AUTHENTIC LEARNING THROUGH GBL: USING INQUIRY AND PBL STRATEGIES TO ACCOMPLISH SPECIFIC LEARNING OUTCOMES THROUGH SMART GAMES IN FORMAL AND INFORMAL SETTINGS

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ABSTRACT

Game-Based Learning (GBL) is a promising and engaging tool for STEM (Science, Technology, Engineering, and Mathematics) learning. How GBL promotes content learning and mastery is unknown, however. For GBL to be more than an engaging tool for delivery of basic knowledge, it must be designed to achieve the goals of Project-Based Learning (PBL). PBL achieves content mastery by using principles of inquiry to promote authentic learning. The challenge is to keep GBL engaging while incorporating inquiry strategies into gameplay. This can be achieved through immersive micromanagement and virtual world games that incorporate content mastery objectives into player strategies for advancement in the game's plot. Complexity introduced through evolving game scenarios can push players towards decisions guided by content lessons. Different applications of GBL in classroom and informal science settings present unique challenges and opportunities. Team play and competition can enhance PBL elements and increase cognitive outcomes in the classroom, while flexibility and portability across multiple formats and delivery mechanisms is crucial to success in informal science education (ISE). This paper provides guidelines for the development of GBL for both formal classroom settings and ISE.

KEYWORDS

Constructivism; Game-Based Learning; Project-Based Learning; Problem-Based Learning; Serious Games; Informal Science Education.

1. INTRODUCTION

Game-based learning (GBL) is proving to be an increasingly promising and engaging tool for STEM learning. The success of Fold It (Cooper et al., 2010), Phylo (Kawrykow et al., 2012), and Eterna (Eterna, 2011) are showing that players will independently engage with games that achieve real-world results. Games such as New Century Energy and many others are showing that GBL can achieve authentic learning in the classroom (Hoge et al., 2012; Hoge & Hughes, 2011; Ahn & Dabbish, 2008). Authentic learning is learning at high levels of bloom's taxonomy by using the same tools and methods as experts use in the real world. This type of learning is fundamental to the pedagogical philosophy of constructivism and has been shown to be the best way to teach STEM content and skills (Slough et al., 2004). Constructivism also provides the basis for achieving learning outcomes through GBL (von Staalduinen & de Freitas, 2011).

Authentic learning is about inquiry and problem solving. For GBL to be more than an engaging tool for delivery of basic understanding and application, it must be designed to achieve the goals of inquiry learning as demonstrated by project-based learning (PBL) models. The challenge is to keep GBL engaging while incorporating inquiry strategies into game play. This can be achieved through immersive micromanagement and virtual world games that incorporate content mastery objectives into player strategies for advancement in the game's plot. Complexity introduced through evolving game scenarios can push players towards decisions based on content knowledge acquisition, analysis, and creation of real outcomes. Team play and competition can also enhance the PBL elements and increase cognitive outcomes in the formal classroom but are difficult to accomplish in informal science settings. A virtual world approach across multiple formats and delivery mechanisms can overcome these limitations in informal settings.

2. GAME-BASED LEARNING AS PROJECT-BASED LEARNING

Games are successful PBL because they tend to put the learner in the role of decision-maker, pushing players through ever harder challenges. Learning is authentic because it is accomplished through trial and error (gee, 2003). Games also provide immediate feedback on the player's strategy which encourages exploration and experimentation (Kirriemuir, 2002). Games are effective for multiple learning styles and levels of understanding since they can challenge players to their specific prior knowledge and skills (gentile and gentile, 2005). Another aspect of gaming that is particularly important for stem education is that games allow players to fail, but reward persistence and risk (Gerber, 2012). Most stem education focuses on what is already known. This does not prepare students for the real world where the focus is on elucidating the unknown, and where new problems arise constantly. Even most PBL presents projects or problems for students with known answers and proscribed strategies for accomplishing the task. While these hands-on approaches do provide a more constructivistic learning experience, they are not giving students the most important skills for stem applications: risk taking, persistence in the face of failure, and creative problem solving. In his 2010 talk to ted.com, Thom Chatfield outlined seven key points about games that can be leveraged to adapt them to learning environments (Chatfield, 2010). *Games provide immediate feedback. They challenge players with a sense of uncertainty, but they reward effort, both small and large. Games should incorporate short and long-term goals, and use avatars to immerse players in an "experience system". Research into neurology and learning can guide the development of games that can create "windows of enhanced attention". And, games can involve players with social contexts in a variety of ways such as collaboration, competition, and identification with shared goals and values.*

Numerous challenges must still be overcome before GBL can reach its full potential, however. Though numerous models exist for achieving learning outcomes through GBL (van Staalduinen & de Freitas), it is not fully understood exactly how GBL accomplishes authentic learning. Formal and informal science environments present unique challenges and opportunities for GBL. In both settings, for GBL to become successful PBL, games should: 1) simulate real-world scenarios; 2) combine aspects of strategy games and construction and management games; 3) allow players to control the progression of the game through their game play and decisions; 4) be played by teams of players formed as cooperative learning groups; and 5) be competitive across multiple levels of difficulty. Variations in difficulty should be incorporated into lessons that students must master in order to open options within the game. Players should be required to answer questions from each lesson, with missed questions affecting the efficiency of outcomes/success. Questions should be based on NAEP guidelines for basic, proficient, and expert levels. Lessons and questions should be designed to lead players to game play decisions that require understanding of STEM concepts. The complexity of the game should push students to seek out content knowledge in order to advance (this makes the experience constructivist project-based learning). A meta-site should be made available outside of game play for students to supplement their learning for subsequent game play. Lessons within the game must be carefully crafted to encourage learning through inquiry.

Over the years, PBL has taken on different meanings depending on whether the project involved is long-term with multiple learning objectives, or short term, centered on a specific problem. GBL should provide aspects of both project-based and problem-based learning. Both types of PBL emphasize "constructing understanding of important science concepts as they inquire into a real life problem" (Schneider et. al, 2002). PjBL requires students to solve problems through hands-on engagement in the entire process of scientific inquiry, from researching the problem, forming hypotheses, designing tests, performing experiments, and communicating results. PbBL can more effectively focus on specific content objectives and skills. Players should be required to solve problems on many levels to advance. The flow of gameplay must be designed so that experienced game players and novices with interactive media will encounter problems appropriate to their levels. Complexity within the game should encourage players to develop strategies and to adapt their strategies throughout the game. A meta-site should be made available to players to conduct research outside of game-play. In the Classroom, the formation of cooperative learning teams should be structured to encourage each team member to take on specific roles within the game and to take on specific research assignments for the team. In informal settings, through virtual worlds, players can benefit by cooperating with other players, and though competition. Each enhance the cognitive outcomes of the game. Players can compete within the game, or through scores based on multiple factors. The total score should be some sum of a knowledge score and a strategy score.

These scores should be weighted equally and converted into points (50/50). The knowledge score could be derived from the number of questions answered correctly divided by the number of questions available at that point of the game, for instance. The strategy score should be derived from the specific success criteria of the game.

NCE is an immersive micromanagement computer game which provides a transformative learning experience to 8-10th grade students. NCE combines aspects of strategy games and construction and management games, requiring players to build energy companies that must meet the needs of cities throughout the US over the next 50 years. Teams of players are formed as cooperative learning groups which compete across three levels of difficulty. Variations in difficulty are incorporated into lessons that students must master in order to open options within the game. Players must answer questions from each lesson, with missed questions affecting the efficiency of plants built. Lessons and questions are designed to lead players to game play decisions that require understanding of physics, chemistry, earth science, and math concepts. Lessons within the game are carefully crafted to encourage learning through inquiry. NCE was strategically designed to encourage students to seek out content knowledge and apply it to real world scenarios. The expectation was that rewards for seeking out and applying knowledge would encourage student's acquisition of content knowledge, and provide the perspective and skills necessary for the application of this knowledge within and outside of the game. Comparisons of score components to total score indicate these expectations were met (Hoge et al., 2012).

A new game similar to NCE is now being developed for informal science settings. As with NCE, development of a smart game for informal science settings requires a complex collaborative process. This provides opportunities to develop innovative game design and cognitive strategies, but also generates unpredictable challenges and opportunities. GBL for ISE has the potential to add many new aspects, including multiple platforms for the game, interactive 3-D graphics, mobile apps for player research, and online extensions. The game will take place in a virtual world allowing players to advance at their own pace as they develop and pursue gameplay strategies. This experience system of advancement keeps the action consistent throughout the game. This also allows for multiple levels of engagement with the game. Casual players will not become lost in the depth of a lengthy game while seasoned players will find a challenging experience to come back to. To accomplish this, the game will be segmented into short challenging mini-games. While a complete play-through of one segment will be relatively short (roughly 20-30 minutes), players can shorten this time by facing one challenge at a time, or increase their engagement with the game by progressing to other segments. Multiple segments will compartmentalize over-riding themes in the game, but will each provide content in all areas of STEM and challenge players on multiple cognitive levels. The segments will be equal in length and complexity. Player experiences with each segment will be uniquely different each time it is played. This will be accomplished by randomness in world attributes, competitive and cooperative competing businesses, and a variety of obstacles for the player to overcome. Each game segment can be played multiple times with different outcomes. With a gameplay of 20-30 minutes assumed, a single scenario can be played very differently each time. These multiple scenarios purposely steer repeat players to progressively higher cognitive levels as they gain knowledge and skill. Players can initiate new projects whenever they want. The "development mode" of the game will not be focused on one city or region. As in NCE, the player has the option to choose from multiple regions around the world per project, depending on what resource they are investing in and what is available to them. The player will be directed within the game parameters by showing them options for investment and building. Although players are given a list of game options, the positives and negatives of each area is initially hidden. Costs, access to resources, and risks to the environment are all unknowns initially. The player can mix risk with reward in this system. This makes the game a "real world" model. The player could potentially take a huge risk and hope that they are successful, or the player could choose to do research before making an investment of time and resources. This operative method will produce better learning because the feedbacks to player choices will be immediate and consequential. If the player is not forced to do some research, it doesn't stress the importance of understanding the risks before taking them. Giving a player the option to fail and return better prepared will teach them the value of preparedness.

3. CONCLUSION

No component of a PBL strategy can be successful by itself, and this is true for GBL as well. NCE was designed to take smart gaming to the next level by encouraging the promises of PBL through GBL. Initial analysis of NCE results indicates that the design strategy of NCE can achieve these goals. Analysis of game scores show that successful teams were likely to seek out content knowledge, and that they used that knowledge effectively to achieve high scores. NCE fulfills the promise of PBL/GBL by not only engaging students in content lessons, but also in the "construction" of advanced knowledge and skills. As the game becomes more complicated, players must not only seek out information on STEM topics, but also conceptual understanding and big-picture perspective. NCE is more than the game, however. The combination of the NCE game with teacher training, curricular support, community resources, and the incentives of competition make NCE a transformative approach which could shift the focus of GBL towards a tool for inquiry rather than simply an engaging content delivery tool. Transitioning into a virtual world scenario for ISE provides new challenges and opportunities, but the same pedagogical principles for authentic learning apply.

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