 1970's (Alvarado, 1994). Throughout the 1990's and 2000's, science proficiency as measured through NAEP has remained startlingly low (U.S. Department of Education). A 2008 Brookings Institute Report, "Changing the Game: The Federal Role in Supporting 21st Century Educational Innovation," on education reform in the 21st century points to trends among U.S. students in educational attainment placing them far below that of their peers in industrialized nations. Results from recent international comparative assessments, including TIMSS and PISA, (Organisation for Economic Co-operation and Development, 2010) rank U.S. student performance in science around the overall average for industrialized nations and significantly below the highest performing nations. Other reports also lament the lack of success in science and mathematics of many students and cite these issues as among the most significant, long-term economic challenges for the nation (Fleischman, Hopstock, Pelczar & Shelley, 2010).

For many students, science education continues to be presented primarily through didactic lectures and rote memorization of information. These outdated modes of teaching create un-motivating learning contexts that can significantly impede learner development of deep conceptual understandings (Barab, Sadler, Heiselt, Hickey & Zuiker, 2007). Researchers, teachers and parents are looking for strategies and technologies that create opportunities for students to not just learn the basic principles of science but understand the relationships that govern these principles and their applications. Science is based on inquisitive, collaborative and disciplined investigation in which individuals, and the groups they form, critically analyze the nature of how and why things work. Problem-Based Learning (PBL) is an instructional strategy that supports this perspective on science education. PBL facilitates learner development of collaborative, problem solving skills and promotes scientific reasoning (Barrows, 1996). In this article, we extend the links between science education and PBL to consider computer-based gaming. We examine the use of gaming as a delivery method for PBL opportunities and suggest biotechnology applications as one area of content for game-based PBL. In the final section we introduce Mission Biotech, a game that we have recently developed, as an example of using gaming as a context for PBL.

Problem-Based Learning

PBL is a strategy for teaching in which learning activities are developed around a problem. Students are challenged to explore and develop potential solutions or decisions about the problem. When done well, the strategy provides students with a rich context for learning, which allows for the anchoring of new knowledge to real problems and experiences (Schneider, Krajcki, Marx & Soloway, 2002). PBL typically features opportunities for students to work cooperatively in groups and challenges them to "learn to learn" (Duch, Groh, & Allen, 2001). It is a system for teaching that accommodates different learning strategies and styles, optimizing critical analyses of complex, challenging problems. By mimicking authentic problems, PBL can leverage student motivation in a way not found in traditional forms of teaching. The consequential nature of the problem also encourages self motivated inquiry. Successfully implemented PBL fosters this learning through problem identification, practice, dissection of a problem and reflecting on conclusions, mirroring processes inherent in scientific reasoning. The end goal is for students to formulate working solutions to real life problems through analysis of supplied resources, researched materials and prior knowledge. The following is an introduction to the core elements of PBL.

Core Elements of Effective PBL

Research in PBL has shown that generating student motivation to 'own' their education is *fundamental* to effective implementation of this strategy. Though there is no one best system, Vande Zande (2006) has provided some basic guidelines for enacting PBL instruction. The solution to the problem is not presented as is often the case in traditional, didactic forms of teaching. Instead, a student generated strategy is used to formulate workable solutions to the problem at hand. The students set the pace for their learning, providing them with genuine ownership of their learning processes. Sole responsibility for their outcomes is an effective intrinsic motivator and supports ownership of problem solving skills and learning processes which are significant in advancing critical thinking.

In PBL, open-ended and/or guided inquiry is built upon a foundation of cooperative learning. It is critical for the teacher to cultivate team dynamics and social networking by role modeling positive social interactions through cooperation and group analysis and by supporting student navigation of new ideas and resources. The dialogue and group thinking that follows from this cooperative atmosphere points the learner in promising directions. Constructive dialogue also engages students in meaningful understanding of both working and non-working conclusions through structured feedback provided by other students, the teacher and interactive resources. The feedback provided through dialogue helps build critical understanding of different learning elements. In-class resources provide for progressive reflection promoted by dialogue and cooperation, engaging students in questioning the deeper meaning of lessons they are learning through opportunities for meta-cognition. Facilitating critical discourse among groups is an essential element for promoting motivation and achievement of core PBL goals.

In order for teachers to effectively leverage the benefits of PBL in the classroom, they must identify key student attributes that will support team dynamics. This development of dynamic group functionality is best approached by dispersing key student characteristics throughout diverse groups. It is important to maintain a balance between teacher and student involvement in forming groups, as engagement empowers and motivates ownership of learning performances and experiences.

Another important element of successful PBL implementation is the use of strategies that involve "guided developments of critical thinking" (Schwartz, 1991, p. 1005). By scaffolding instruction, we bring learners to their zones of proximal development. This guided development promotes student successes and positive learning outcomes. By bridging dialogue with scaffolded evaluations and feedback, we nudge the learner's development forward, at the student's own pace. These problems should require the learner to think, perform and learn through trial and error as opposed to didactic lecturing and rote memorization (Barrows and Tamblyn, 1980), providing repeated opportunities for engaging critical understanding of an issue. Within this scaffolded framework it is important to notice that PBL focuses on problem identification and needs assessments for problem solving formulations.

This essay extends the links between education and PBL to consider computer-based gaming for increasing critical understandings of science. In examining the use of PBL as a delivery method for science education, we include suggestions for incorporating open-ended and/or guided inquiry, dialogue, gaming and changes in classroom management in order to successfully engage students in their own educational growth. This article looks at current trends of student interest and leverages these attributes for promoting learning in the sciences.

Gaming

Gaming as used in this article refers to the use of electronic video technology and systems designed to enhance learning and meaningful play that incorporate teachable moments in simulated environments. Though there exists a variety of gaming formats, this article refers to first-person, interactive computer-based gaming. The success of gaming as an entertainment medium forecasted the emergence of electronic gaming in educational arenas; both have long been overshadowed by an association with violent video games. The facts speak for themselves: some of the most popular games and virtual environments like SIMS, Guitar Hero, Second Life and Tetris involve no such violence (Barab, Thomas, Dodge, Carteaux & Tuzun, 2005). Instead they reflect the emerging technologically-dependant workforce combining multi-tasking and parallel processing to solve problems. In leveraging these attributes to enhance learning, educationally oriented computer-based games can be used as an effective platform for delivering PBL (Shaffer, 2006).

Core Elements of Effective Educational Gaming

James Gee's research in the field of learning through gaming, suggests that principles incorporated in good games are strongly supported by current research in cognitive sciences (Gee, 2007). Video games help us develop resources for future learning and problem solving in the domain to which the game is related. Good games are designed to allow learners to develop their goals and achieve those goals at their own pace, customizing learning to the learner's level of proximal development. Games help learners scaffold acquired knowledge, building our way up to solving problems requiring increasingly complex critical reasoning. Use of video games also incorporates a "psychosocial moratorium" (Gee, 2007, p. 64), where the learner can take risks without the associated consequences. Failure is leveraged as an opportunity for constructive learning, as the game prompts learners that have erred forward by providing them with formative guidance to accomplish the given goal. Some of this game play may not overlap with desired learning outcomes, but much of the complex reasoning, systems thinking, hypothesis testing and theorizing that necessarily take place in many of today's most popular games are certainly consistent with modern educational goals (Gee, 2007). These learning principles describe the strategies behind effective use of gaming for educational purposes and provide a roadmap for the effective use of gaming as a context for PBL.

Gaming as a Platform for Delivering PBL

Gaming contexts can provide virtual environments which offer compelling problems for learners to confront. Furthermore, the gaming environment affords a range of resources and opportunities for participation to which students might not otherwise have access. In essence, the multitudinous design options that technology affords makes computer-based games an outstanding platform for problem-based learning opportunities.

The argument that we wish to advance as a part of this article is that educationally-purposed games can serve as an effective context for PBL. Inherent in both gaming and PBL is an inquiry-based learning strategy that encourages investigation of new learning experiences. The effective core elements of PBL can be fruitfully woven into good educational game design. As an example of one way that gaming can be used to support PBL, consider the issue of generating student motivation, an essential element of successful PBL implementation (Van Zande, 2006). Generating student motivation to own their education is reinforced by game designers who have mastered the issue of motivation and player engagement. Despite contemporary criticisms of students' short attention span and lack of interest, games regularly engage players in literally thousands of hours of participation (Prenzky, 2001). Specifically, good games peak student motivation and keep student interest focused on process development.

Another core element of successful PBL that can be optimized by using gaming as the launching pad for instructional delivery is the development of social networking and team dynamics. As is evidenced by the numerous chat rooms that populate gaming forums, dialogue is enhanced, not stymied, through the use of gaming. Players regularly engage in problem solving discussions, constructive dialogue, brainstorming of ideas and reinforcement of encouraging conclusions. By sharing their learned experiences, students practice effectively cooperating in problem solving and benefit from the feedback and reflections of their peers. Gaming activates this dialogue through an interest in learning that can be seen in player engagement. When confronted with problems, a player's first recourse is typically another player that has mastered the particular level or skill set. In addition, in-class resources also provide for meaningful learning opportunities that leverage the union of PBL and gaming with inquiry and dialogue. By providing for reflective opportunities, the deeper meanings of learned lessons can be engaged, built and questioned (Barab et al., 2007).

Building student learning and understanding of information is also fostered by using gaming as a platform for PBL. Games are designed to keep and hold player engagement through scaffolding of pertinent knowledge and guided developments that lead to successful outcomes, much in the way that PBL does. In successfully implemented educational games, players use past experience, learned skills and feedback to progress through game play in an organized and effective manner directly tied to the player's current level of development. By incrementally providing relevant information for future problem solving, PBL delivered through gaming provides for learning situations that lead to more fruitful problem solving generalizations. As this knowledge is built, increasingly complex problems are addressed and increasing complex understanding of disciplinary knowledge are constructed (Squire, 2006).

Using gaming as a delivery method for PBL allows for simulating real world conditions associated with scientific research without the costs, accessibility issues and inherent dangers of real research settings. Gaming environments are interactive, socially stimulating, animated, feedback-laden, self-motivating and challenging— all important features for PBL.

Gaming for K-12 Science Education

A growing body of empirical evidence supports the use of gaming in K-12 science education (Barab et al., 2007; Gee, 2007; Shaffer, 2006; Squire, 2006). For example, Steinkuehler and Duncan investigated *World of Warcraft,* an extremely popular off-the-shelf game as a platform for supporting scientific reasoning. The findings suggested that the gaming environment promoted student reasoning and "scientific habits of mind" which are central to contemporary calls for scientific literacy (Roberts, 2007). They argue that the cultural homogeneity stifling our educational system with regimented doses of standardized testing can benefit from delivery of instruction via games that incorporate popular culture in an otherwise stagnant curriculum. This networking of cultural diversity facilitates team building skills in cooperation with PBLs social nature. The authors concluded that game play was even more supportive of these important learning outcomes than student experiences in classroom science labs (Steinkuehler & Duncan, 2008).

Marriage of Gaming and PBL: Mission Biotech

In keeping with the core elements of effective PBL and good educational gaming practices, Mission Biotech (MBt) was created to answer the call for engaging, empowering, socially relevant and powerful learning. MBt takes the form of a first person narrative and interactive role playing game and incorporates elements from some of the most popular games on the market including SIMS, World of Warcraft and Atari style mini-games. MBt challenges players to use science to help solve important societal problems including the spread of deadly viral diseases. MBt also teaches the importance of biotechnology in medical applications. These attributes help make this learning experience relevant to students, leveraging their motivation in combination with other elements of the game. Relevance provides for optimized engagement as these diseases are ones that directly affect all elements of society as was recently seen with the spread of H1N1, a form of influenza. Procedures for viral identification are routinely practiced after players navigate the requisite content to develop these procedures. Powerful learning moments are achieved through the reflective nature that students must exhibit in order to successfully complete the game. Our preliminary research results support the theoretical arguments that students are, in fact, learning significant scientific content through game play. Pre-/post-intervention testing of standards-based science content reveals statistically significant improvements in student understandings (Barko & Sadler, 2011). Students are learning key concepts related to genetics and genetic technologies through game play.

In MBt, students begin their virtual journey at the National Laboratory for Biotechnology and Bioinformatics (NLBB) and game play takes place within this virtual environment. Throughout the game, players interact with computer-generated characters and equipment used in leading biotechnology laboratories to help identify and contain the spread of virulent diseases. In-game and in-class resources are used to guide learners' cognitive processes towards fruitful outcomes. The in-game resources are presented through character dialogue, virtual posters, magazines, documents, brochures, bulletin board papers and feedback screens that provide information on viruses, a historical perspective on viral genealogy, geography of viral outbreaks, and biotechnology-related careers. Detailed schematics of the processes used to determine a viral outbreak are also virtually represented. As part of the design features in MBt, the ill-structured problem that students are faced with includes symptomatic identification of diseases to determine the biological agent responsible for the virtual outbreak.

Providing players with a virtual environment in which they can suspend fear of failure and the risks associated with working with viral contagions, allows room for the psycho-social moratorium suggested by Gee (2007) to develop as players project their views onto a virtual identity. It would be impossible to do these kinds of experiments with children otherwise. MBt provides an opportunity for normally inaccessible learning moments by allowing players to work with materials and technologies with which they would typically not come into contact.

The social dynamics explored and strengthened within MBt also play a crucial role in fostering team work and cooperative learning. Students may be paired up in groups while they work through the game, encouraging dialogue which, in turn, promotes engagement and meaningful understanding of relevant concepts. As is often seen in gaming chat rooms, difficult problems within games foster an environment of group dynamics, cooperative learning and reflection of ideas. Gaming can achieve what few other disciplines offer: students will talk about their learning experiences to further their successes within the game. Mission Biotech thus promotes social networking, dialogue and team work, all of which increase meaningful learning opportunities and MBt does this in a non-violent gaming format.

Conclusion

We offer biotechnology as a content area to be featured in game-based PBL opportunities as a means to demonstrate the potential of leveraging an innovative technology (i.e., gaming) for supporting an effective pedagogical approach (i.e., PBL). Mission Biotech has been designed in accordance with the best practices associated with PBL and gaming giving it a unique advantage in generating student support of their own learning. As biotechnology fields grow in prominence, a knowledgeable and capable work-force is needed to meet their demands. Use of gaming as a context for providing PBL opportunities is an innovative marriage of ideas that can ready students for the demands of our globally competitive economy.

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