Studying the Impact of Gamification on Motivation in Remote Programming Education

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Abstract: With the increasing hybrid blend of face-to-face and remote study in the higher education, finding strategies to keep students motivated when working from home is pertinent. This paper describes gamification in online learning environments, from the viewpoint of individuals undertaking programming education. In this empirical study, both qualitative and quantitative research methods are employed to investigate the hypothesis that gamified motivational methods would increase students' motivation when learning programming remotely at a higher education level. This hypothesis was formed following an observed motivational drop regarding studies during the COVID-19 pandemic, combined with an observed consistency of engagement in the video games industry. An initial questionnaire with 90 respondents from multiple backgrounds explores game design elements as a concept and investigates the current or historical motivation of individuals working from home. Conclusions were drawn that participants' motivation working from home were mixed, and that formative feedback and game design elements were perceived to be motivating to a learner, and these results were used to inform the design of two learner-centred virtual learning environments. These virtual learning environments were designed to facilitate programming tasks online in two settings: one being a traditional academic setting with staged communication with a virtual tutor, and the second being a gamified setting, completing missions and gaining rewards in line with a storyline. These programming environments were then used in a practical, yet remote, experiment with 25 participants who were current university students, graduates or recent education-leavers. These experiments gained statistically significant results, showing that the gamified system and specific gamified elements were found to be considerably motivating to the learner. This work therefore makes the following contribution: that gamified elements such as badges, rewards and missions do increase students' motivation when engaging with virtual learning environments for programming. This work is relevant for programming and Computing educators, digital education researchers and gamification researchers.

Keywords: Gamification, Programming, Digital Education, Higher Education, Virtual Learning Environment, Education.

1. Introduction

With the increasingly digital world in which we reside, Computer Science has had, and is having a sustained impact on the world. A High percentage of the population has a personal computer in their pocket, in the form of a mobile telephone. The world's reliance on technology has increased further due to the change to social contact methods as a result of the COVID-19 pandemic. It is therefore clear that as the use of computers increases, the need for programmers will increase. However, that need is not being met (Mims, 2014). There is a substantial divide between the supply and demand of programmers. As motivation correlates with knowledge retention (Naidr *et al.*, 2004), it is hypothesised that an increase in motivation would increase the knowledge retained and hereby the level of proficiency in programming. This paper will investigate online learning and the integration of gamification with learning solutions to address this; with the intention of uncovering methods and testing them to ascertain how students' motivation could be improved when learning programming in a higher education setting. This will then outline recommendations with which educators can design future online programming environments, to maintain high levels of student motivation with future remote or hybrid learning, to increase students' motivation when learning programming; with an aim to address the gaps in programming knowledge amongst graduates.

2. Background

With the significantly higher drop-out rate of Computer Science students in comparison to other subjects at a higher-education level (10.7% vs 5.7%-7.9%) (Lee, 2017; Mantle, 2019; The Telegraph, 2014) and those that do graduate can do so without adequate programming knowledge for the workplace (Mims, 2014). This, in combination with the current online learning culture, is the rationale behind this project. The first element to investigate is that of programming skills and student retention on a programming course. The significantly high drop-out rates could indicate a low motivation in the course overall; which would impact students' motivations in home-learning. Then, it is key to establish methods via which students can complete their work at home, with the same success as found in Chinese educational facilities (Huang *et al.*, 2020). As the increased adoption of Virtual Learning Environments (VLEs) in the Higher Education landscape to access learning materials and online learning sessions has resulted in students undertaking more work at home.

Another hypothesis is that a lack of formative feedback reduces the motivation students have for learning programming. With the large intakes of students onto Computer Science courses due to increased popularity (Rasheed, 2020), the courses often do not have the time to have copious amounts of classes where the students are physically present. This has led to the adoption of Electronic Learning Portals (ELP) such as Blackboard Learn (Blackboard Inc., 2020). These systems allow students to access their learning materials at home and are used to facilitate online learning sessions (such as Blackboard Collaborate). Although these are vitally important to the university learning environment as, with the number of students who have other time commitments rising (Lowe and Gayle, 2007; Richardson, Evans and Gbadamosi, 2014); doing work at home can reduce the students' motivations to do coursework.

As this study focusses on the motivations of students when working from home, it is important to consider the successes of remote learning environments. Two examples of popular online learning resources are Codecademy. (Codecademy, 2020) and Khan Academy (Khan Academy, 2020). Where Khan Academy offers online resources to assist in teaching many academic subjects, Codecademy focusses on programming specifically and offers programming courses of multiple languages. The learning experience when using these two systems differs, with Khan Academy offering what may feel to be a one to one learning experience (Thompson, 2011) and Codecademy offers a fun and engaging learning experience with gamified elements such as rewards, badges and achievement recognition (Pritchard and Vasiga, 2013).

Studies have evaluated the successes of Codecademy and Khan Academy, highlighting the key features that these systems have. When comparing cost vs reward, these systems are frontrunners. Mainly because they are both free and you can become skilled in a matter of weeks or months (Mims, 2014). Secondly, for Codecademy specifically, the gamified elements have a massive motivational boost.

In addition to the more in-depth contextual understanding gamification can give to the student (Quinn, 2014), users of Codecademy pride the system on its continued engagement. Gamification, is described by Mårell-Olsson as a teaching approach aiming to 'increase student motivation and engagement' (Mårell-Olsson, 2021) and users have identified that they found unlocking avatars to be extremely motivating, with users noting that although the gamified elements weren't why they were drawn to the system, it is why they kept using it (van Roy, Deterding and Zaman, 2018). Other researchers describe the gamified elements as being addictive, due to their fun and engaging nature (Pritchard and Vasiga, 2013). Some highlight that these systems (unlike university courses) embrace the enrolment of women to the system and retain their interest levels whilst studying the course (Perkel, 2015). These elements have then been used in further experiments seen in literature. Iosup and Epema's study, brought the gamification element away from online and remote study and into the classroom, giving us a valuable insight into how gamification could be integrated into a physical learning environment (Iosup and Epema, 2014).

The main aspect to draw from Iosup and Epema's study, is the exceedingly positive impact that gamification had on the students. Although top students choose to learn for learning's sake, gamification elements caused an increase in attainment levels, student participation and student satisfaction across the board (Iosup and Epema, 2014). These were detailed in the study by means of testimonials from the students. The study also highlighted the bias that students can feel when given points by the teacher (Iosup and Epema, 2014), which became an issue when employing this strategy the a physical learning environment scope of their study. What Iosup and Epema show is, however, that gamification does have a place in the higher education system, with the limitation that their study was undertaken in a physical classroom environment.

Further literature has begun to delve into the complex topic that is gamification in learning. However, it does not investigate gamification in practice, moreover, reviewing literature regarding gamification concepts and their *possible* uses in a learning environment. The most common including Badges, Avatars, Points Levels (Dicheva *et al.*, 2015).

When evaluating the points above, it is clear that there are issues in the current Computer Science Higher Education. This study will investigate in the coming sections, what impact gamification could have on learning

Programming. It will take note from the literature reviewed above on shortcomings of gamified and academic learning methods and will try to emphasise those that have succeeded in experimentation and in business. This study will try and fill the gap between the cited literature. To investigate the impact of gamification elements in a VLE on student motivation when learning programming with both an explanatory questionnaire, and a practical experiment. They will provide data to be evaluated in later sections to investigate the hypothesis that gamification will assist students with their motivation to learn programming.

3. Experiment methodology

Two elements were incorporated into the experimental methodology of this study. The former was an exploratory questionnaire, and the latter was an experiment testing two systems. One following the traditional academic settings, the other including a range of gamified elements. Both systems were guided by the literature review above and the gamified system would be designed using the data obtained from the exploratory questionnaire.

3.1 Exploratory Questionnaire Design

The questionnaire, delivered through Google Forms, was designed with the following goals:

- To obtain background knowledge to see whether participants were more attracted to the idea of academic learning environments or gamified learning environments.
- To see which elements of each learning style would be considered useful to take forward into the experimental system.
- To see what access to technology different participants, have at this current time, to allow for the experimental system to be designed with a wide range of technologies in mind.
- To obtain data on participants' feelings regarding working from home. As a large part of this study revolves around the point that the work undertaken is work on an online learning environment, obtaining data pertaining to overall motivation when working from home is therefore important.

To allow for remote participation in this questionnaire, the questionnaire was posted onto social media platforms. This allowed for a large range of data to be gained, from varying age groups. It was also shared with university-based society and groups to obtain the views of university-age students. Questions pertaining to missions, ranking, achievements and personalised competition were in the style of a Likert scale, from 0-10.

3.2 Exploratory Questionnaire Results

With 90 responses, the questionnaire gained results from ages 18-40. It clearly showed a generational difference between those that did or did not find gamification motivating. Respondents who were over 30 years of age were more motivated to improve their own rank as a reward for their own work whereas under 30s were more motivated by the instant gratification provided by receiving achievements and rewards for their work. Respondents overall were motivated when achieving grades in their prior classroom-based education and as documented extensively in literature, formative feedback remained a frontrunner in strategies that had previously motivated respondents.

When exploring the data pertaining to working remotely, there were mixed reactions when asked about their motivation when working from home. Additionally, in over 25% of cases, individuals working from home had to obtain new technologies to allow them to do so, however almost all participants owned a smartphone, with most also owning a laptop or tablet.

3.3 Experimental System Design

Following the exploratory questionnaire, two systems were designed with the purpose of allowing the participants to compare one to another. The first included many gamified elements with missions, goals and rewards alongside a storyline to provide a game-like experience. The second system was designed to provide a more academic experience, using regular, simulated formative feedback and a clear indication of the student's grade as opposed to points and a score. To prevent experimental bias, the system delivery was designed to be randomised. Screenshots of both systems can be seen in figure 1.

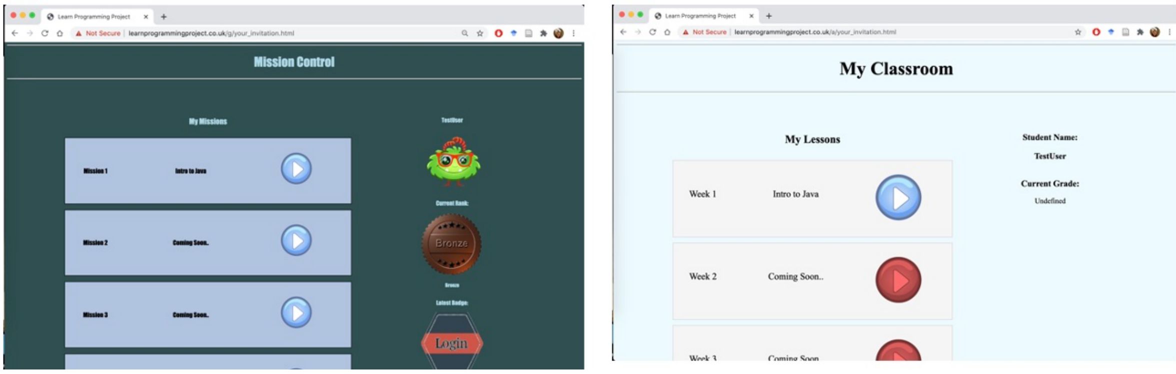

Figure 1: (Left) A screenshot of the gamified system's homepage. (Right) A screenshot of the academic system.

The gamified elements of missions, a storyline, rewards and individual ranking were established from the data evaluated in section 3.2, in combination with the literature evaluated in section 2. The academic environment was built with regular formative feedback and academic grading at its core. These elements are ingrained throughout both systems. Due to the number of questionnaire participants who had to invest in new technologies whilst owning a mobile phone, this experimental system was also designed to run on a mobile, allowing more participants to access the system with ease.

This system was designed to address a short programming curriculum plan using Java, as Java was the introductory programming language at the university at the host institution. Tasks were incorporated in the system, designed as mini-assessments in context, the importance of which can be seen in Yadev's works (Yadav *et al.*, 2016). The tasks that the participants were offered can be seen in figure 2. Tasks A and B were compulsory and tasks C and D were optional. This is with the intention of measuring participants' engagement as the number of completed tasks would be assessed as part of the experiment. The system would mark the students' work instantly, providing the instant formative feedback or reward to allow the participant to experience all elements of the system during the experiment.

Task No.	Gamified task	Academic task	Learning Aim
A	Recruit Allies by writing the codeword: SQUIRREL to the console	Write Hello World to the console	To understand that System.out.print() outputs to the console.
B	Complete a function that can be used to convey the codeword.	Complete a function that outputs to the console.	To understand how functions work and the use of variables, and the view of a class structure.
C	Complete a function to get the codeword.	Complete a function that gets a variable's value.	To understand the use of get functions within a class.
D	Complete a function to set the codeword.	Complete a function to set a variable's value.	To understand the use of set functions within a class.

Figure 2: A table containing the tasks that participants would be able to complete.

In addition to the number of tasks completed, the time the user spent on each system was measured, again to determine engagement. Furthermore, post-task questions were posed to the participants use of each system. These questions explored the following areas:

Background knowledge: Similar to the exploratory questionnaire, the background knowledge section covers areas such as previously obtained qualifications, previous programming knowledge and video game knowledge.

Task questions: These questions depend on each learning environment. For the gamified learning environment, the questions explore the motivational value of the badges, rewards and ranking system. For the academic learning environment, the questions explore the motivational value of the simulated tutor feedback and grade attainment. In both sets of questions, the progress the participant made through the tasks is checked, as this could be indicative to the engagement the system provides; and the questions ask users' views on each individual learning environment.

Comparison questions: These questions explore the users' opinions on the two different learning environments, finding out which elements they find more motivating. It will also explore the ease with which the users are able to interact with the system. This section will also investigate the participants' motivation when learning previously in both classroom environments and home learning environments as this was an area of further exploration noted in the first questionnaire.

3.4 Experimental System Results

The experiment described above was completed by 25 participants across four different demographics based upon highest qualification level as follows: GCSE (2), A-Level (8), Bachelor's Degree (9), Master's Degree (6). Participants were asked whether they were studying/had studied/intended to study Computer Science, of which 21 of the participants shared. There were no external incentives given to take part as to not influence the outcome. The experiment was undertaken with students who were either recent graduates or current university students, suggesting that findings closely matched the opinions of current students. Therefore, this group can be seen as representative of individuals who would use this system in the future.

The results show that the gamified learning environment was preferred in comparison to the academic learning environment with 17 participants selecting the gamified version, 4 showing equal preference and 4 preferring the academic learning environment.

When investigating the qualitative feedback on individual elements of each system (ranking system, badges and overall motivation for the gamified system; tutor feedback, grade attainment and undertaking tasks for the academic system), the three gamified elements were more motivating to the participants than the academic elements, with badges and rewards having the most motivation. This was determined with scores that users gave regarding how motivating they found the system, conveyed on a Lycett scale and can be seen in Figure 3.

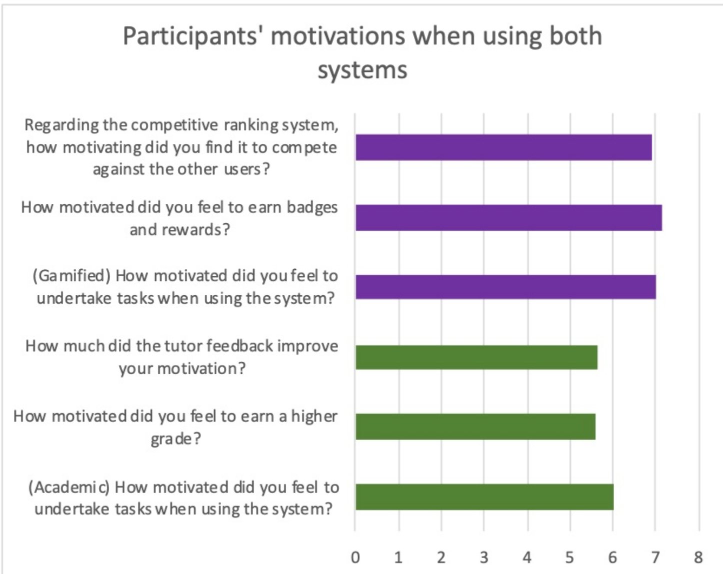

Figure 3: A bar chart showing participants' motivation in relation to elements of each of system.

A two-way ANOVA was run on the 25 participants to examine the effects of the gamified and academic environments on participants' motivation when using the completing the tasks. There was a significant interaction between the effects of incorporating gamified and academic environments on motivation (ρ = .015). This was then followed up with two a paired T-tests with a 99% confidence interval. The first explored the overall motivation when each system, obtaining a result of ρ = .006 and the second compared the means of all three questions (two for features and one for overall motivation seen in Figure 3) obtaining a result of ρ = .003. This shows that the null hypothesis can be rejected and that the type of learning environment and features incorporated into these environments make a clear difference to students' motivation as reflected in Figure 4.

Qualification Level	Gamification Motivation Mean	Academic Motivation Mean	Preference
Masters	6.66	6	Equal
Bachelors	7.33	6.22	Gamified
A-Levels/Equivalent	6.75	5.5	Gamified
GCSE/Equivalent	7.5	7	Gamified

Figure 4: Table showing the correlation between different qualifications and their respective motivation and preference.

When investigating the amount of time spent in each system, participants spent more time on the gamified system again reflecting on its engagement. However, one element that was not as popular in the gamified system, was the competitive ranking system. There were mixed scores regarding motivation in a competitive ranking scenario, and it obtained a mean motivation score of 6.92. P8's feedback detailed that they felt "*that the leaderboard should be an opt-into scenario as some who may use the system may have anxiety about their performance being compared*". When comparing this against the wider mental health profile of the UK, making design decisions that have positive mental health implications should be prioritized.

4. Discussion

The main finding to discuss as a result of this study is the clear motivational impact that the gamified elements had on engagement during introductory programming tasks. This can be shown by the evidence gained in both the exploratory questionnaire and the experiment. This work builds on the work of Domínguez et al. (Domínguez *et al.*, 2013) and does show the benefit of gamification and reinforces the findings of Iosup and Epema's study (Iosup and Epema, 2014) outside of the physical classroom.

One element which is present in the gamified system, was the use of competitive ranking against peers during learning. This received mixed feedback in both the questionnaire and in the experiment and suggests future implementation of this element should be undertaken with caution and an opt-in approach could be used. It is clear from this study as it was the participants' most important measure of learning as shown in the experimental questionnaire results.

4.1 Limitations

The conclusions drawn from this study have to be considered with the following limitations. Due to when the project was undertaken, the individuals (most of whom had previous programming knowledge) there was no additional learning materials. This system is designed to be used alongside a course, so although feedback shows that more in-depth descriptions are needed, in practice, students would have access to slides and other resources provided by the tutor. This is the same case for tutor feedback in the system itself. Due to the nature of the experiment conditions, the feedback given was standard, and did not change based upon the student. This would not give a full impression of built-in tutor feedback to the participant and should be included in further study.

5. Conclusions

The difficulties in student retention and engagement in Computer Science higher education have been investigated for several years. As yet no 'magic bullet' has been discovered. This study focused on gamification and the impact of integrating gamified elements into programming environments for students' motivation when learning programming. The results show that this is the case, and that the integration of gamified elements do have a positive impact on students' motivation. Previous work was uncertain in this matter and our study seems to reinforce that given many computer science students play digital games, it seems natural that they respond to familiar motivating factors in the learning place.

In a world which seems to have been accelerated by the pandemic towards more in-place or in-home learning. We need to acknowledge that students' time for learning is in competition with more distracting forces in the home, forces which are designed to be far more compelling. Remote education offers many distinct advantages including flexibility and scalability. Education about computer science must adapt to students' social and cultural aspects and their learning contexts. This is necessary for the ongoing success of this discipline.

6. Future Work

To provide detailed feedback for the staff to go alongside environments such as this, future study could include investigating recording and visualisation methods to assist tutors in observing where students are struggling, how often students had to repeat a task and where their efforts can be focussed in the classroom.

As part of this future study, involving existing programming tutors in the design of the system, producing it in a user-centred manner, would increase the usability of the system and would ensure that the system met the needs of the tutor. Additional investigations include assessing the long-term benefits to student attainment with use of a system such as this and would the increased motivation cause higher grades over time?

Although gamification has been shown to not have cognitive impacts on students' work (Domínguez *et al.*, 2013) it has been shown to have impacts on the update and student retention of subjects that were previously struggling with attendance rates (Rohrbach, 2018). When considering research relating to this system specifically, reviewing the system further with students in a participatory design methodology to investigate additional elements that may benefit the system could be a further area of future study.

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