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FOSTERING 21st CENTURY SKILL DEVELOPMENT BY ENGAGING STUDENTS IN AUTHENTIC GAME DESIGN PROJECTS IN A HIGH SCHOOL COMPUTER PROGRAMMING CLASS

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ABSTRACT

This study used technology-rich ethnography (TRE) to examine the use of game development in a high school computer programming class for the development of 21st century skills. High school students created games for elementary school students while obtaining formative feedback from their younger clients. Our experience suggests that in the teaching of computer science in high schools, the development of games that include common game features such as dynamic feedback systems, backstory, levels, cheats, and compelling graphics challenges students and engages them in learning. Incorporating real client feedback is also useful for improving their work and connecting it to the "real" world. This article reports findings from the second year of a research project with a high school computer programming class. The authors argue that such approaches that leverage video games, design, programming, authenticity, and cooperation mobilize multiple 21st century skills that must be nurtured among contemporary young people so that they may grow to be part of a productive citizenry.

As concern about potential negative effects of video and computer games on the achievement of students has been increasing (e.g., Bauerlein, 2008), the potential

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benefits of using games for learning have also gained momentum (e.g., Gee, 2003; Squire, 2006). One positive approach is to provide games that encourage critical, pro-social problem solving to support the development of the 21st century skills, which involve three aspects: (a) critical thinking and systems thinking, (b) problem identification, formulation, and solutions, and (c) creativity and intellectual curiosity (Partnership for 21st Century Skills, 2009). One particularly powerful game used by over 25,000 children around the world is Quest Atlantis (QA; http://questatlantis.org) (Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005; Thomas, Barab, & Tuzun, 2009), which was designed for the purpose of developing skills in problem solving, critical reasoning, and creativity. This learning environment makes use of an online Multi-User Virtual Environment (MUVE). QA involves challenges related to the environment, society, and science and activities designed to engage students in complex, pro-social "Quests" using the myth of Atlantis as the basis for a background story that underpins the game.

In the present study, we used QA as a backdrop for examining problem solving in a high school computer programming class when an open-ended learning environment was presented. We conducted a qualitative extension of an earlier study on problem solving in the culture of a high school computer programming class (Ge, Thomas, & Greene, 2006). In that first study, salient findings were that students' motivation for the project decreased, while time playing unrelated computer games increased. We argued that students were distracted by the possibility of playing their favorite games during class (Ge et al., 2006).

We believed a follow-up study would allow us to further examine how a gaming environment could be structured to facilitate learning that was both complex and authentic. For the first study we developed an ethnographic method to use in conjunction with design-based research so that we could examine how students' interest in gaming could be leveraged to sustain intrinsic motivation for the QA tasks and how the culture of a classroom changed during the implementation of the QA project. The methodology employed seven distinct sources of data that included observation protocols, audio recordings of students' interactions with group members, logs of student work, chats within QA, the projects developed, and peer evaluations of the projects. We called this method technology-rich ethnography (TRE) (Ge et al., 2006).

TRE is an approach that makes use of an array of electronic tools used to collect data that allow the researchers to construct an ethnographic account. Such accounts or *writings of culture* (ethnos) are, by definition, portrayals of fields of action and descriptions of common experience (van Manen, 1990). Resulting cultural portraits may be written or read from emic (experience near) or etic (experience distant) perspectives (Creswell, 2007). A form of classroom ethnography was used because we were interested in how the culture of that particular class evolved when the instructional approach changed from teacher-led to problem-based with the introduction of the QA project. We were interested in studying how the students in that environment adapted to something different from their normal classroom routines. We found that ethnography worked well for the first investigation, so we tweaked our methods keeping ethnography as the overarching design. In addition, we continued to use the design-based research approach for this study, which allowed us to play the roles of both designers and researchers (Brown, 1992; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). Since our research took an iterative design approach, with previous research findings cycled back into the design of instruction and learning environment, it is necessary to summarize and review the findings of the 2006 study. First, though, we turn to games as a central concept in our research.

While gaming culture has evolved considerably in recent years, there are certain elements of computer games that are so ubiquitous that they might be considered cultural memes themselves. Given the difficulty in defining the nebulous concept of *game* and that definitions vary considerably, our operational definition is based upon the possession of these particular affordances:

- Fantasy & Story—Games are expected to contain a story and games which allow for multiple play trajectories also allow stories to be interactive multi-threaded experiences. Stories provide context and enhance game experiences (Apperley, 2006).
- Competition—Games have "win states." That is, there are ways to win and there are ways to lose or at least ways to *not* win.
- Role play (Identity Play)—Games allow players to try on other identities and in doing so; players pretend to be someone or something else. This can be a powerful way to explore seeing the world as that character.
- Rules and Cheats—Games have rules to govern play and there are also ways to subvert these rules. This type of subversion often serves to optimize play, and also commonly has rules of behavior. Designers of video games realize this and commonly design complex and esoteric ways to "cheat" the game.
- Expert Abilities—Well designed games become more difficult as the player becomes more expert at playing. This adaptation of difficulty is important to maintain a delicate balance between player anxiety, frustration, and player boredom.
- Leveling Systems—Related to adaptive difficulty are leveling systems. Leveling systems *reward* experience as increasing expertise by promoting players to higher levels in the game. There is not only increased difficulty at higher levels to keep the game challenging. There is also increased *prestige* and *power*.
- Numerical scoring—Games manage win states and leveling systems with quantitative scoring systems.
- Simulation—Games function in ways that offer designed experiences (Squire, 2006). Such experiences may be completely fictional or may closely resemble actions in "real life."

- Affinity groups—Affinity groups are collections of people who are bonded together by something they enjoy doing. They are a community who share information, expertise, and views about the activity they enjoy.

For the remainder of the article our definition of *game* will essentially be an activity that contains a majority of these elements. In our studies, we used QA to create an authentic experience for students learning computer programming. We were interested in increasing the authenticity of the experience by leveraging game elements to get the students to think about their work in terms that they could likely appreciate. Thus, they were not just programmers anymore, but also game designers.

In the previous study, high school computer programming students were asked to design learning materials that would then be incorporated into the QA gaming environment. Before the initiation of the QA project, the students typically were presented with well-defined tasks to complete using the Java computer programming language. While the tasks they were given normally had several possible solutions, the task itself was always fixed. All of the students were given the same goal by the teacher and this goal was to write code and get it to run to perform a specific, predetermined function. By contrast, the QA project provided an open-ended learning environment that emphasized flexible problem solving, as well as a client base (the younger students) that went beyond the classroom and teacher (Ge et al., 2006). Such an arrangement presented the high school students with a genuinely ill-defined problem without fixed solutions, requiring the development of creative, adaptive, and highly nuanced strategies which may lead to the development of 21st century skills.

We found that the high school students were initially engaged in this problem solving task as they had control over the design and development of the task and said they enjoyed being in charge of the project. However, their initial motivation was not sustained beyond a few days. Instead, many students became distracted in class and chose to play interactive computer games during class time that were unrelated to the work of the project. We believe this waning motivation was largely due to not having the younger students provide direct and immediate feedback to the high school students' on their design work, and was compounded by the intrinsic enjoyment of playing the available computer games (e.g., CounterStrike). Individual interviews demonstrated that students had a high degree of metacognitive awareness of their learning and study habits. Unfortunately, they seemed to often use that awareness to make schoolwork easier rather than to confront and complete more challenging work—like our project offered. We found that students were quick to say that they were done with their work on our project before they had created a high quality product. They knew that if they said they were done, they were free to play the interactive computer games that they enjoyed (Ge et al., 2006).

RESEARCH QUESTIONS

The present study sought to further examine the 21st century skill of problem solving in the culture of a high school computer programming class but with attempts to make the feedback of the elementary school *user clients* more immediate and salient to the high school student *designers*. Having noted the prominence of computer games in the computer programming class in the previous study, the present study explicitly pursued this theme. The following research questions guided the present study:

1. How did students approach their design work, particularly in formulating and reformulating problems and developing solutions for their projects?
2. What role, if any, did computer gaming culture play in promoting the 21st century skills of reasoning, problem solving, and creativity among students through the QA project?
3. How and in what ways did feedback from elementary school clients influence the design work of the high school student designers in reformulating problems and modifying their solutions?
4. How did this year's iteration of the project compare with that of the previous year?

METHOD

Since this was a follow-up to an earlier study (Ge et al., 2006; same school and teacher, but different students), we used essentially the same methodology or TRE. However, in this iteration of the study, we also used video recording of both the high school and elementary students working on the project. In the same sessions we used multiple audio recording devices so as to attempt to obtain the most complete record possible of the goings on in the classrooms. We also omitted two data sources that were not effective in the last iteration of our study (daily work logs and peer evaluations). The following components of TRE were employed in the present study:

- *observation protocols* from the three researchers;
- *interviews* and *focus groups* with students and the teacher;
- *video recordings* of daily work
- audio-recorded *group interactions;*
- *chats within* QA;
- the *projects* produced by the students; and
- elementary students' *evaluations* of the student projects

Participants and Context

This study involved the students and teacher of an advanced computer programming class in a suburban high school in the southwest part of the United

States. There were 12 high school students, one of whom was a girl. The class was the second in a two course sequence focusing on Java programming comparable to a college freshman course. The teacher was an experienced teacher who had recently earned a master's degree in the area of the design of computer-mediated instruction. Additionally, the 4th- and 5th-grade students in an elementary school in the same school district were invited to provide feedback to the high school students about their designs.

The primary resource used was Quest Atlantis (QA), which is an educational program in which K-8 students explore and solve problems in virtual worlds. For the present study, our participants were presented with the task of developing new quests or modifying quests existing in the QA environment, and they could work with others or alone. While the students had not seen QA before, they were all familiar with the genre of adventure gaming and recognized QA as resembling Massively Multiplayer Online Games (MMOGs) (Schrader & McCreery, 2008). Their task was to develop a quest that would engage the 4th- or 5th-grade students in an educational task that followed the standards of fun expected with games. Their quest would then be incorporated into the QA platform and become a permanent part of QA.

Procedures

There were three researchers who went to collect data together for 2 weeks. Although the computer programming teacher was known to the researchers from the previous research collaboration, none of the students were known to the researchers. On the first day of the project, one of the researchers demonstrated QA, explained the task to be performed, and conducted a brainstorming session with the students. The brainstorming session involved discussion of what constituted a good game and what were examples of games that could also be educational. By the second class period, students had explored the QA environment, chosen with whom they would work, and started generating ideas for their projects. The third and fourth days were spent developing and testing out their ideas. On the fifth day, students were told to summarize their projects so that the elementary school students could give feedback.

At the elementary school, the 4th- and 5th-grade students were shown QA and the projects created by their high school peers in groups of two. Feedback sheets were provided to the elementary school children and they were asked to give feedback on at least two of the projects. They were all told to pick one of the projects they "really liked" and one they "did not like so much." All of the students contributed at least two items of feedback, which were handwritten on the feedback sheets.

The researchers summarized the student feedback. That summary was presented to the high school students first, and then the project-specific feedback was given to the groups. Several of the high school students were quite disappointed by the feedback and realized that major changes were needed. One student even felt hurt at the negative feedback his group had received. In addition to the comment "boring" that several projects received, one project idea was deemed "too simple." Based on the feedback, one group completely changed their topic. One individual kept his topic, but tried to make it more "game like" when it had been more like a stand-alone tool (a calculator). The high school students worked for another 5 days after getting feedback, then spent the last day demonstrating their projects to one another using an LCD projector.

Analysis

The analysis for this study began as the three researchers discussed the daily observations. First, global observations about the classroom were noted, and then specific groups of students were discussed. The observation protocols were completed by each researcher and summaries generated and discussed. The results reported here are based primarily on the observations and discussion among researchers as well as observations of the video recordings of the student interactions. We used the other data sources to help interpret what we thought we were seeing in the visual data. For example, we often did informal interviews to get more insight into ideas that were forming from observations. The video and audio data were also used when researchers were trying to substantiate an idea that initially came from the on-site observations. We used formal interviews to find out if the students and the teacher were seeing the context in ways similar to what we were inferring from other data sources. Lincoln and Guba (1985) use the term *confirmability* in place of objectivity as a means for qualitative researchers to address the problem of bias. We used these multiple sources of data and cross checking between them so as to increase the confirmability of our findings and the trustworthiness of our account.

Although the quantification of textual data may allow for the appropriate comparison of conceptual categories the emergent nature of our findings precluded the utility of this procedure. Further, in inductive approaches to research, the object is not to employ preexisting theoretical frameworks but to build assertions rather than test them. The appropriateness of the procedures must take precedence given the complex contextual dimensions of this study that took place in the messy context of a real classroom.

RESULTS

Six games were completed by the high school students as part of the project and were incorporated into QA as Quests. Each game is summarized in Table 1. Quests also have three parts that the students also had to develop: A description

Table 1. Project Summary and Description of How the Design Work of the High School Students' Projects Changed in Light of Feedback from Elementary Student Clients

Project name	Description before client feedback	Summary of feedback	Changes made and whether they were based on client feedback
Color Wheel (2 boys)	Players matched the RGB values of colors to obtain a perfect color match to a provided color. This project received only partial feedback. The entire project was not completely visible because of technical problems.	Unclear since it did not work	They added a timing element to make it more game like
Rugrats—A Day in the Life (3 boys, 1 girl)	Cartoon characters that looked like Rugrats were used to teach elementary school children about colors and coloring.	Too babyish	The high school designers kept the cartoon idea, but created a game in which students could make choices about school activities and "experience" different consequences (see Barab, Gresalfi, & Arici, 2009 on the notion of "consequentiality").
Trajectories (1 boy)	Arrows are set flying through the air based on directional input from users.	Fun and exciting	The game elements of the project were retained, but changed to canons.
Calculator (1 boy)	Was simply a tool provided for solving math problems	Boring	The designers created a treasure hunt in the 3D world of QA involving navigation using math problems.
Seven Wonders (1 boy)	Involved hunting through a map of ancient Alexandria to find and get information about the "Seven Wonders" of the world.	Clients loved idea. Thought is was adventurous	The designer found that he had to scale back the project because the programming proved to be too complex and time-consuming.
Stock Market (3 boys)	Allow students to invest money and watch it "grow" over time	Good idea but better graphics needed	The designer did not create better graphics but improved the usability of the game.

that situates the quest in the backstory of QA, a list of goals which serve as specific instructions to the Quester, and then some resources to be used by the Quester in completing the quest. Screen shots of different games are shown in Figures 1 to 3.

Question 1: Description of How the QA Projects Unfolded

On the first day there was about 40 minutes of whole-group brainstorming, then students formed six work configurations (see Table 1). By the end of the second day, the students were all well into developing their ideas. Only one group (called Rugrats) did not consider using Java for their project, while the other students used Java programming by starting with the general project idea then searched for existing scripts to get them started. Some used scripts from class while others

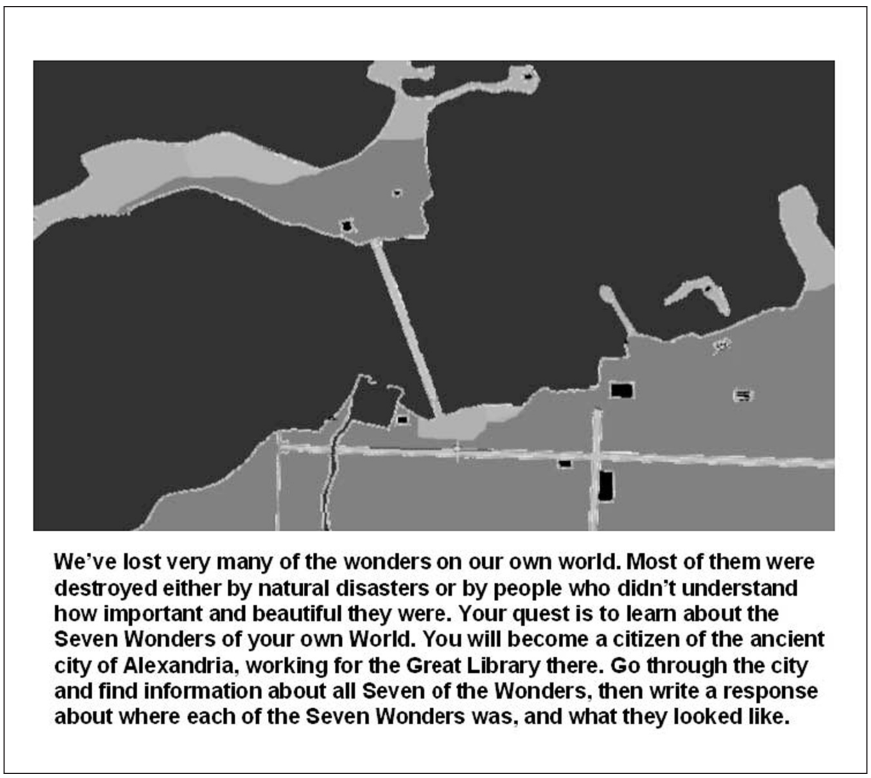

Figure 1. This is a screen shot from the Seven Wonders game.
It includes text written by the student who created it.

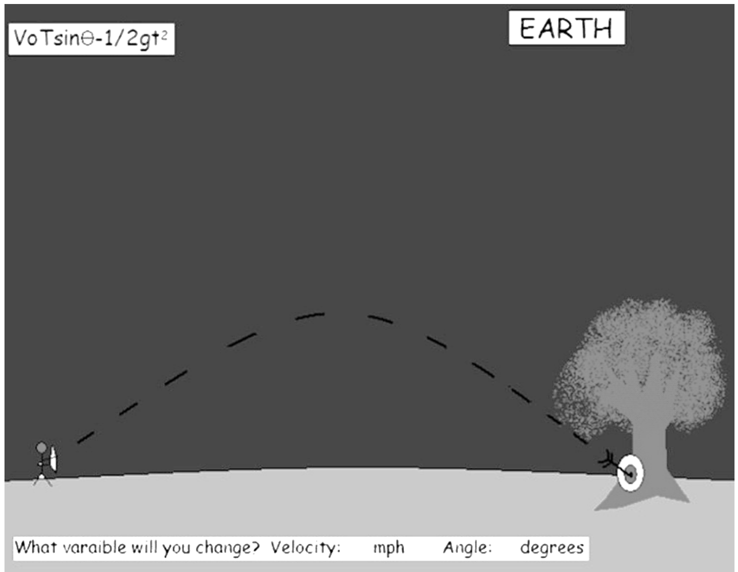

Figure 2. This is a screen shot from an early iteration of the trajectory game during which the student experimented with a stick figure firing an arrow at a bull's eye.

Figure 3. A screen shot from the four-person group's "A day in the life" project.

sought out resources and other programs on the internet. All of the Java programs had to be adapted to QA and to the intended project, which meant that the students were engaged in programming that went beyond what they currently knew how to do. Some students used a lot of trial and error in order to get the new program or version to work while others searched internet sites for Java help. Still other students relied more heavily on the teacher, although most students called on the teacher's expertise at several points in the process of designing their project. The teacher was busy each day trying to help students with their different ideas and it became apparent that the teacher's knowledge of programming was being stretched every day. He noted in the interview that he was working much harder than he normally does, since most of the students' ideas were challenging for both them and him.

The largest of the groups was comprised of four students. Even though this group had more students than the other groups, we noticed that this group was more effective in collaboration than either the group comprised of three boys or the group made up of two boys, though the latter worked fine together. The group that had three members had one student take control over the group and did most of the work himself, while the other two played a car racing game most of the time. One of the two car racers actually did some of the non-programming work, but the third did very little work at all for the duration of the project. In contrast, the four member group engaged in a lot of "give and take" with respect to project ideas throughout the entire project. They also seemed to portion out their work appropriately, managing to keep everyone contributing similar amounts of participation. Although they suffered a fair amount of absenteeism, due to testing and band trips, they seemed to plan well and recover from loss of time together.

There was only one other configuration of more than one and that was the two boys who worked on the color wheel idea. One student took the lead in this dyad, but the other student seemed to work consistently on what the other asked him to do. The lead student was clearly responsible for learning and developing the Java programming.

Most of the project ideas were started with the brainstorming session, though most of them evolved quite a bit in the following days. The color wheel idea was generated during the initial brainstorming session and remained pretty much the same as its early conception. The stock market idea also remained similar, though the student in charge realized how much he needed to learn to make it work. The trajectory project started out with a focus on archery, but then came to involve a more advanced technology, a tank cannon firing, to demonstrate the notion of trajectory.

The projects that either evolved the most, or were abandoned, were those in which the feedback from younger students was not favorable. After working for 4 full days on their projects, the project ideas were evaluated by the 4th- and 5th-grade students. The calculator project was deemed very boring by most of the younger students and the project involving Rugrats characters was deemed too babyish. The single student working on the calculator changed his project considerably, though kept the calculator as the central program. He was initially quite discouraged by the feedback from the elementary school students but then decided to change the project to be more game-like. The four-person configuration completely changed their topic so that it did not include the Rugrats characters.

Due to the complexity of the project ideas and the interruptions caused by school-related absenteeism (standardized testing during the school day and a band trip); we needed to give the students extra time to work on their projects. Most students were able to get to a reasonable stopping place, though the student working on the Seven Wonders project did not finish. He was out several times, once for an exam make up and another time for a band trip. Given the complexity of his project and the programming involved, it was unrealistic for him to complete the project in the time available. However, he said he was motivated to finish it after our project formally ended. Most students seemed pleased with their work, which was obvious from the enthusiasm they showed before and during the presentations of their projects to the class.

Question 2: The Role of Gaming Culture

In the previous iteration of our study, we found that the high school students were not just game enthusiasts, but rushed through their work so that they could play games during class. This year, we found that students were enthusiastic to create games that were in some ways similar to the games they were used to playing. It also made the feedback from the younger children resonate. The younger children wanted there to be missions, goals, levels, and cheats in the games. They did not want the games to be tools without some sort of situated purpose. They also did not want things to be "babyish," and while the high school students understood that games should be challenging and not condescending, they needed input regarding what would be challenging or too easy for younger students.

Gaming elements were incorporated into the students' games in several ways. While this may make it appear that gaming culture was so intertwined in the culture of this classroom that its influence could not be gauged, we argue that the explicit use of aspects of gaming culture scaffolds learning and motivates children for learning. We believe that this worked in a way that engaged them and inspired them to think more deeply about their design work, thereby making the experience more authentic, rich, deep, creative, and more in line with 21st century skills. The student who made the trajectory game used an online fantasy adventure game not only as inspiration for a simple game that he created but even borrowed images from the game and incorporated them into his own project. The group of students who created the game that was made with PowerPoint used branching possibilities in an interactive short story, and incorporated methods of immediate feedback common to "chutes and ladders" sorts of games. The student who was inspired by Civilization III, a simulation in which players manipulate variables to create a new civilization, incorporated the notion of fantasy into his game. The color wheel game in which players would match colors using RGB numbers included a time-limit challenge common to many games. This included a digital clock that was programmed by the students to allow players a limited amount of time to match the colors. In this way, all of the projects were explicitly *games situated in game culture* that were then woven into the back-story of the overarching structure of the QA meta-game environment. These projects may be thought of as games because they incorporate elements included in the above mentioned list of game affordances that served as an operational definition for this project. Further, the feedback from the younger children was expressed in ways that used terms and symbolism from gaming culture.

Question 3: Influence of Feedback from Elementary School Clients

The elementary school clients were consistent in their feedback. They wanted to see action, story backgrounds, good graphics, and some form of feedback to tell them they were progressing relative to the learning. These are features of video games and of QA. Some mentioned wanting a choice of characters and "cheats" to help them learn the program. They did not want to interact with a program that presented a tool, like a calculator, without some sort of situated purpose or mission. This is typical of young digital natives and gamers who insist on authenticity and meaningfulness (Prensky, 2001). They also did not want things to be "babyish" since good games are challenging and they were not babies.

The four-person group decided that they needed to re-evaluate their whole project based on client feedback. They in fact made the most changes, relative to other designers in the class, dropping the coloring concept and instead using similar graphics without the appearance of Rugrats characters.

They used PowerPoint to create a series of choices that students could make in a school day that would lead to different consequences. They worked hard to create graphics that were colorful, funny cartoons that better matched the level of 4th- and 5th-grade students. The four people collaborated well, and consequently they were able to evenly distribute the considerable workload that included hand drawing and coloring of the cartoons. The learning objective could be summarized as "smart choices at school," but they were able to convey positive choices with humor and without heavy handed moralizing.

The boy working alone on the calculator project was another student who made major changes following considerable negative feedback from the elementary school students. He was committed to using the calculator program, but decided to embed the tool within a game. He admitted that he would not have chosen to work alone, but his usual partner had started on another project when he was out for testing and he did not want to ask to join him. He seemed discouraged following the feedback, and became overwhelmed in terms of the challenge of his project. Given these limitations, his revisions were reasonable.

The stock market project did not get much feedback and what they did get was mixed, with some of the elementary students praising the project while others requested narrative story elements and better aesthetics. As a result, the one student who took the lead continued with what he had in mind originally. He knew that he already had a lot of programming work to complete, and requests for a story and better graphics were beyond what he could do in the time allotted.

Neither the Seven Wonders nor Color Wheel projects were revised based on feedback. In the first case, the younger clients were satisfied with the pace of development of the project, but in the second case they seemed less optimistic. However, the two boys did not know how to modify their plan to accommodate the clients' concerns. Unfortunately, the student working on the Seven Wonders project ended up having to simplify his project, rather than scale up to meet the clients' desire for action figures and better graphics. This ultimately proved to be too difficult for the designer; however, he remained strongly motivated and worked hard on the project for the duration.

Finally, the trajectory project changed but it is unclear whether the major change was in response to feedback or expediency. First, he changed from archery to a tank shooting in order to get at the notion of trajectories. He reported in his interview that he chose his topic because it allowed him to put together a lot of the pieces he had learned in the class. He seemed more guided by that desire than by the student feedback. That said, it should also be noted that most of his feedback was positive.

Question 4: Comparisons from the Previous Study

This year, the students actually used Java script for their projects. Only one project did not, but even that one project was more sophisticated than the last year's projects. This was probably due to the brainstorming session led by one of the researchers on the first day and increased scaffolding we provided to students through stimulating their interest in and prior knowledge of game playing to facilitate their learning in creating their projects. Like last year, we had trouble with absenteeism and the lack of sustained time. Interestingly, this is a problem due to the format of school itself, rather than with the students, as the time periods are too short. Other researchers of games in learning environments have found that schools are difficult environments for implementing game-based approaches. This is due to their strict structures, strong traditions, and complex political dimensions (Clarke & Dede, 2009; Gee, 2003; Squire, 2006).

We also did some procedures differently. We began by talking about gaming in general, while last year the focus was on QA. The teacher also said in an interview that he scaffolded the project better by making the general curriculum more challenging. The class was also smaller and the teacher said that his introduction to programming classes seemed to attract more talented students every year. He stated, "I'm pushing the intro class harder."

In short, we were all more experienced in how to introduce and scaffold this type of open-ended problem-solving task in a high school class. Incorporating younger student feedback was another major difference from the previous study. The high school students found the feedback frustrating but also caused them to respond to the feedback. Most chose something challenging and difficult for them to develop. They all used something from their programming experience and incorporated their experiences and new ideas into QA by way of the quests they produced. These quests all provided a link that, when clicked on, would launch the Java applet or the PowerPoint.

DISCUSSION

Our findings gave us a nuanced picture of what high school students do when presented with an ill-defined problem that was couched within a context familiar to them (a Multi User Virtual Environment). Using games and gaming culture as the context for developing an instructional program for younger students allowed the students to view a challenging task as something that was largely fun. Our findings also showed that the gaming culture provided a familiar anchor for an unfamiliar task. For example, it provided a language that students were able to use while negotiating the problem-solving space and that all members of the larger context of the study used to share ideas. The high school students used that language to communicate with each other, we (the researchers) used it to help scaffold their ideas, and the elementary students used it to communicate their feedback to the high school designers. The gaming culture also gave students fairly concrete parameters for what a *good* project would entail.

We found that most of the high school students were able to incorporate the feedback from younger students to strengthen their designs. It was interesting to see how affected they were by negative comments. In retrospect we wondered if that was because they were high achieving students who rarely heard that their work needed improvement. As we noted, the most dramatic changes in project designs were the direct result of the feedback from students. There was one project in which the two male designers were simply unable to figure out how to make their project more appealing. Another boy who worked on the Seven Wonders project was more focused on integrating his programming knowledge, which was a noble task albeit not the main goal of the QA project. So, while the high school designers were able to comprehend the feedback, a few of them were neither willing nor able to use it.

In general we found that the quality of the projects was improved over the previous study (Ge et al., 2006). The projects in the present study were more appropriate for younger students, more complex in terms of programming required, more game-like, and more creative. We believe that the increased time spent brainstorming on the first day and the ongoing emphasis of the gaming aspect of their project were central to the improved quality and creativity. Having younger students working as the clients in this case was a powerful improvement over the past year's study and clearly helped the high school students understand what were and were not appropriate educational games.

In this open-ended and nearly real world project, the students simultaneously enjoyed their autonomy and felt overwhelmed by the demands placed upon their limited programming skills. This limitation did prevent them from actualizing the full range of the projects as they initially envisioned them. Further, the teacher's job is more complex and less well defined. The teacher may be called upon to solve many different problems that students face as they work on their real world projects, which could be a challenge to the teacher as well. Twenty-first century creativity and problem-based approaches involve problem solving on the part of the teacher as well. Our findings suggest that computer science teaching should involve the use of real clients and incorporate feedback from user populations.

Again we found that TRE was an effective means for collecting data. However, the methodology is somewhat difficult to manage and can be expensive. Plus, the intrusive nature of the video cameras is not well understood. Nonetheless, we think that TRE is a viable option for capturing the complexities of learning environments that include technology as a focal point for the instruction. We found that TRE provided many lenses and angles for examining the inferences we were drawing as we analyzed our primary data sources. In future work we will examine how we might streamline the use of data from the different sources.

Perhaps most interestingly, gaming culture emerged as a powerful force among both the high school students and the elementary school students. Learning to leverage this for more powerful learning in schools remains a formidable but imperative challenge for educators. One problem faced by proponents of the use of video games for learning in schools is that the structures of the school environment (curricula, testing, scheduling) short-circuit the gaming experience. Further, games are still looked upon as somewhat frivolous by many parents, teachers, and administrators. This project found an effective means to utilize games for learning for both the high school students and the elementary school students.

Although gaming culture was, for the most part, a positive feature of this computer programming class, some students remained off task and preferred *playing* games to *creating* them. Future work must examine how these students may be motivated to accomplish learning tasks that are difficult. The use of self-determination theory (SDT) might provide us with a framework for understanding why some students remained unmotivated (e.g., Vallerand, Fortier, & Guay, 1997). We learned from our previous findings that students in computer programming classes are motivated by having a sense of autonomy in the classroom, but research from a SDT perspective has also shown that students must also believe that they possess the competence needed to be successful in a given situation (Guay, Boggiano, & Vallerand, 2001). It is possible that our focus on autonomy with an ill-defined problem is simply too challenging for some students. In future work we will examine how perceived competence can also be supported in a complex problem-solving context.

REFERENCES

Apperley, T. H. (2006). Genre and game studies: Toward a critical approach to video game genres. *Simulation and Gaming, 37*(1), 6-23.

Barab, S., Gresalfi, M., & Arici, A. (2009). Why educators should care about games? *Teaching for the 21st Century, 67*(1), 76-80.

Barab, S., Thomas, M., Dodge, T., Carteaux, R., & Tuzun, H. (2005). Making learning fun: Quest Atlantis, A game without guns. *Educational Technology Research and Development, 53*(1), 86-107.

Bauerlein, M. (2008). *The dumbest generation: How the digital age stupefies young Americans and jeopardizes our future.* New York: Jeremy P. Tarcher/Penguin.

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of the Learning Sciences, 2*(2), 141-178.

Clarke, J., & Dede, C. (2009). Design for scalability: A case study of the River City curriculum. *Journal of Science Education and Technology, 18*(4), 353-365.

Cobb, P., Confrey, J., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in education research. *Educational Researcher, 32*(1), 9-13.

Creswell, J. W. (2007). *Qualitative inquiry and research design: Choosing among five approaches.* Thousand Oaks, CA: Sage.

Ge, X., Thomas, M. K., & Greene, B. A. (2006). Technology-rich ethnography for examining the transition to authentic problem-solving in a high school computer programming class. *Journal of Educational Computing Research, 34*(4), 333-366.

Gee, J. P. (2003). *What video games have to teach us about learning and literacy.* New York: Palgrave/Macmillan.

Guay, F., Boggiano, A. K., & Vallerand, R. J. (2001). Autonomy support, intrinsic motivation, and perceived competence: Conceptual and empirical linkages. *Personality and Social Psychology Bulletin, 27*(6), 643-650.

Lincoln, Y. S., & Guba, E. G. (1985) *Naturalistic inquiry.* Newbury Park, CA: Sage.

Partnership for 21st Century Skills. (2009, May). *P21 framework definitions document*. Retrieved November 21, 2009, from http://www.p21.org/documents/P21_Framework_Definitions.pdf

Prensky, M. (2001). Digital natives, digital immigrants. *On the Horizon 9*(5), 1-6. Retrieved from http://www.marcprensky.com/writing/Prensky%20-%20Digital%20Natives,%20Digital%20Immigrants%20-%20Part1.pdf

Schrader, P. G., & McCreery, M. (2008). The acquisition of skill and expertise in massively multiplayer online games. *Educational Technology Research & Development, 56*, 557-574.

Squire, K. D. (2006). From content to context: Video games as designed experiences. *Educational Researcher, 35*(8), 19-29.

Thomas, M. K., Barab, S. A., & Tuzun, H. (2009). Developing critical implementations of technology-rich innovations. *Journal of Educational Computing Research, 41*(2), 125-154.

Vallerand, R. J., Fortier, M. S., & Guay, F. (1997). Self-determination and persistence in a real-life setting: Toward a motivational model of high school dropout. *Journal of Personality and Social Psychology, 72*(5), 1161-1176.

van Manen, M. (1990). *Researching lived experience: Human science for an action sensitive pedagogy.* London, Ontario, Canada: The University of Western Ontario.

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