

# WHO WANTS TO BE A PYTHONISTA? USING GAMIFICATION TO TEACH COMPUTER PROGRAMMING

P. Fotaris<sup>1</sup>, T. Mastoras<sup>2</sup>, R. Leinfellner<sup>3</sup>, Y. Rosunally<sup>4</sup>

<sup>1, 3</sup> *University of East London (UNITED KINGDOM)*

<sup>2</sup> *University of Macedonia (GREECE)*

<sup>4</sup> *University of West London (UNITED KINGDOM)*

## Abstract

As video games are continuously growing in popularity and number of users, the academic community has shown an increasing interest in their potential as innovative teaching tools. Typical games contain tasks that players must complete repetitively in order to advance to later levels, yet somehow they manage to keep them constantly motivated. Enjoyable engagement is achieved by using a number of interlocking techniques; these effectively hide repetitive or complex tasks by presenting them as a series of smaller challenges embedded in a reward system. Learning occurs through the use of a seamless combination of motor and high level problem solving skills with rapid feedback. Individual problem resolution cycles range from split second decisions to hours, if not days. Matching reward systems are used to maintain player interest throughout these cycles by ensuring that there is always a new reward just out of reach, yet still obtainable with relatively minor additional effort. As a result, players are propelled through the entire experience at a pace matched to their abilities. Based on these well-tested methods from the gaming industry, educators are trying to instil the motivational power of video games to the learning process by following a practice known as “gamification”. When used in education, gamification incorporates gaming elements to non-game processes in order to aid learning and information retention. However, its application in the classroom has been challenging, since most attempts have generally been limited to implementing points, achievement badges and leader boards to existing course material. These rewards can potentially undermine the intrinsic sense of satisfaction that engaging in creative and productive work can generate. However, when used well, game elements can reinforce intrinsic satisfaction and rewards instead of replacing them. This quasi-experimental study employed a classroom version of the TV game show “Who Wants To Be A Millionaire®” to improve the delivery of an undergraduate programming course. To assess how gamification impacted the learning experience, empirical data on student satisfaction and performance from the gamified group were compared with a control group that followed traditional didactic methods. Despite the fact that the sample size was relatively small, the results were promising, showing significant increases in class attendance and final grades. Moreover, students participating in the gamified cohort considered their learning experience very engaging and motivating, thus encouraging the adoption of this technique in other courses.

Keywords: Gamification, Game-Based Learning, Assessment, Learning and Teaching, Technology Enhanced Learning.

## 1 INTRODUCTION

With the average young person recording 10,000 hours of gaming by the age of 21 [1], it is apparent that today’s students invest a remarkable amount of their time engaged in games. Since gamers often exhibit behaviours that ideally would be regularly demonstrated in school, such as persistence, experimentation, problem solving, attention to detail, and risk taking [2], the academic community is looking for ways to harness elements of gaming for educational purposes. Findings of independent studies performed in secondary and higher education settings showed that students who were subjects to learning with video games reported significant improvements in subject understanding, diligence, and motivation [3 – 8]. Research has also indicated that successful video games are natural learning machines [9], as they help stimulate the production of dopamine, a chemical that provokes learning by reinforcing neuronal connections and communications [10]. Additionally, they are designed to deliver concrete challenges which are tailored to the players’ skill level [11] in order to prevent

them from becoming frustrated or bored, thus allowing them to experience “flow”, i.e., a user’s state of “optimal experience” [3, 12, 13].

Gamers share common factors such as blissful productivity, urgent optimism, social fabric, and epic meaning, which transform them into super empowered hopeful individuals [14]. Nevertheless, in real life people are more likely to feel depressed, frustrated, cynical or overwhelmed when confronted with obstacles; they also prefer instant gratification to stay engaged and motivated. A promising way to address these negative feelings which are not present in a gaming environment, and at the same time to support student engagement, make learning more effective, and increase social interaction, is to adopt the concept of “gamification” in education, i.e., the use of game-based mechanics, aesthetics and game-thinking to engage people, motivate action, promote learning, and solve problems [15]. Borrowing aspects from several motivational models (e.g., ARCS Model, Malone’s Theory of Intrinsically Motivating Instruction, Lepper’s Instructional Design Principles for Intrinsic Motivation, The Taxonomy of Intrinsic Motivation, Operant Conditioning, Self-Determination Theory, Distributed Practice, Scaffolding, Episodic Memory, Cognitive Apprenticeship, Social Learning Theory, Flow) [15], a gamified learning experience can re-captivate students and provide a beneficial break without producing any detrimental effects, thus offering a whole new set of opportunities to make students more involved, engaged, and motivated. By introducing game mechanics into an unpopular activity such as assessment to make it more fun and rewarding, students would possibly want to participate in this task proactively and continuously. The present paper explores this notion by studying the design and consequences of applying gamification in a real educational setting.

## 2 BACKGROUND

The idea of using gamification for learning is not entirely new. In the 1980s Malone [16] did research on what makes video games attractive to players and how these aspects can be applied to education as a means to promote student engagement and motivation. Carroll [17] analysed the design of the seminal text adventure “Adventure”, which in turn led him to propose redressing routine work activities in varying “metaphoric cover stories” so as to turn them into something more intrinsically interesting, and to “urge for a research program on fun and its relation to ease of use” [18, 19]. The last decade saw the emergence of “funology”, the science of enjoyable technology [20], while terms such as “ludic engagement”, “ludic design” and “ludic activities” were introduced in order to describe activities motivated by curiosity, exploration, and reflection” [21]. Related research focused on using game interfaces and controllers in other contexts [22], creating “games with a purpose” in which game play is employed to solve human information tasks (e.g., tagging images) [23], and exploring “playfulness” as a desirable user experience or mode of interaction.

More recently, major corporations and organisations including Adobe (LevelUp, Jigsaw) [24], Microsoft (Ribbon Hero), IBM (SimArchitect) [25], and Autodesk (GamiCAD) [26] consulted with game experts to develop gamified systems that focus on keeping users engaged while learning new software and techniques. In the context of higher and secondary education, gamification can be applied at vastly different scales to any discipline. At one end is gamification at the micro-scale: individual teachers who gamify their own class structures [6] such as Lee Sheldon [27], a professor at Rensselaer Polytechnic Institute who turned a conventional learning experience into a game without resorting to technology by discarding traditional grading and replacing it with earning “experience points”, while also converting homework assignments into quests [28]. At the other end of the scale, a charter school in New York City called Quest to Learn uses game design as its organizing framework for teaching and learning. Teachers collaborate with game designers to develop playful curricula and base the entire school day around game elements [29].

Learning computer programming typically requires the student to be able to solve abstract logic puzzles by using a programming language’s specific syntax and library functions. In general, programming on modern systems would take place in an Integrated Development Environment (IDE), which would offer limited feedback. The computer code would compile if the syntax is correct, and then, depending on the student’s design of the abstracted logic, the program would either function as intended or fail. Programmers learn the syntax and optimal ways of problem abstraction by repetition and by drawing on their experience with related prior work. Code would later be optimised to operate faster or use fewer resources. This

iterative spiral is not unlike what is experienced by video game players; however, for them the forced repetition is masked and even made enjoyable through the use of a number of gamification techniques.

Given that video games are themselves computer programs, it is not surprising that there has been an increasing number of attempts to exploit the enjoyment of games-related techniques to facilitate the learning of programming. Institutions are experimenting with the use of discretionary online resources (e.g., Khan Academy, Codecademy, CodeHS etc.), which incorporate game mechanics such as structured mastery learning, concrete goals, scaffolded materials, badges, and points to make learning more fun. However, even these resources occasionally struggle to keep learners engaged [30], with few of them involving explicit evaluations of learning, thus making it unclear how much learners actually learn or retain. As these resources become more popular, there will be a need to identify how to increase their effectiveness. A potential way to address this issue is to use assessments [31], which can measure learners' progress and knowledge, as well as improve students' learning itself by helping them practice course material and by clearing up misconceptions. However, not only is there lack of research about how including assessments might affect learners' use of discretionary learning resources [32], but there is a fear that assessments could actually harm engagement, even if they improve learning. For example, students can experience test anxiety, especially if they get the wrong answer or if feedback is lacking, which in return can negatively affect their engagement. Including assessments in gamified resources may prove to be even more harmful, as they could interfere with a player's enjoyment of the game and lead him/her to disengage or even quit the activity [33].

### 3 METHODOLOGY

The aim of this study was to evaluate how the application of gamification to assessment can affect the learning experience as well as students' motivation, recall ability, and performance in a computer-programming course. For that purpose, a controlled experiment measuring student satisfaction and performance was conducted on "Fundamentals of Software Development", an annual semester-long 20-credit module, which introduced students to the popular programming language Python. From the 77 students who enrolled to this module, 60 attended classes and were randomly divided into 4 groups of 15 students each, with groups A, B, and C being the control groups, and D the experimental.

The module's evaluation consisted of six theoretical quizzes (20% of total grade), and two mandatory assessments: a final exam (40%) and a programming project (40%). The syllabus included 12 regular one-hour lectures, which covered fundamental Python concepts (loops, functions, classes, conditionals etc.), 12 two-hour lab classes that required students to complete a series of programming tasks, and 12 one-hour revision seminars. The latter were delivered to the control groups in typical didactic fashion, which was a combination of Q+A and lectures. Contrastingly, the experimental group revised the same topics by playing an open-source OpenGL implementation of the popular TV game show "Who Wants To Be A Millionaire®"<sup>1</sup> that was modified, updated with Python-related multiple-choice questions, and renamed "Who Wants To Be A Pythonista?". Creating new set of questions on a weekly basis was a straightforward process, requiring lecturers to edit a simple text file using any text editor and replace old questions with new ones.

The experimental group comprised of 15 students (13 male, 2 female) between the ages of 19 and 22. 6 of them were regular gamers, 7 played games occasionally, and only the 2 female students reported not playing video games at all. During the first seminar, the group was randomly split into 3 teams of 5 contestants that remained the same for the duration of module, and then the gaming activity started as outlined below.

The team of contestants sat in front of the class facing the screen with their backs to their peers, in order to avoid any unsolicited assistance. They were then asked 15 increasingly difficult questions on the programming concept of the week. These were multiple-choice with 4 possible answers (Fig.1) and followed the mastery learning paradigm [34], i.e., each of the

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<sup>1</sup> The original "Who Wants To Be A Millionaire®" open-source game can be downloaded from <http://sourceforge.net/projects/wwtbam/>

game's question was designed to be passable only if the learners had grasped a particular Python concept.

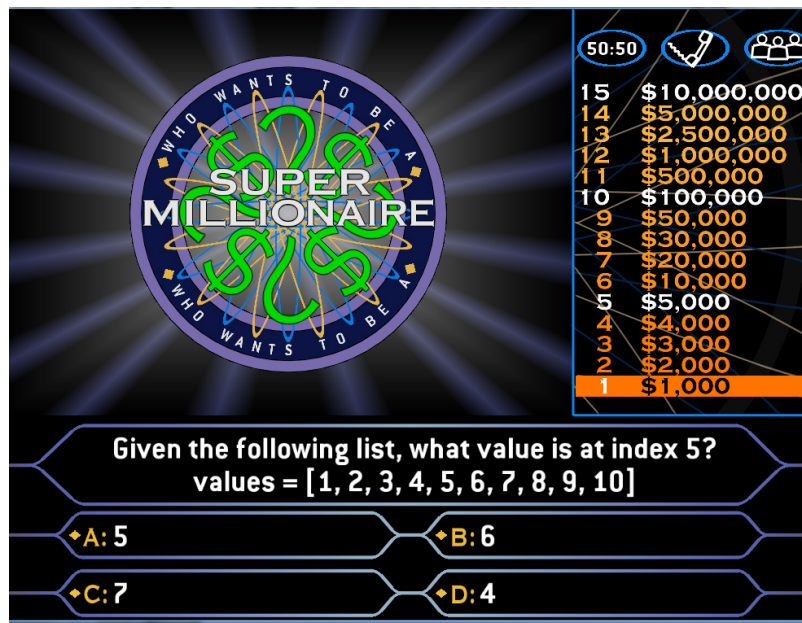


Figure 1: In-game screenshot

Despite not having an official time limit to answer a question, lecturers ensured that the duration of every game would not exceed 20 minutes so that all teams could play once during the seminar. After being presented with a question, the team could respond in one of the following ways:

- Collaborate, reach a consensus, and give a single response. If it were correct, the team would earn points and continue to play. On the other hand, if the answer were wrong, the team would forfeit their right to continue playing and would lose all points earned up until then, with the exception of the 5,000 and 100,000 prizes, which were guaranteed: if a team got a question wrong above these levels, then the prize dropped to the previous guaranteed prize.
- Refuse to answer the question, quit the game, and retain all points earned up to that point.
- Use one of three available lifelines (Ask A Classmate, Poll The Class, 50/50).

Once a question was answered, all possible answers were reviewed and discussed in the classroom before the game proceeded, thus leading to better understanding of the material and reducing the likelihood of students encountering difficulties if a similar question appeared in one of the theoretical quizzes. Finally, the game came to an end when contestants gave a wrong answer, decided not to answer a question, or answered all 15 questions correctly.

At the end of every seminar, faculty members wrote down each team's score and then updated accordingly a leader board webpage, which was available at the institutional Virtual Learning Environment (Blackboard). The game scores gave direct feedback on the students' success and also served as instant gratification, which has been found to be a successful student motivator [3, 35]. Once all seminars were completed, the team with the highest total score was awarded the title "Pythonista of the year" and received complimentary custom-made T-shirts.

Finally, in order to promote self-assessment and to allow students from the control groups to experience this alternative form of learning, the game along with its weekly set of questions became available for downloading after every seminar. This action gave students the opportunity to replay the game on their personal devices at a later time.

## 4 RESULTS

In an effort to assess the impact of the gamified assessment to the learning experience, both formative and summative monitoring of student engagement were performed using the following methods [36]:

- Instructor observation of student behaviour;
- Collection of administrative data (student attendance, number of “Who Wants To Be A Pythonista?” game downloads, academic performance)
- Students’ self-report of activity through interviews, focus groups and a final survey.

Within the seminar sessions, specific dimensions of student engagement (i.e., interest, attitude, persistence) were monitored as a function of students’ behaviour. These classroom observations returned the following characteristics, which are considered immediate indicators of engagement [36, 37]:

- Students questioned, explored, discussed and brainstormed the question topics with their peers and faculty;
- They demonstrated problem solving and decision-making skills in questioning and responding;
- They actively participated in the game;
- They responded to faculty prompts;
- They actively listened, focused attention and made eye contact;
- They demonstrated body language that was open and relaxed, with appropriate smiles or laughter.

In order to gauge student persistence, interest, and effort in the gamified seminars, attendance data were examined and compared. Average attendance by seminar for control groups A, B, C, and for the experimental group D was 67.2%, 71.1%, 77.2%, and 91.1 %, respectively, which suggests that gamification motivated students from group D to attend classes more often than their peers from the other groups. The combined downloads of “Who Wants To Be A Pythonista?” and the weekly set of questions were 162 for the whole semester, with only 29% of them coming from groups A, B, and C combined. The low value seen in the control groups may be related to their lack of active participation in the classroom activity. Since they did not have the benefit of experiencing the dynamics of the quiz and follow-up peer review during class, it is possible that a significant intrinsic benefit of the activity was lost. Without active participation the download may simply have been regarded as another traditional, supplemental formative assessment. As for academic performance, the experimental group had the best overall grades compared to the control groups, with all group D students passing the module and achieving an average final grade of 59.4% (Table 1). Although this find may suggest that the gamified seminars acted as a catalyst for getting better results, the relatively low number of participants limits the generalizability of the study, thus requiring additional studies to identify possibly correlations between gamification and academic performance.

Table 1: Academic performance of control groups A, B, C, and experimental group D

Group Name	Average Grade	Median	Std. Dev.	Min	Max
Group A	38.93%	40%	8.58	24%	52%
Group B	41.73%	40%	10.40	22%	55%
Group C	44.33%	42%	8.01	30%	60%
Group D	59.40%	61%	9.80	44%	73%

At the end of the semester, faculty conducted focus groups and interviews with the experimental group, which focused on collaborative learning, cognitive development, and

personal skills development. As demonstrated by the sample of responses below, the overall reaction by the interviewees and the focus groups was very positive:

- “The game helped me work effectively with other individuals.”
- “Seeing my team on top of the leader board made me proud.”
- “I looked forward to attending every seminar.”
- “It makes you think and gets you excited about the material.”
- “I learnt to listen and consider my classmates’ opinions even if I disagreed.”
- “I enjoyed the adrenaline rush and the competition.”
- “The discussions following every question helped me understand why I was wrong.”
- “Playing the game at home helped me prepare for the theoretical quizzes.”

The analysis of the final survey results provided another indicator of the students’ psychosocial engagement with the gamified assessment. The experimental group was asked to complete a 15-question online survey (Q1-Q15) with five possible answers measured on a Likert scale of 1 (Strongly Disagree) to 5 (Strongly Agree) (Fig. 2).

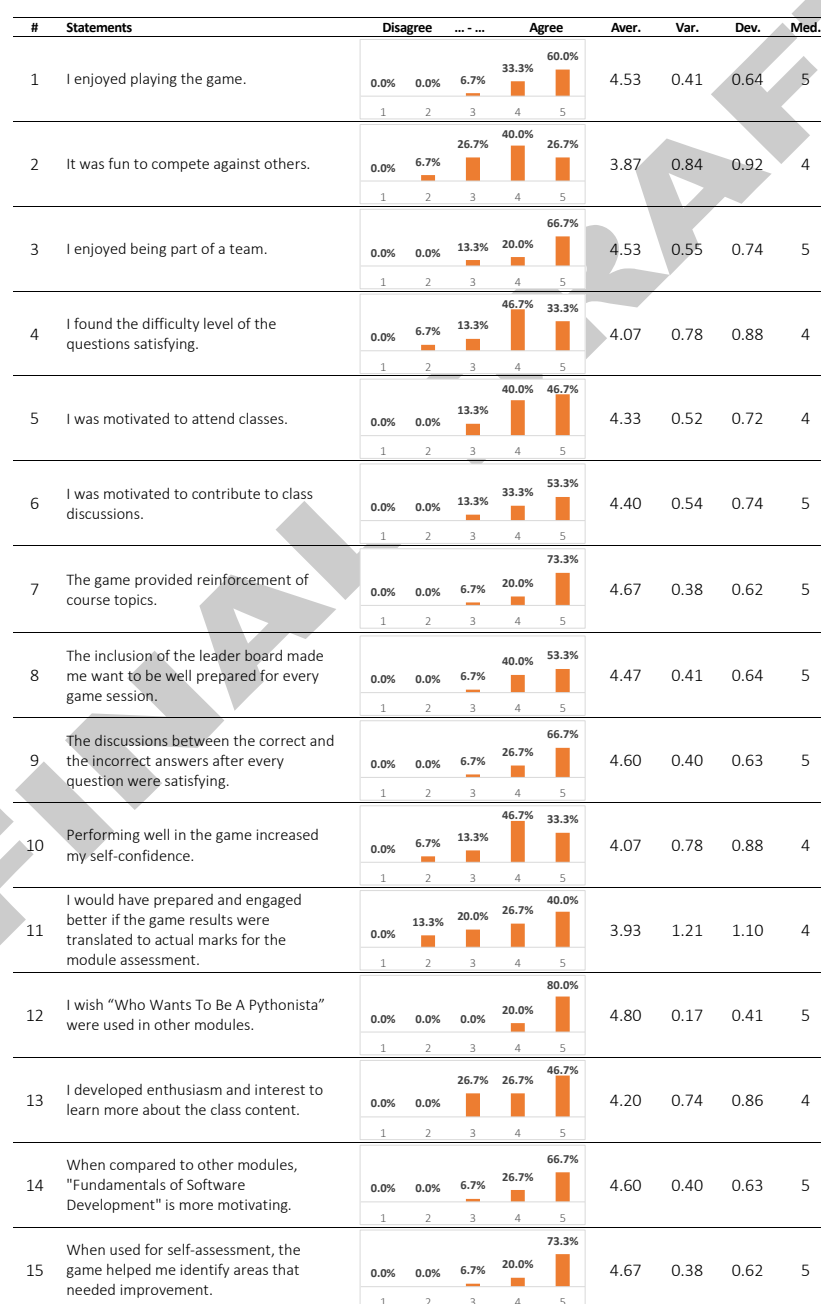


Figure 2: Survey results

Considering the data modally suggests that teamwork (Q3) and topic reinforcement (Q7) had a significant positive clustering, which is very encouraging as both are critical aspects of commercial programming. Furthermore, it is interesting to note that both are also intrinsic features of successful video games. This could be an early indication that the outcome of the experiment was indeed related to its use of gamified techniques.

However, the modal score for the leader board (Q8) is less conclusive, as this result is corroborated by a significant spread of responses to Q2 regarding the student's enjoyment of competition in this learning activity, which indicates only limited success. Responses to Q10 indicated a wide distribution; this could be due to the nature of the question focusing on success, when clearly not all would have succeeded on the leader board. It may have been better to invert it into a negative to get more meaningful results, which could have helped assess the impact of competition in a deeper way.

Even though the data is limited, some conclusions could be drawn, such as that competition is not an optimal motivator in this kind of activity. This might be a potentially significant outcome, as many standard gamification techniques have an almost exclusive reliance on competitive behaviour as a motivational tool.

In terms of integrating this technique into assessment, the response to Q11 seems to suggest that students were treating it as a game with no real world consequences, not unlike a real game. This could be an important result, since it suggests that they enjoyed the task simply for its intrinsic benefits rather than for the need to be able to be assessed on it. Combined with the clustering found for Q15 regarding students self-assessing their progress, this feels indicative of the behaviour, which is often attributed to a student who learns deeply [38].

## 5 CONCLUSIONS AND FUTURE WORK

The findings from this study suggest that including "Who Wants To Be A Pythonista?" as a form of gamified assessment in a computer-programming course can improve learners' engagement and successfully achieve the pedagogical goals outlined in the introduction section of this paper. By turning the seminar's didactic approach to a playful experience, students' attendance and final grades were increased. The study suggests that teamwork and an intrinsic enjoyment of the task could be more impactful than the competitive techniques often used as forms as motivation.

However, due to the small number of participants, further experiments with larger sample sizes must be conducted to get more conclusive results. The game also provided an instant application opportunity and allowed common misconceptions to be revealed and explored. Students were required to compare and discuss their answers with their teammates in order to come to a consensus, which in turn helped them exercise important skills for future jobs, such as problem solving, collaboration, and communication.

Although originally focused on programming modules, "Who Wants To Be A Pythonista?" allows for easy implementation in any course through the addition of discipline-specific questions to its question bank. Nevertheless, in its current state the game supports only Windows-based devices and the question length is limited to only two lines of text without any image support, thus making the authoring of new questions quite challenging. With these issues in mind, an enhanced web-version of the game is currently being developed, which will be platform independent and will support longer questions, images, leader boards, avatars, and analytics.

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