Gamification to Engage and Motivate Students to Achieve Computer Science Learning Goals

Shannon Butler, Dewan Tanvir Ahmed
Department of Computer Science
University of North Carolina at Charlotte
Charlotte, NC, USA
Email: sbutle31@uncc.edu, dahmed@uncc.edu

***Abstract*—Despite rapid growth and the promise of a lucrative degree, the attrition rate for students studying Computer Science is high. Computer Science learning is a difficult, tedious process with a heavy workload which demands a lot from those studying it. A student who loses motivation or interest in the field is more likely to find a new area of study. In order to keep students interested and motivated, difficult concepts need to be taught in new, more engaging and interactive ways that feel fun. Students are willing to take on hard, frustrating, and even time-consuming challenges within video games for intangible rewards and feelings of accomplishment. Therefore, our goal is to gamify Computer Science learning to achieve the same levels of engagement and fulfillment as video games do. To do so, we have begun development of a serious game that introduces CS concepts in a fun and interactive way. To measure the level of interest and engagement brought on by this game, we let volunteers from CS as well as in other majors play our prototype. After playing the games, each volunteer filled out a survey comparing their enjoyment in learning through games as opposed to traditional classroom learning. With this feedback we concluded that gamification is key in changing the learning experience for CS students and will help them achieve their learning goals.**

Keywords—gamification; serious games; CS education; engagement; motivation

I. Introduction

Nowadays, nearly every student carries around a portable game console with them at all times. They may spend hours on difficult, tedious challenges playing games on their phones not for money or tangible rewards but for points or in-game items. Yet, these students will give up on lucrative degrees such as Computer Science or other STEM fields due to difficulty, amount of time required, and the boring presentation of material. Between 40-50% of students who enroll in Computer Science either drop out or switch majors, usually within the first two years of their study [1]. One-third of students who take an introductory CS course worldwide are unable to pass [2]. There is a national need for more professionals in STEM fields such as CS and a low-cost way to fill this demand is by increasing retention rate in respective college degrees [3]. Students are well aware of the benefits of the CS major but are getting discouraged from reaching the finish line and receiving the degree. CS has a negative image of being difficult and boring, an image that needs to be changed in order to retain students and attract those who would otherwise be put off by its reputation. This stigma can disappear through a change in the learning experience. There is a push to shift education from a didactic model where students take a passive role in lessons to a constructivist model that focuses on the student becoming a more active, engaged learner [4]. If learning CS concepts were as fun and interactive as playing games, perhaps students would spend hours learning without even realizing it. A serious game should "bear the features of the multimedia-rich, adventurous games that students experience outside school in order to meet students' expectations, to retain their interest and to be exploitable within long-term educational interventions" [5]. Students can achieve their learning goals in an enjoyable and stress-free way and remain motivated to continue their education. Educational games have been proven to generate more effective learning outcomes and more motivation than other approaches and need further exploration in teaching CS concepts over programming skills as well as focusing on older students as opposed to children [5]. This study intends to further establish the needs of CS learners, which will shape development of an engaging and interactive learning game.

II. Methods

A. Game Design

In order to see how an educational game could engage and motivate learners, we first needed to create one. Using the game engine Unity3D and the C# programming language we integrated three CS concepts in the form of game levels. More advanced concepts above the introductory level were chosen, such as those from the core sophomore classes, to make sure the concepts were difficult but not impossible to learn without having a base knowledge. The first game level introduces the CS data structure concepts "stacks" and "queues" and demonstrates their basic methods of adding and accessing data. The second level has the player perform the sorting algorithm "selection sort" from start to finish. Each level begins with an introduction on the concepts and allows players to perform actions at certain points in the tutorial, later allowing more freedom. At the end of each level a five question true or false quiz is given to test what the player has learned.

The premise of the game is that players are cadets at a space academy. They are given their own robot to control and customize while performing missions ranging from sorting

978-1-5090-5510-4/16 $31.00 © 2016 IEEE
DOI 10.1109/CSCI.2016.52

crates in the cargo bay of a spaceship to fighting aliens to exploring space, all while learning code. As the setting for the developing levels is a spaceship cargo bay and players control their own robot, high quality models were purchased on the Unity asset store and used as graphics for the game.

B. Testing

Once the prototype levels were ready, 20 anonymous volunteers tested the selection sort level (Fig. 1) by either downloading the level and playing it or watching a YouTube video showing a narrated demonstration of the level.

Fig. 1. Selection sort level.

In this level, players are first taught about the sorting algorithm and begin the sort step-by-step by following directions given at the bottom of the screen. Then, they finish performing the sort on their own, without instruction. The sort is performed in-game by clicking lit-up buttons on crates in order with the mouse, changing the colors of the buttons. Each crate has a value, and the minimum value (starting with the first unsorted crate value) is stored in the upper left-hand corner of the screen. Clicking on buttons compares the clicked crate's stored value with the minimum. The color changes depending on whether it is higher or lower. If lower, it is stored as the new minimum. The player also controls a robot with arrow keys and uses the robot's Shock Attack (a lightning effect) by clicking the spacebar to activate one of the sorting functions, a "swap", where the minimum value is swapped with the first unsorted crate. There are help buttons at the top right of the screen in case players have forgotten previously learned topics. Clicking these reveals an information box below them that can be closed after reading. Once the sort is completed, the player takes the true or false quiz on selection sort and are told their scores at the end of the quiz.

C. Survey Method

After volunteers demoed the game themselves or watched the demonstration, they were asked to fill out a 15 question online survey using Google Forms. Questions were meant to establish demographics, ask about respondents' learning style preferences, and see if the game fit into their expectations of a fun and interactive way to learn difficult concepts.

III. Survey Results and Discussion

The first two questions in the survey established the demographics of those being surveyed and asked for an answer of "yes" or "no".

Q1. I currently study or have studied Computer Science.

Of the 20 respondents, 65% (13 out of 20) have studied or currently study CS.

Q2. I am currently a student.

50% (10 out of 20) are currently students (in any degree). 35% of the respondents (7 out of 20) are current CS students. It was intended to get a variety of opinions since the goal is to make CS learning appeal and appear fun to everyone, even those who might be intimidated by the difficulty of CS concepts.

Q3. Which of these methods of learning is most effective to you? Options: Lecture, Hands-on Activities, Reading text, Online media (videos, forums, etc.), Other.

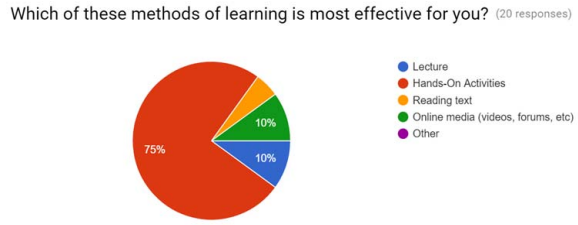

Fig. 2. Preferred learning methods (Q3).

As shown in Fig. 2 above, 75% of people (15 out of 20) chose "Hands-on Activities" as their favored learning style. Despite this strong preference of hands-on learning, CS concepts are often taught in lecture format. In order to become more effective, CS lessons need to be taught in a more interactive way.

To explore the needs of learners further, the next eleven questions measured how strongly respondents felt about the statements presented, using a scale of 1 to 5 (1 – Strongly Disagree, 2 – Disagree, 3 – Neutral, 4 – Agree, 5 – Strongly Agree).

Q4. I learn better when I am actively engaged in a lesson.

85% of respondents (17 out of 20) strongly agreed yes. 10% agreed, and 5% (1 out of 20) were neutral. Responses to Q3 and Q4 make it clear that interactive learning is preferred and there is a need to provide hands-on activities within lessons. Our game aims to resolve the lack of interactivity within lessons. Next, questions were asked to establish the need for interactive games within CS due to its difficulty and strain on learners.

Q5. Computer Science concepts are difficult.

45% (9 out of 20) agreed that CS concepts are difficult, while 30% (6 out of 20) selected neutral and 15% (3 out of 20) disagreed. 10% of respondents strongly agreed that CS concepts are hard, and these respondents are those who have never studied CS. It indeed has a perception of being difficult by those who have not studied it. The 15% that disagreed with the statement have studied CS at some point. Perhaps these students are naturally inclined towards learning CS, since the other 85% did not disagree with the statement. Based on these responses the overall perception of CS concepts is that they are difficult.

Q6. If concepts are too difficult, I lose motivation to learn.

Part of the goal with making a fun game is to help keep motivation strong. This question tried to find out whether difficult concepts such as CS ones (as determined in the previous question) cause a lack of motivation and thus could lead to a student giving up. Results were fairly dispersed, though the majority either agreed (40%) or strongly agreed (15%). 25% were neutral, 10% disagreed, and another 10% strongly disagreed. From this question, there is no strong correlation between difficulty and losing motivation.

Another goal in creating an interactive game is to help learners visualize a concept. Reading text or having someone verbally explain an idea to you can be lost when trying to picture it in your head, so the following two questions were asked to determine a need for games as visualization tools.

Q7. I have trouble visualizing and understanding a difficult concept when it is explained to me.

In response to the statement in Q7, 45% responded neutrally, 30% agreed, 15% disagreed, and 5% strongly agreed and disagreed. With such a high neutral response, this question was most likely too ambiguous. However, respondents were very clear on how they felt towards the next statement (Q8), as shown in Fig. 3.

Q8. Playing an interactive learning game would help me visualize and understand a difficult concept.

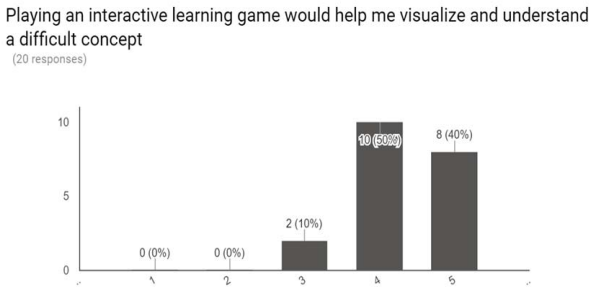

Fig. 3. 8th survey question on whether interactive learning games can help visualize and understand a difficult concept.

As shown above, 50% of respondents agree and 40% strongly agree that playing an interactive learning game would help them visualize and understand a difficult concept, while no respondents disagreed in any way. 10% were neutral in their responses. Respondents are in strong agreement that an interactive learning game would help with visualization and comprehension of a challenging concept. The game developed for this study takes difficult CS concepts and turns them into interactive activities that help the player visualize the concepts at work. Being able to see the sorting algorithm and manually performing it yourself is more helpful than trying to picture it in your head.

Q9. If learning is more like a game, I am more motivated to learn.

Fig. 4. 9th survey question. 85% of respondents agree or strongly agree that

It is clear from Q9 (Fig. 4 above) that if learning is more like a game then motivation will improve. 45% of respondents agreed, while 40% strongly agreed. 10% were neutral and 5% disagreed. There is no reason that learning should not be fun in order to keep the attention and engagement of learners, except that methods of making learning fun are still in development, such as our game.

Q10. Learning through games makes difficult concepts more approachable.

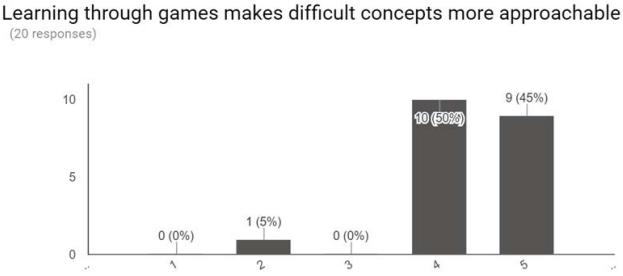

Fig. 5. 10th survey question. 95% of respondents agree or strongly agree that learning through games makes difficult concepts more approachable.

Difficult concepts can become overwhelming for learners and may scare them away before an understanding is even attempted, so it is important to portray challenging material in a way that is more approachable and gently introduced. 45% of respondents strongly agreed, and 50% agreed that games can help with this.

Q11. I like that playing an educational game lets me learn at my own pace.

The majority (55%) strongly agreed and another 25% agreed that learning at one's own pace is a benefit to educational games. They can also be replayed until the player is confident in the material so that eventually a difficult concept can be learned. Learning games help learners take

control of what and how they are learning. After opinions on interactive learning games were collected, questions specifically about the game created for this study were asked.

Q12. The follow-up quiz helped me reflect on what I had learned.

A way to test what was learned by playing the game level was by taking the true or false quiz at the end of the level. 50% of respondents agreed and 30% strongly agreed that the quiz helped them reflect on what they had learned. There is no penalty for getting answers wrong nor currently any benefit for getting questions right, it is simply for players to see their progress in learning a concept.

Q13. This game offers a fun and interactive way to learn.

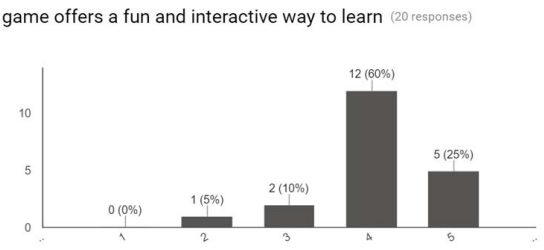

Fig. 6. 13th survey question. 85% of respondents agree or strongly agree that the game is a fun and interactive way to learn.

60% of respondents agreed and 25% strongly agreed that the game succeeded in being a fun and interactive learning game. The one respondent who disagreed had this to say in the additional comments section of the survey: "The problem I have with education games is that they really aren't games. You are reading along to do tasks and then there is a bit of action. I would like more playing." There is indeed a gap in the level of fun between educational games and normal games which needs to be bridged, but for now educational games still offer more fun and interactivity than other methods of learning.

Q14. This game is a helpful tool and addition to core Computer Science classes.

The goal of this game at this point is not to replace CS lectures but to be a supplemental tool for students to help them learn concepts. This game could be used as an in-class activity to give a foundation for the concepts before taught in-depth or can be used to reiterate knowledge learned. 45% of respondents agree and 40% strongly agree that this game would be helpful in a class. The one respondent who disagreed was the same one to argue that educational games are just not fun and also does not find CS concepts to be difficult.

Q15. Please share any additional comments.

Overall the comments were positive. One respondent commented, "A fun little way to learn sorting! I felt like the concept was explained well." The only negative comment was mentioned before, about how educational games need to involve more playing and less explaining. For now, it has been established that respondents reacted positively to learning games and the example game created.

IV. Future Work

Upon further development, this game intends to absorb players in a vast universe full of exploration and discovery, with many different CS concepts to learn. Serious games can utilize techniques that make learning environments fun, such as challenges of varying difficulty levels, using fantasy that engages interest but also reflects real-life practicality of lessons, and creating curiosity that is piqued and satisfied [6]. Our game will offer levels for many CS concepts of varying difficulties, will demonstrate their usage in analogical situations to real-life, and stimulate players' intellectual curiosity to learn the next concept and progress in the game. As players beat missions and level up, they will be able to explore the game universe further as well as their field of Computer Science. They will also be able to earn parts and abilities for their customizable robot, which may drive them to continue playing or replay levels. The game needs to develop in ways that mimic current popular games so that players see it as fun and competitive and not think of it as an educational game. At that stage, we can implement it in CS classes to test its learning, engagement, and motivational effectiveness further.

V. Conclusion

There is an apparent need for concepts to be converted into games to increase engagement and motivation. Retention and interest in the CS field can be increased by changing the image of CS from difficult and tedious to interactive and fun. There is no reason learning cannot be fun; the CS field especially has the technology to create all kinds of games and incorporate learning into them. In the future, students will be able to go to class and play games that teach them difficult concepts in fun and interactive ways, satiating their need for hands-on engagement in lessons. Students will be provided with a stress free, self-paced way to learn and will keep up their motivation in classes that are no longer too demanding or boring but rather are as enjoyable as the games they play outside of class.

References

[1] T. Beaubouef and M. John, "Why the high attrition rate for Computer Science students: some thoughts and observations," in ACM SIGCSE Bulletin, vol. 37, New York: ACM, 2005, pp. 103-106.

[2] C. Watson and F. W. B. Li, "Failure rates in introductory programming revisited," in Proceedings of the 2014 conference on Innovation technology in Computer Science education, New York: Association for Computing Machinery, 2014, pp. 39-44.

[3] X. Chen, "STEM attrition: college students' paths into and out of STEM fields," National Center for Education Statistics, Institute of Education Services, U. S. Department of Education, Washington, D. C., 2003.

[4] M. Jong, J. Shang, F. Lee and J. Lee, "Harnessing Computer Games in Education", International Journal of Distance Education Technologies, vol. 6, no. 1, pp. 1-9, 2008.

[5] M. Papastergiou, "Digital Game-Based Learning in high school Computer Science education: Impact on educational effectiveness and student motivation", Computers & Education, vol. 52, pp. 1-12, 2009.

[6] T. W. Malone, What Makes Things Fun to Learn? A Study of Intrinsically Motivating Computer Games (Cognitive and Instructional Sciences Series 7), Palo Alto: Xerox, 1980.