Fundamental Computer Science Conceptual Understandings for High School Students Using Original Computer Game Design

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Abstract

In 2009, the North Carolina Virtual Public Schools worked with researchers at the William and Ida Friday Institute to produce and evaluate the use of game creation by secondary students as a means for learning content related to career awareness in Science, Technology, Engineering and Mathematics (STEM) disciplines, with particular emphasis in computer science areas. The study required the development of various forms of multimedia that were inclusive of content and activities delivered in a distance environment via the Internet. The team worked with a game art and design graduate class to produce materials and assessment instruments to be included in the project. The multimedia-based materials were piloted and field tested in online Career and Technical Education (CTE) courses titled Computer Applications I. The evaluation and assessment of this project focused on student learning gains in content-specific computer science areas and overall appreciation of the technology studies used during the project. Teacher and student interviews, along with teacher journals, helped track the progress of both the students and edited materials. Conclusions from this study include support of gaming as a pedagogical process and the need for technological literacy. Based on teacher and student feedback, the study concluded that informational technology software serves as an influential variable in the success of this type of instructional unit. More research is needed on the use of gaming as a pedagogical tool in STEM disciplines as professionals in education prepare 21st century learners.

Introduction

Educational tools and vehicles that create student excitement and promote learner engagement while enhancing student competency are instructional priorities across STEM-based disciplines. Vast arrays of digital media-oriented technologies are directly accessible for classroom use, ranging from traditionally licensed software to web-based applications (Branoff & Scales, 2010). The educators' dilemma is determining where to access the learning tools and vehicles, mastering their uses, and then integrating them into an existing curricular structure. Many of these dynamic tools call for supplemental instructional design to assist educators in technological infusion.

Over the past decade, educational gaming has been a popular learning vehicle to further engage and enhance classroom discovery and application, most notably in science and mathematics (Clark & Ernst, 2009). Implementation of educational video games also has identified progressions in general visual literacies (Gee, 2003). Graphics, animations, and other static and dynamic symbols present universal vehicles that span beyond traditional discipline structure (Clark & Ernst, 2010). Squire (2005) states that, "given emerging research on how videogames and associated pedagogies work in designed settings, it seems the important question is not can games be used to support learning, but how (pp.1).

Virtual Public Schools

The North Carolina Virtual Public School (NC-VPS) was originally formed in 2002 by the state's General Assembly to create the Business Education Technology Alliance (BETA) (North Carolina Virtual Public Schools, 2010). This taskforce of state business, education and political leaders were charged with bringing technology into the North Carolina School System so that students would have the resources to be globally competitive and skill sets for the 21st century (Partnership for 21st Century Skills, 2011). This alliance determined that students need online course offerings using a variety of instructional approaches that can be accessed throughout the state at any given time. Later, BETA established the E-Learning Commission that led in the development and startup of the North Carolina Public School. The purpose of this new online school is to provide courses that students want, but are unable to take at their local schools or school system. Also, students that need to be away from the traditional classroom for whatever reason will have access to a public education. The first courses offered by the NC-VPS were for high school students only, but later middle school courses became available.

Computer Science Literacy

Computer science literacy has become an important aspect to learning and living in an information age. Computer education has experienced a large decline in enrollment for career fields related to computer science since the start of this millennium (Morrison & Preston, 2009). Fewer than 65 percent of U.S. public schools for K-12 offer a basic fundamental course in computer applications. "The nation has embraced much more the importance of STEM education, but computer science [education] is very often missing from that conversation," said Robert Schnabel, dean of the School of Informatics at Indiana University. "Computer science has by far the largest demand for jobs in any period than you see out of the STEM sphere" (Zwang, 2010). Considering the need for students to be technologically literate in areas associated with computer science, digital gaming as a vehicle for learning has seen a resurgence of interest for supporting instruction in various fields of study (Wolz, Barnes, Parberry, & Wick, 2006). This crossover between technology, learning processes and contemporary culture can be accomplished through the study of gaming, as well as the creation of games (Squire & Giovanetto, 2005). Researchers in areas related to gaming have identified unique skills and competencies that are needed for students wishing to pursue computer science, and especially gaming, as a career. These areas include obtaining an appropriate level of education, having experiences, the developing problem-solving and communication skills, developing software and programming, and supporting knowledge in areas associated with computer technology, math and graphics (McGill, 2008). Having students study and develop games as part of a pedagogical practice can help facilitate these fundamental needs for career development and fur-

ther increase the use of gaming in the classroom as an inherent potential for producing learning gains (Royle, 2008).

Over the past 10 years, numerous studies have been conducted that evaluated the use of gaming and the development of games as an educational media for the "Net" generation (Chen, Chen & Liu, 2010). The use of gaming as a pedagogical tool is just one of many alternatives that teachers can use to better design engaging environments in which students can learn (Lim, 2008). The creation of a simple game can help reinforce learning and have positive effects on knowledge acquisition and the motivation of students (Papastergiou, 2009). Also, the potential for using online learning in virtual schools can play a major role in reshaping learning experiences using all forms of electronic media. With more than 30 states offering online classes as one facet of e-learning, this type of new initiative leads the way for new endeavors in electronic delivery of information and gaming can be just one component or pedagogical practice that matches well with these new virtual classrooms (Clark, 2008).

Supplemental Unit Design

The supplemental unit was designed to introduce gaming to students and inform them of the role that gaming and programming fulfill in computer science literacy. The format for the supplemental unit required students to view content demonstrations, complete tutorials to learn about gaming and programming, independently create an original game using a design brief research-based format, and participate in cognitive and performance-based testing for feedback. The complete sequence was designed to take approximately 8 hours to complete. The unit was completely self-contained to prevent instructors from requiring additional preparation in order to offer the unit to their students. The researchers and their graduate students, who were enrolled in a graduate level game art and design in technology education course, developed materials used in the unit. All software required for both media support and game development was freeware for ease of access for both students and teachers.

Content videos, tutorials, a design brief, a performance rubric, a study guide, a post-assessment, and instruments to gauge supplemental student and teacher understandings and comments were developed for the project after a period of recurring VPS teacher consultation, continual research, and materials development. The content videos were created for students to view to learn about gaming and computer literacy concepts that related to career awareness in fields associated with computer science. The areas selected to develop content information were the history of gaming, video games and computer programming, logic in games and programming, basic networking, and computer syntax in gaming. Also, there were designated video materials for teachers to use to gain process and procedure information concerning conducting and implementing the gaming project.

The project gaming tutorials on how to use the freeware applications were designed to teach students the basics of how to develop a simple two-dimensional computer game. GameMaker was the selected freeware because of its simple icon driven logic (YoYo Games, 2011). Tutorials were created in a game art and design graduate classroom under the direction of the researchers for this project. Tutorials began with fundamental processes and step-by-step programming procedure. The sequence of tutorials called for students to incorporate information from previous sequences in order to develop and demonstrate operating proficiency in the freeware. A design brief provided a guide for researching and creating individual games under a selected computer science topic and for the final game creation, a simple assessment rubric for 2D student computer games was developed. The participating teachers also used the performance rubric for assigning grades. A post-test used to indicate content gains from students was developed. Also, teachers used the post-test to identify cognitive understandings for the unit of instruction. At the request of the participating teachers during the bi-weekly online meetings, a study guide containing highlighted information in the videos was created for student use. Finally, two surveys were created to receive feedback from both participating students and teachers. These two instruments were based on previous instruments used by the researchers on a previous STEM-based dynamic media project. The survey solicited information on student and teacher understandings, as well as likes and dislikes about the supplemental unit. Areas of improvement in the form of constructive feedback was the primary objective for administering these two instruments at the end of both the piloting and field testing stages of the project.

Research Questions

This research study was designed to investigate and identify the impacts, if any, that using gaming as an instructional approach has on the development of computer science competency. The overarching research question proposed that specifically guided this study is, "Can the use of gaming as an instructional tool enhance basic computer science competency for distance education CTE programs?" The associated directional investigational hypothesis that was derived to provide specific evaluation of the research question is, "Can the use of gaming as an instructional tool result in attainment of computer science proficiency?"

Methodology

The identified CTE offering was Computer Applications I primarily as a result of the nature of the existing content in the course as well as the specified prerequisites for enrolling in the course. The research team consulted with the NCVPS teachers and confirmed that Computer Applications I was the appropriate course to implement the unit. However, the supplemental unit was structured to not be course or program area specific. This model was used so that the unit would be transferrable in the future. Although, the intent for the project targeted CTE course offerings with a central objective of the unit being implemented to not only convey computer science concepts, but also enhance content within the existing course offering of Computer Applications I.

The following sequence was used in both pilot and field-testing of the computer science literacy supplemental unit. First, students were asked to view an introductory video created to introduce the supplemental unit and sequence of activities for completion, including any relevant evaluations that will take place. Next, students watched a content video titled "A Brief History of Video Games." This video was the first of five content-based videos for cognitive-based information on computer science areas that will be tested at the end of the unit. It gave a brief overview of gaming and its link to computer science. The second content video was titled "Video Games and Computer Programming." This video introduced gaming and its link to computer programming. Students learned a general overview from history to concepts that makes computer science a career of choice if a student wants to pursue a gaming career. After watching this video, students were now ready for their first hands-on assignment related to gaming. Each student was asked to complete the YoYo Games ™ "Catch the Clown Tutorial." This was the introductory tutorial that taught students the basics of using simple, two-dimensional gaming software that is icon driven to help students to understand the computer logic associated with game creation. Once the tutorial was completed, students were asked next to view content video three titled "Basic Networking." This content-based video taught students basic networking concepts and terminology. The focus of this video was defining the components of a network and describing the four primary network topologies. A fourth content video was then watched by students titled "Logic in Games and Programming." This content video explained simple computer programming logic and its role in computer

game development. The fifth and final content video was titled "Computer Syntax and Gaming." This final content-based video introduced students to basic computer syntax and its use in game development. It also referenced the software used in this supplemental unit so that students from this point on would understand why simple game development is being used to learn basic computer science literacy with a career awareness emphasis. Upon completion of the content videos, students were asked to complete a second tutorial titled "Bug Catcher Game tutorial." This tutorial began the process of allowing students to learn more details of game development and more advanced functions of the selected software. A third and final gaming tutorial was designed to get students to use past knowledge gains about the gaming software and create a final tutorial titled "Falling Fruit Tutorial." This final tutorial completed the needed knowledge of the selected gaming software for students to make their own individual game. The tutorial was not as detailed as the others so that students would use previous knowledge gained from completing the other tutorials in sequence.

After all the basic information and game develop practice was complete, students were asked to review a design brief and complete a game design challenge final exercise. Using a design brief created by the researchers for this project, students developed their own game using all knowledge and concepts learned in the previous tutorials and content videos. Students had to create a simple multi-level two-dimensional game that reinforced concepts in computer science. Students were given an assessment rubric for use in game creation; this same rubric was used by participating teachers to assess students' final games. Once all materials were completed, students were given an end of unit assessment with 50 questions based on their understanding of the supplemental unit content from the videos. At the request of participating teachers, a review sheet was created by the researchers for student use as a study guide. The last request of the researchers was for both participating students and teachers to give constructive feedback on the implementation and overall effectiveness of the supplemental unit in survey form. A limitation of the research design is that initial benchmarking for content knowledge of participants was not gauged and analyzed in a pretest format, therefore only permitting analysis of learner competence and not progression of learning.

Once the students completed their final projects, participating teachers submitted the following materials for research and evaluation: student original games (.exe files), a spreadsheet with game and multiple choice assessment scores, a unit summary and teacher rating sheet, a class information and background sheet, and student attitude surveys. Below is the timeline and content development strategy that explains both processes and products that were created and a guide for the research methodology: During the spring of 2009, details on the pedagogical content and research methodology used to complete the revised STEM-based project were negotiated. Communication between stakeholders took place and formalized commitment from industry representatives was requested. Content for the project was developed, including online communication technologies that students used to learn about gaming and the application of computer science. These electronic materials and the completed tutorial that students used to learn the software were reviewed by professionals. Permissions for software and other auxiliary materials were obtained by the researchers. During the summer of 2009, the project design brief was developed that students used to create a simple 2D computer game that demonstrates and/or teaches a computer science concept. A post-test for gaming and computer science was created by the researchers. At the start of the fall semester in 2009, final edits were made to the tutorials, instructional materials and design brief. Also, a final web-based video was created for pilot instructors to use to gain needed knowledge about how to administer the supplemental project into an existing Career and Technical Education (CTE) course. Three CTE instructors and classes were selected and trained for this first pilot testing of materials. In December of 2009, pilot sites integrated this project into their existing courses. This process continued into the next semester and the spring of 2010. During this time, materials were edited based on feedback from pilot sites, industry and education representatives reviewed materials before field testing, and materials were field tested by CTE instructors from NC VPS. Also, students and participating teachers were surveyed for constructive feedback on the implementation and content related to the project. Once all data were collected, the information was analyzed and tested during the summer of 2010. This led the researchers to edit materials for improvement and conducted online interviews with selected teachers for comments about the project. A final report was competed about the project and materials were demonstrated with results disseminated in various venues including workshops and regional, national, and international conferences in 2011.

Data Analysis and Findings

The average of the post-assessment scores (of a possible 50) for the 28 NC VPS Computer Applications I course student participants is determined to be 36.39. The variance (78.84) and standard deviation (8.88) of the computer science gaming post-assessment scores are categorically large. The standard error (1.68) of the post-assessment scores, paired with the variance and standard deviation, highlights a somewhat large fluctuation in score values from participant to participant for the post-assessment. The calculated median of the post-assessment exhibits minimal deviance from the calculated mean of the post-assessment, suggesting a somewhat symmetrical participant score distribution. The range is calculated based on the minimum and maximum scores on the post-assessment. The sizable range (28) reiterates the degree of difference in variability of student participant scores (see Table 1).

Post-Assessment Summary Statistics

Measure	n	Mean	Variance	Std. Dev.	Std. Err.	Median	Range
Post-Assessment	28	36.39	78.84	8.88	1.68	36	28

Table 1

The evaluated hypothesis was: The use of gaming as an instructional tool will result in the attainment of computer science proficiency. This hypothesis was evaluated in Table 2 using the nonparametric Wilcoxon Signed Ranks Test. The test statistic for the Wilcoxon Signed Ranks Test was compared to the des-

Wilcoxon Signed Ranks Test Results

Measure	n	Median Est.	Test Stat.	P-value
Post-Assessment	28	36.5	384.5	<0.0001

Table 2

ignated critical value table based on the sample size of the student participants. The participant data for the sample size was less than 50, denoting that no normal approximation with continuity correction was necessary and the reported p-value is exact. The critical alpha value was set at 0.05 for this investigation. The p-value for the test (<0.0001) was determined to be smaller than 0.05, therefore, the hypothesis is rejected. The analysis of data suggests that the use of gaming as an instructional tool results in student attainment of computer science proficiency (specified parameter > 26 or > 52 percent attainment).

A supplemental instrument was used to identify student perceptions and approaches concerning technological tools, computer video generated games, and technological knowledge. Summary statistics were calculated for each Student Functional Priorities Survey item where Likert Scale responses were acquired (Table 3). The highest collectively agreed upon item, based on the calculated mean, on the Student Functional Priorities Survey was Item 6: It is important to know about technology. The second highest collectively agreed upon item was Item 3: I have a good understanding of the ways in which technology can be used in the real world. The lowest collective calculated mean is for Item 5: Learning technology is too difficult for me. The second lowest collective calculated mean is for Item 16: I have an interest in developing computer-video generated games. The calculated variance for Item 16 is (1.81) is high in comparison to other calculated survey items.

Student Functional Priorities Survey Summary Statistics

Item #	n	Mean	Variance	Std. Dev.	Std. Err.	Median
1	43	4.07	0.78	0.88	0.13	4
2	43	3.26	1.62	1.27	0.19	3
3	42	2.62	1.27	1.13	0.17	2
4	43	4.30	0.41	0.64	0.10	4
5	43	3.77	0.66	0.81	0.12	4
6	43	3.33	0.94	0.97	0.15	3
7	43	3.23	1.28	1.13	0.17	3
8	43	3.53	0.78	0.88	0.13	4
9	43	3.11	1.58	1.26	0.19	3
10	43	3.26	1.24	1.11	0.17	3
11	43	3.60	0.91	0.95	0.15	4
12	43	2.63	1.81	1.35	0.21	2
13	43	3.60	0.77	0.88	0.13	4
14	43	3.63	0.76	0.87	0.13	4

Table 3

The intent of Item 18 of the Student Functional Priorities Survey was to identify if students support or oppose gaming development in an educational setting. Student comments were recorded through the online instrument and the recurring and enduring themes are represented in Table 4.

Conclusions

The following conclusions were made based on the findings within this project: The supplemental unit of instruction holistically supports computer science knowledge development. However, there are some preventive implementation considerations identified by the participating teachers. First, the "high-end" nature of the content being presented was difficult for some students. With heightened course requirements, it was difficult for participating teachers to find room in their curriculum for implementation of the supplemental unit. Also, the freeware software executable file structure presented barriers in file sharing and during the application process. The software was not easily downloaded to school computers because of local school software restrictions, and the files were difficult to share between student and teacher. This problem can be improved by finding better freeware software than the one used for this project. To resolve the time issue, teachers need to have this supplemental unit before the semester begins so they can allocate implementation and laboratory time for their students.

The second conclusion the researchers can make from the overall findings of the project is that the use of gaming as an instructional tool supports computer science competency attainment. The knowledge gains by students and comments made on the student survey, as well as from the participating teachers, supports this conclusion. Overall, students liked the idea of using gaming as a means for learning and obtaining learner outcomes; they were less interested in the actual creation of computer games. Considering this, a third conclusion gathered from the student survey related to technology and career awareness in computer science areas. Student participants identified the importance of being technological literate. Based upon the previous conclusions, students had a high degree of variance and mean central to the overall range for the study, that they had a strong opinion as to whether or not they preferred to make and/or play games as a form of learning basic computer science concepts. Students were divided as to whether or not they experience learning through the playing or making of computer games. More research is needed in this field; this project was too narrowly focused to draw any determination about students' attitudes about this pedagogical strategy. Students did indicate in the post-survey that they do have an understanding of the role technology plays in the "real world". Therefore, students like this type of unit of instruction that brings authentic learning to the classroom, even in a distance environment.

From the teacher feedback and survey data, a conclusion can be made from this project that would indicate that informational technology software plays a large variable in the success of this type of instructional unit. As previously mentioned in this section, problems with implementing software and its selec-

tion plays a major role in the overall success of a project of this type. It is the view of the researchers for this project that more time should be spent selecting the appropriate software with teacher feedback. Also, training on usage and implementation of software is needed for participating teachers and information on proper installation needs to be given to the technology coordinators at participating schools. The variable that the software used for this project issued a new version and interface during the field testing of this project could not be foreseen by the researchers; no announcement from the company was ever made to the public about the update and change in interface. Although this posed a slight problem pertaining to the implementation of the project, participating teacher feedback from the teacher survey instrument indicated a mild increase in the number of students wanting to pursue a computer science associated career. The researchers for this project consider this a successful attempt of the overall mission of the study, to create student interest in computer science related careers. If more time could be given for supplemental integration of these types of materials, the researchers of this project feel more students would consider computer science fields because of having time to expose them to the many different occupations associated with computer science. Finally, more research is needed in the study of gaming as a pedagogical tool and the use of gaming in a distance education environment. Both teachers and students expressed the complexity of video game development but also, similar to that of Clark & Ernst, 2009, an identified appreciation for student interest that it can bring to the classroom. As computer science professionals continue to recruit and educate the public on computer related careers, it is the suggestion of the researchers of this study that time and effort be spent on the use of gaming to entice and enhance learning. This is of high importance as the educational focus rapidly transitions to 21st century skills and learning.

Item 18 Student Comments

Thematic Student Comments
I am a big gamer, and so are a lot of people that I know. I think many people would enjoy playing games at school. Even if they are educational. However, they have to be presented in an enjoyable and fun way.
I believe that it could help students in the classroom.
I would only support it if it was constructed in a class as an elective.
It's too much time for only one assignment
I do not think that computer video-gaming development needs to be taught as a requirement. It should be an option. Some people get stressed easily and are not patient. This would make the course very frustrating and not enjoyable.
I think it would be good for some people but others may have a difficult time with it.
I like video games so I want people to keep making them :) it also is a good line of work and it's very educational.
I would love for students to enjoy gaming while studying; it would make it all so much easier.
Children love to play the games. If it helps them learn, why not let them play?
I think it helps kids stay involved.
I think it would help kids who have troubles listening to teachers teach all day.
I would support computer-video gaming development in education because it would make learning easier for students.
Well it would help out a lot of kids.
Students should be learning about other things other than working on video games.
I would support but tentatively because I think that in some circumstances it is better for a student to learn from a teacher.
I would support because maybe kids would stay in class and learn. If you know class is going to be fun you're more likely to go than skip because it is too boring.
In a way it could make learning fun for certain students. Then again it could be a little tricky for others.
I would be glad if the school board announced that we would be having computer-video gaming development, because it would be a great opportunity for students to start their careers this early in their lives.
I think it will help a lot and make learning more fun!

Table 4

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