INVESTIGATING THE USE OF GAMES FOR CREATING A CONTEXTUALIZED AND GENDER INCLUSIVE COMPUTER SCIENCE CURRICULUM

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ABSTRACT

There has been an international decline in university enrolment rates for computer science courses in recent years. There also exists a distinct gender divide in the subject, with female students exhibiting disinterest in a useful and interesting field due to a wide variety of reasons. In order to try to counteract these two deficiencies in computer science, the way the subject is being taught and presented to students should be revisited and improved upon. The use of educational games to teach basic computer science skills in contextualized and interactive ways could generate enthusiasm and interest for the subject. This approach should be tailored towards a gender neutral teaching method, in order to be more inclusive and approachable. Teaching computational thinking through situational problem solving will place what the students learn in context as well as help reveal the relevance of these skills. The abstract nature of computer science causes a lot of females to shy away from the field but a contextualized approach has been shown to increase students' interest and investment in subject matter, regardless of gender. Research has revealed that females feel less comfortable about interacting with computers for various reasons. By presenting these students with an easy to play game, the confidence levels amongst female students could be increased. An adventure style game was developed with increasing levels of difficulty to be used by first year computer science students during their computational thinking module. By researching teaching and game trends, the game is specifically designed to appeal to both genders. Through continuous encouragement, veiled assistance and enjoyment, computer science can hopefully be re-evaluated by students as a fascinating field that is worth becoming involved in. This paper presents a discussion of the design and development of the adventure style game for teaching computational thinking basics.

Categories and Subject Descriptors

M.1.4 **[Social and professional topics]:** Computing education – *computing education programs, computational thinking*

M.3.3 **[Social and professional topics]**: Gender

General Terms

Performance and Human Factors.

Keywords

Computational thinking, gender, contextualized learning, educational games.

1. INTRODUCTION

Despite the influx of computer driven technologies in all aspects of life, some universities are reporting that more than 50% of students that begin studying computer science abandon the field before graduation [16]. This is a strong indication that the way computer science education is taught and presented needs to be re-evaluated. An idea that is gaining popularity is the use of contextualized learning. Several institutions have begun using this approach and have been receiving positive feedback and increased student retention rates [2] [13] [14]. An added benefit of this approach is that it is gender inclusive, increasing the understanding and enthusiasm of all students. A highly dynamic and interactive approach, that works consciously to entertain and engage the student, is the use of games. With the use of strong narrative frameworks that support and promote computational thinking skills, the students will learn what is required of them in a way that does not feel like learning. A positive side effect of this approach is that the use of games has been shown to increase the popularity of a subject [2]. If more students perceive a course as fun and inclusive, enrolment rates could be affected for the better.

2. PRIOR WORK

2.1 Contextualized learning

There has been an increasing need in recent years for a more comprehensive and holistic presentation of science in education [12]. It is no longer accurate to assume that teaching the same abstract concepts in every learning situation is effective [17]. It has been proposed that teaching computer science, and indeed any scientific subject, with a strong relation to real world contexts, will increase student understanding and participation by turning a concept into a relatable, everyday problem solving exercise [12]. In computer science, contextualized learning can help bridge the gap between ordinary computer use and what is taught in computer science [16]. The computer environments students interact with on a daily basis, to communicate or for entertainment, is very different from the one they use for learning programming. The connection between these two environments is not immediately obvious to many students, and so by reinforcing the link between their everyday computer interaction and what they are learning could help prevent the theory of computer science appearing disconnected and obsolete [16].

Cordova & Lepper explored how contextualizing, personalizing and offering a choice in what was taught not only improved students' motivation, but also their level of engagement with the material [8]. Owing to the positive outlooks, this approach also increased students' perceived level of competence and raised their aspirations. Cordova & Lepper commented on how the enthusiasm small children have towards learning is lost as they move through school, which they attribute to the decontextualization of instruction [8]. The information being taught is no longer immediately relevant to them and presented in an abstract way that is meant to help generalize learning [8]. By presenting material in a meaningful context, Cordova & Lepper intended to appeal to the intrinsic motivation for learning that is found in children [8].

2.2 Learning through game play

Games provide a dynamic and interesting platform from which to teach. A game can simulate a real world example and require real-time interpretations of concepts [11]. The benefit of intermittent reward in games (such as completing a level or receiving a prize) helps motivate students to continue working [8] [18]. Also, contextualized cases require students to make practical decisions based on learnt principals, allowing them to learn concepts by working with them [9] [12].

Leutenegger & Edgington used games to teach an entire introductory computer science course and found that this approach improved student understanding across all examined topics [14]. This study greatly valued instant visual feedback for students to try to directly relate their understanding to what their code actually means [14]. This approach not only increased understanding and retention, it also raised the level of enjoyment in the class. The course gained a new reputation for being fun and interesting. Having a better reputation doubled enrolment rates for the course and increased the number of students deciding to major in computer science.

Cordova & Lepper used computer games to teach mathematical concepts to fourth and fifth grade children. The first approach to try and encourage the students to be motivated about learning was to personalize several key features of the learning context to make the work appeal directly to students [8]. The second strategy was to include an element of choice into the learning activities. This was done in an attempt to increase the students' sense of control and self-determination [8]. When students are given a choice, they become more invested in the material they have selected, which has been shown to not only increase enjoyment, but also to make students perform better and be more persistent about completing tasks [8]. Bayliss noted the same point, and also acknowledged that this level of investment made students less likely to cheat [2].

Laurel led a team of researchers to try to discover why females were being left behind by the rapidly advancing gaming industry [13]. They concluded that the type of adventure game that would appeal to females would feature a `real-life' setting as well as new places to explore. Females preferred games with story lines and a leading character they could identify with (who could be their friend). Friendship was seen as an important aspect of the game. Females require feeling social and safe in the gaming environment, and prefer being able to design, create and communicate [15]. Males, however, preferred games with violent feedback, such as ending the game by the main character dying or by killing another character [15]. Males also strongly favoured adventure-style games that had a level of escapism [15]. Another genre that appeals to both genders is strategy games, where logic and planning allow players to move ahead [16]. This genre both appeals to a sense of safety in females and the males' wish for escapism (especially if the game is centred on war strategies).

An important suggestion made Jorgensen, Logan, and Lowrie was that games could be used to trigger an awareness of real-world settings or contexts where different skills and approaches could be applied [11]. Dickey made a different point that narrative games provide environments that allow students to practice and gain skills that have a use in the real world [9]. This second observation disconnects the game narrative from a real world application, but if a skill can be learnt in a way where its application is understood, it should be easier to transfer across contexts and uses. In other words giving an indirect context, whether in a fantasy or real world example, will still enhance the concept.

2.3 Gender and educational games

Females are under-represented in the field of computer science, and this may be due to a male-biased education system that does not adequately address female learning. Horne found that in schools, though there was no gender difference on standardized pen-and-paper tests, males performed better on computerized tests than females [10]. This was attributed to a lack of confidence on computers amongst females.

Contrary to popular belief, females make up 45% of all game players, if casual gaming is included [14]. As such the use of games is relatively gender neutral. Genders have shown equal success in computer science educational games [4]. Females have been shown to be less attracted to violent and online multi-player games, however this is not true for all games [14]. In fact, females can be equally motivated by learning through games as males [14]. Repenning, Webb, and Ioannidou reported a significant increase in female participation in computer science related electives after the inclusion of game design courses in high school curriculums [18]. Rochester Institute of Technology developed a new degree for game design, which received 14% more female freshman than the traditional computer science degree program [2].

Jorgensen et al. explored how computer games can be used for contextualized learning by trying to break away from the traditional structure of educational games [11]. Instead of using a drill-and-practice framework, they aimed to mix education and entertainment to use a narrative-like framework with a more informal approach to learning. This would also have the added benefit of the learning not being perceived as a `lesson' to students. This study also focused on the difference in responses and abilities between genders in game play. The skill Jorgensen et al. (2013) were concentrating on was map reading and interpretation. In their initial surveys they found that though males were more likely to play map-based games, females were more likely to play problem solving games [11].

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3. RESEARCH DESIGN FOR INITIAL SURVEY

A survey was run at the beginning of CS1 academic course to assess the students' attitudes towards computer science. This was done in order to confirm the research found in prior works as well as to assess the initial opinions of the students to compare to an evaluation done after the use of the educational game. The questions posed to the students were based on the Computer Science Attitude Survey by Wiebe *et al*. [19]. Responses were given on a five point scale that ranged from strongly agree to strongly disagree. The survey covered five areas of attitudes towards computer science:

- confidence in their own abilities
- their attitude towards success
- how they perceived the gender dynamic in the subject
- the usefulness of computer science
- their motivation for taking the subject

These same questions will be asked to the students again after the use of the game.

3.1 Participants

The survey was run amongst the students enrolled in the introductory computer science course at Rhodes University, a small university in South Africa. 405 students participated, of which almost exactly half were female (50%, n=203 female, 50%, n=202 male). Of this group only 18% were considering majoring in computer science (7%, n=26 females; 11%, n=45 males).

3.2 Method and Analysis

The survey was run during July 2014 in an introductory practical. Students were made aware of the intentions and purpose of the study, and that their participation was voluntary and confidential. The survey was conducted electronically using Google Forms and the collected data was stored anonymously in a spreadsheet. The results were statistically analyzed using Statistica. The response scales were converted to ordinal numbers (with strongly agree being given the highest value). From this data, a one way ANOVA with assumed equal variance was used to determine if differences between the responses of the different genders were statistically significant.

4. Survey results

Participants were asked why they were taking the course. They could select from a combination of reasons: 82% took it for their degree, 42% wanted to improve their computer skills, 34% wanted to learn basic programming skills, 3% took it to because they had heard the course was fun, 19% wanted to improve their confidence on a computer, and 29% thought the course sounded interesting. The low values of 3% that indicated they had heard the course was fun and 29% that thought the course sounded interesting shows that computer science does not have a good reputation amongst students. Games could help change how the course is perceived, and therefore increase student retention and enrolment [2].

Table 1: Selected ANOVA results from Survey

(N = 403 and p-value < 0.05 considered significant)

#	Survey Questions	Mean	Factor	p-value
1	I plan to major in computer science	2.15594	8.40	**0.00394**
2	I have a lot of experience with computers	3.19154	13.72	**0.00024**
3	Generally I feel confident on computers	3.50124	24.93	**0.00000**
4	I already have programming experience	2.16625	20.89	**0.00001**
5	Programming looks interesting	3.47264	15.47	**0.00010**
6	Programming looks very difficult	3.49876	0.17	0.67914
7	I think I can learn programming	4.21092	0.00	0.96360
9	I enjoy solving problems	3.77970	7.25	**0.00738**
13	Females are as good as males at programming	4.16790	8.62	**0.00352**
14	Studying programming is just as appropriate for women as for men	4.44307	7.79	**0.00550**
15	It is hard to believe a female would do as well as males in programming	1.710396	6.73	**0.00983**
16	It makes sense that there are more men than women in computer science	2.490099	5.82	**0.01629**
17	Programming is a very important skill to have	3.942500	0.30	0.58700
18	Problem solving is a very important skill to have	4.639303	0.03	0.86145
19	Computer science is a worthwhile and necessary subject	4.089330	0.20	0.65665
23	I try and avoid computers as much as I can	1.659204	3.86	0.05170
24	I am very excited to learn more about computers	4.111663	3.58	0.05912

Due to the size of the survey, only certain results that proved significant will be discussed here (survey results in Table 1). The first question showed there is a statistically significant disparity between male and female participation in the subject (p-value < 0.05). There was a statistical difference between the number of males and females that are planning to continue with the subject. There was also a significant difference in the questions related to confidence and interest in studying the subject (questions 2, 3, 4, 9), with males proving consistently more comfortable on computers [6]. Using games to teach could create a fun and encouraging environment for females to build their confidence. Establishing a sense of enjoyment and confidence for females in computing is an important aspect of narrowing the gender gap [15].

An interesting response is that there is a large disparity between genders belief about whether programming is interesting (question 5). With females entering university with already solidified ideas of their opinions on computer science, future works should look at encouraging females from high school, or even primary school. Both genders agreed that programming appeared difficult (question 6) but they also both agreed that they could learn it (question 7). This is encouraging as it indicates that both female and male students (over 90% of the sample) believe they are capable of learning programming. If the students believe they could learn programming, why are more students not exploring this option? The answer may lie in question 9, “I enjoy problem solving” ($p < 0.05$). Problem solving is one of the key features of computer science. Though many females do enjoy problem solving, males enjoyed it more by a significant factor.

All the questions relating to gender within the survey have been shown in Table 1. In every question, there is a significant p-value for the difference in responses between genders. Females were consistently more supportive of their gender in the field, and males the opposite. A level of bias towards females in computer science is endemic. Many females can become discouraged by this and chose to work in more “female friendly” environments. If more females were encouraged to remain within the field, and were able to succeed, the reputation of the gender could change. Clewell & Campbell believe that stereotypes are one of the main causes of the gender divide within computer science [7].

Both genders acknowledged the importance and relevance of programming and problem solving (questions 17 – 19 with p-values > 0.05). Perceived importance of educational subjects helps motivate students as they are invested in the topic [16].

5. GAME STRUCTURE

The genre of adventure style game was chosen due to having a strong narrative framework that allows goal based scenarios that encourage skill development to be integrated into a situational context [9]. Due to the time constraints of the research, a fully realised narrative could not be developed. However, strong narrative themes run throughout the game. To set up the storyline, there was an initial animated scene with conversation between the main character, to be controlled by the player, and the teacher, who acts as the antagonist in the game (as seen in Figure 1). The scene sets up the motivation and goal for the game while establishing the roles of the characters [9]. The focus of the game was placed on the problem solving challenges, rather than the narrative, allowing the game to remain casual. The motivation for this choice is that casual gaming appeals to a greater percentage of both genders than very complex gaming [14] [16].

To include an element of personalization in the game, players were allowed to a select their character from four choices, as shown in Figure 2, which included a variety of genders and ethnicities. Personalization acts to improve students’ motivation and their level of engagement with the material [8].

Figure 1: Narrative cut scene

Throughout the game, players are presented with a map that indicates their progress. Each section is represented by a door on the map. The challenges in the game were grouped by concept: trial and error, if statements, variables (and abstraction), while loops and algorithmic thinking (and pattern detection). The player must advance through these sections in order as the sections build on each other. Each section begins with the teacher giving an explanation of the concept (Figure 3). The player can read these instructions at their own pace, using arrows located at the bottom of the screen, and can choose to skip through them very quickly if they already understand the concept. This was allowed to maintain a high ceiling where students who have already learnt the concepts or would rather learn by experimentation can do so without becoming frustrated [18]. Also, slow readers, or players that rely heavily on written instruction, can get the full benefit of these explanations. Jorgensen *et al*. found that male students relied heavily on graphical cues, whereas female students rely more on hints and written information [11]. If the player fails to succeed in the upcoming levels, they are offered the choice to return to the instructions. After finishing each level, the player receives encouragement and congratulations, trying to use positive reinforcement to build the player’s confidence. They also receive marks based on their performance in the level.

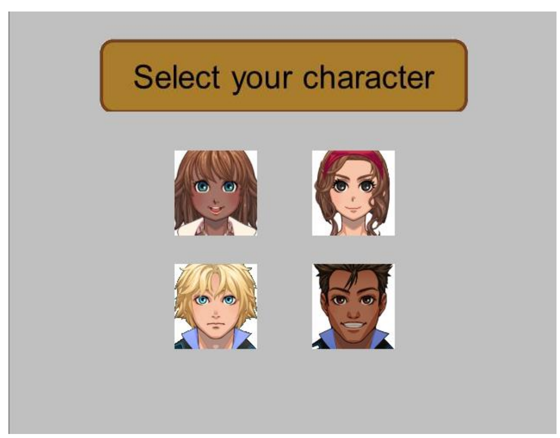

Figure 2: Character selection

The first introductory level is entirely mouse based, comprising of a mixture of logical and trial-and-error style problems. These were included to encourage the students to make use of what they had without receiving any instructions. As previously discussed, female students tend to be hesitant to act without hints or clear directions. Problem solving does not always come with these hints, and so it is to try and encourage students to branch out from needing to be told what to do. It also an attempt to build their problem solving confidence as they can solve the levels on their own, without needing hints.

The if statement section required the player to sort items using a set of if statements as an indicator of how to sort them. The levels increase in difficulty, beginning with just one if statement and then increasing to several cases and nested if statements. The instructions for this section were split into two parts so that the player could try simple statements and understand them, before receiving explanation for how multiple if statements can interact. This allows the focus to remain on the context of the information instead of inundating the player with information before they can explore what they have been taught.

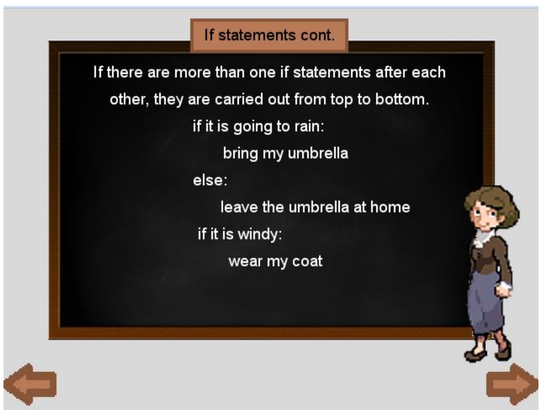

Figure 3: A single scene for the if statement instructions room

The variable section instructions focused on how the use of variables allows for abstraction, and why abstraction can be so powerful and useful. The players had to track expressions and give the value of the variables at various points.

As with the if statement section, players were presented with while loop expressions that they had to follow. The narrative structure of the game was that there are room filed with booby-trapped tiles and the player has to follow the while loop expressions exactly, or they will not make it across the room. If the player makes an incorrect move, an explosion occurs and the player must restart. This allows some violent feedback that males respond well to, but within a problem solving framework that females enjoy [15].

In the final section, algorithmic thinking, the player must write the expressions required to traverse a maze. This requires them to think through the implications of their instructions. The number of instructions is limited to encourage the player to use them as concisely and effectively as possible. The levels also require the players to put repeated instructions into a function, in order to teach pattern detection and another level of abstraction.

6. CONCLUSION

Enrolment rates in university computer science courses are dropping around the world [2] and literature suggests making computer science more fun and relevant for students could be an effective solution for counteracting this problem [2]. There have been a great many successes when using contextualized learning to teach science subjects [8]. It appears to be an effective teaching tool that aims to entertain, motivate and actively engage students in learning. Games in particular provide effective, interactive environments to test student knowledge within a context that could be related back to real life [8]. Teaching contextually through games also appears to equally encourage both genders, proving to be a very inclusive approach to education [2]. Female students in particular have low confidence levels in the field, which could be raised through motivational and supportive teaching practices [2].

This research will be extended to evaluate the students' responses to the game and the idea of contextualized learning. Students will be observed during their use of the game. A second survey will also be run to re-assess the students' attitudes in order to see whether computer science courses, and the use of the game, are effecting how the students view themselves and the subject.

7. FUTURE WORK

This project has a lot of scope for future work. More complex games could be developed that would teach concepts more thoroughly and perhaps include a test framework to allow the progress of individual students to be tracked. The effect of more complex and engaging narratives should also be explored.

Future works should explore how computational thinking skills could be integrated into high school, or even primary school, curriculums. By addressing the problem in high school, it may be easier to adjust gender perceptions and stereotypes that have already become ingrained at university level.

Future works should consider interviewing students (particularly female students) that chose to leave the field. They could provide insights into the short fallings of computer science tertiary education and reveal what about computer science is discouraging (female) students.

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9. REFERENCES

[1] Anderson, N., Lankshear, C., Timms, C., & Courtney, L. (2008). 'Because it's boring, irrelevant and I don't like computers': Why high school girls avoid professionally-oriented ICT subjects. Computers & Education, 50(4), 1304-1318.

[2] Bayliss, J. D. (2009). Using games in introductory courses: tips from the trenches. ACM SIGCSE Bulletin, 41, pp. 337-341.

[3] Beyer, S., Rynes, K., Perrault, J., Hay, K., & Haller, S. (2003). Gender differences in computer science students. ACM SIGCSE Bulletin, 35, pp. 49-53.

[4] Carbonaro, M., Szafron, D., Cutumisu, M., & Schaeffer, J. (2010). Computer-game construction: A gender-neutral attractor to Computing Science. Computers & Education, 55(3), 1098-1111.

[5] Carter, L. (2006). Why students with an apparent aptitude for computer science don't choose to major in computer science. ACM SIGCSE Bulletin, 38(1), 27-31.

[6] Casey, M. B., Nuttall, R. L., & Pezaris, E. (1997). Mediators of gender differences in mathematics college entrance test scores: a comparison of spatial skills with internalized beliefs and anxieties. Developmental psychology, 33(4), 669.

[7] Clewell, B., & Campbell, P. B. (2002). Taking stock: Where we've been, where we are, where we're going. Journal of

Women and Minorities in Science and Engineering, 8, 255-284.

[8] Cordova, D. I., & Lepper, M. R. (1996). Intrinsic Motivation and the Process of Learning: Beneficial Effects of Contextualization, Personalization, and Choice. Journal of Educational Psychology, 88(4), 715-730.

[9] Dickey, M. D. (2006). Game design narrative for learning: Appropriating adventure game design narrative devices and techniques for the design of interactive learning environments. Educational Technology Research and Development, 54(3), 245-263.

[10] Horne, J. (2007). Gender Differences in computerised and conventional educational tests. Journal of Computer Assisted Learning, 23, 47-55.

[11] Jorgensen, R., Logan, T., & Lowrie, T. (2013). Navigating and decoding dynamic maps: Gender preferences and engagement Differences within- and outside-of game experiences. Australian Journal of Educational Technology, 29(5), 626-637.

[12] Koul, R., & Dana, T. (1997). Contextualized Science for Teaching Science and Technology. Interchange, 28(2-3), 121-144.

[13] Laurel, B. (1998). From Barbie to Mortal Kombat: Gender and computer games. (J. Cassell, & H. Jenkins, Eds.) MIT Press.

[14] Leutenegger, S., & Edgington, J. (2007, March). A game first approach to teaching introductory programming. Proceedings of the 38th SIGCSE Technical Symposium on Computer Science Education.

[15] Margolis, J., & Fisher, A. (2002). Unlocking the clubhouse: Women in Computing. (Anon., Ed.) The MIT Press.

[16] Muratet, M., Torguet, P., Jessel, J., & Viallet, F. (2009). Towards a serious game to help students learn computer programming. International Journal of Computer Games Technology, 2009, 3.

[17] Oers, B. V. (1998). From Context to Contextualizing. Learning and Instruction, 8(6), 473-488.

[18] Repenning, A., Webb, D., & Ioannidou, A. (2010). Scalable game design and the development of a checklist for getting computational thinking into public schools. Proceedings of the 41st ACM technical symposium on Computer science education, (pp. 265-269).

[19] Wiebe, E. N., Williams, L., Yang, K., & Miller, C. (2003). Computer science attitude survey (NCSU CSC TR-2003-1). Raleigh: North Carolina State University.