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Implementing gamification in a university-level UML modeling course: A case study

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Abstract

The paper analyses the effect of applying gamification in a course for undergraduate computer science students in the Faculty of Informatics at Kaunas University of Technology. The course teaches Unified Modelling Language (UML) and its application in the Unified Process for software development. In this paper, the gamified course metamodel is presented, and it specifies a level-based course structure as well as other gamification elements used in the course, such as points and other types of rewards (coins, items, and badges), the leaderboard, content locking and trading. The gamified course was implemented on Moodle platform, and the experiment was carried out during spring semester 2018. The analysis of students' grades confirms the hypothesis which states that students' grades can increase as a result of applying gamification to their learning process. The results of students' questionnaire (based on the Intrinsic Motivation Inventory scale) also confirm the hypothesis which states that gamification can improve students' motivation.

KEYWORDS

education, gamification, Moodle, UML, Unified Process

1 | INTRODUCTION

Increasing student motivation and engagement in the learning process requires a continuous educators' effort. Teaching students subjects or topics that encompass a large amount of learning material can be really challenging. That especially holds true when students find themselves burdened with too much information and thus lose their interest.

Gamification could be one of the means for making the learning process more attractive, motivating and engaging to students, thus improving the outcomes of their studies [7]. This paper analyses the effect of applying gamification in a course for undergraduate students in Faculty of Informatics at Kaunas University of Technology. The course teaches Unified Modelling Language (UML) [30] and its application in the process of software development. UML is only a language, so it does not define the guidelines for applying its diagrams during software development [31]. These guidelines should be defined in software development methodology, which utilizes UML for development of the process artifacts. Our gamified course teaches the Unified Process (UP) [13,26] development methodology. Unified Process is a framework rather than a process. It can be tailored to the needs of the organization and to the specifics of the software under development [1]. In the aforementioned gamified course, students are taught three disciplines of the Unified Process: Requirements, Design and Implementation. The other disciplines of the UP (i.e., Business Analysis, Testing, and Deployment) are out of scope of the analyzed course. The teaching process of the UML and UP delivers knowledge in two areas, namely, syntax of UML diagrams and their semantics. The diagram syntax part mostly focusses on

diagram notation, model elements and rules of their usage. Furthermore, the semantics part is focused on the appropriate application of certain diagrams in software development process for specific domains.

In this paper, the proposed structure for the gamification of the UML learning course is presented as a gamified course metamodel. This metamodel specifies the course structure and main gamification elements used in the course. The proposed metamodel is intended specifically for gamification of learning UML syntax and semantics, where the semantics part is based on Unified Process disciplines. The gamification elements that are used in the course are points and other types of rewards (i.e., coins, items, and badges), leaderboard, content locking and trading.

Our gamified course was implemented on Moodle platform [17]. For enabling the required gamification elements, two Moodle plugins were used, namely, Stash [11] and Level up! [15]. The plugins were configured according to the specifics of the UML learning course and modified to support the Lithuanian language, which is the working language of the course.

Two hypotheses were raised, stating that gamification increases students' motivation and can help to improve students' grades. The experiment of using the implemented gamified course in the learning process was carried out during spring semester 2018.

The rest of the paper is organized as follows. The second section analyses related work in the area of improving the UML teaching process and applying gamification in education. The third section describes the proposed gamified course metamodel and the implementation of the course in Moodle environment. In the fourth section, the experiment of applying the gamified course during the UML teaching process is presented and the experiment results are analyzed. The last section concludes the results and outlines the future work.

2 | RELATED WORK

UML is a popular and commonly used modeling notation for the specification of software development artifacts [31]. Even though UML is a complex language, it is used to a varying extent during software development [20]. Teaching UML modeling and its application during software development is a complicated task [16]. UML encompasses different types of diagrams, which are used for defining structural and behavioral aspects of the system under development. Furthermore, UML cannot be taught in isolation as it requires the methodology for defining the process of applying certain UML diagrams. There is no universal methodology for UML-based software development. Various methodologies, including UP [26], ICONIX [22], MERODE [29], and even specific Agile methodologies [23] utilize UML. Learning both UML and the development methodology requires a lot of effort from the students as the course covers a broad range of topics and is difficult to become skilled at.

There exist many solutions for improving the process of teaching UML modeling and its application in software engineering. Sedrakyan and Snoeck [27] presented a learning environment, which is used for teaching modeling based on the UML and MERODE [29] methodology. MERODE is a UML-based methodology, which emphasizes the consistency of the diagrams in the model. MERODE utilizes UML Class diagrams and State machines. Sedrakyan and Snoeck [27] developed a solution for the course "Architecture and Modeling of Management Information Systems." This solution uses a specific modeling tool, proposes diagram simulation possibilities and introduces a testing environment which provides extensive feedback.

It is difficult to automate the teaching process in order to ensure instant feedback for evaluating UML diagram contents. Py et al. [21] present a specific learning environment dedicated to teaching UML class diagrams. The tool provides feedback on the student-developed diagrams by comparing them to the teacher-developed examples. The principle of comparing diagrams is especially valuable for teaching the semantics of the UML diagrams. However, the proposed solution focuses only on structural (Class) diagrams and does not cover the behavioral UML diagrams.

The analyzed solutions improve the UML learning process by providing automated feedback, using modeling and simulation tools. The learning process can be further improved by introducing gamification, which can increase student engagement and motivation [9]. Motivation is difficult to evaluate, therefore, there are several theories that analyze human behavior and propose techniques for assessing motivation changes, for instance, Fogg's Behavior Model (FBM) [10], Self-determination theory (SDT) [24], or Flow theory [6]. Self-determination theory offers various scales for measuring the intrinsic motivation, which can be used to assess the behavior changes caused by applying gamification. Intrinsic motivation can be described as doing something for inherent satisfaction, fun or challenge rather than for external reward [25]. SDT analyses how to effectively increase intrinsic motivation, and can be used to determine different motivational aspects. It defines a number of tested measuring scales for different environments. One of these scales is the Intrinsic Motivation Inventory (IMI) scale [28], which was developed to assess participants' experience of completing specific tasks. It can measure such aspects as interest/enjoyment, perceived competence, effort, value/usefulness, felt pressure and tension, perceived choice, and can be later customized. In our work, the IMI scale is used to measure the changes of intrinsic motivation of the students enrolled in a gamified course.

There exist many methods for gamifying specific activities. Some simply introduce popular game elements [9], others base their elements on core drivers [4] or try to incorporate suitable motivation elements based on player types [19].

Cosentino et al. [5] proposed a model-based gamification methodology, which can be used not only for teaching modeling language (UML), but other languages too (e.g., SQL). These authors specify the gamification environment by using a Game metamodel. Although the teaching subject of Cosentino et al. [5] approach is similar to our gamified course, the authors concentrate on developing a game rather than a gamified course. The proposed evaluation of student answers is based on OCL and is suitable for teaching and evaluating the syntax of the UML diagrams, but does not cover the diagram semantics part and does not analyze the process of applying the UML diagrams in software development. Based on the definition of gamification by Deterding et al. [8], our proposed course leans closer to the gamification field, while Cosentino et al. [5] methodology is oriented towards the field of serious games.

The case study on gamification aimed at engaging computer science students in learning activities [12] attempted to assess the effectiveness of gamification. Gamification was applied to a C-programming language learning course, and a platform for engaging students in the process was developed. The authors tried to measure which of the learning activities were the most popular amongst the students. They also assessed student learning effectiveness and engagement as well as measured the effect of gamification for students' learning outcome. The authors collected and analyzed data from systems' logs and surveys, that were conducted before and after the course. The results showed a positive influence on students' learning results. The results also showed that most of the students continued work even after achieving maximum available points, which means that student engagement did increase. The biggest contributor to student motivation was the possibility to collect badges. Other gamification elements were also present, although not as popular amongst the students. These elements include a leaderboard, titles, a market and a blog for communication between the students.

The research on Gamification in Higher Education [14] aims to determine whether gamification can effectively improve student engagement in the learning process. The authors of [14] present a Computer Science course where several gamification elements were incorporated into the teaching process. In the experiment, a total of 62 first year graduate students participated, who were later divided into four groups. Two of these groups were taught in a traditional manner, and the other two were taught by incorporating gamification. After the semester, the collected system data and student results (e.g., attendance, grade average, bonus work) were analyzed. The authors conclude that gamification elements can be used in the teaching process because of their positive effect on student activities. However, they also admit that the results are inconclusive as the sample sizes were too small to make generalizable conclusions.

Barna and Fodor [2] implemented gamification by using Moodle (Modular Object Oriented Dynamic Learning Environment) [17], which is an open-source learning management system. Their gamified course employed such gamification elements as rewards, instant feedback, and freedom to choose the learning activities. The course itself was aimed at teaching Information Technology for undergraduate students at Corvinus University of Budapest. The experiment was performed twice—in 2015 and 2016, and in total, more than 2500 students participated in the courses. Although the results show that students' willingness to participate, satisfaction, and results of final exams improved, the authors state that the gamification effect cannot be clearly measured as there was no control group for comparing gamified and non-gamified course results.

Doyle and Buckley [3] attempted to measure student motivation by implementing a group decision making system based on a simulation of the national taxation system. The authors determined that the usage of such a system significantly increased students' knowledge of the national taxation system. Additionally, a correlation between participation and motivation was discovered.

Based on the existing research results, the main gamification elements chosen for using in our proposed course were the following: levels, a leaderboard, rewards, content locking and trading. We also decided to ensure instant feedback for the performed tasks by implementing these tasks as tests on Moodle platform, which also has a means for implementation of required gamification elements.

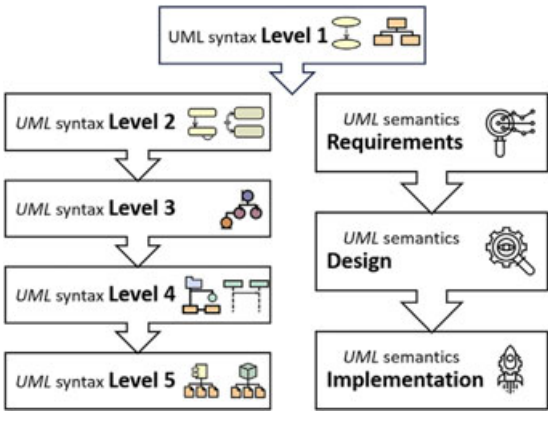

FIGURE 1 The level structure for the gamified UML modeling course

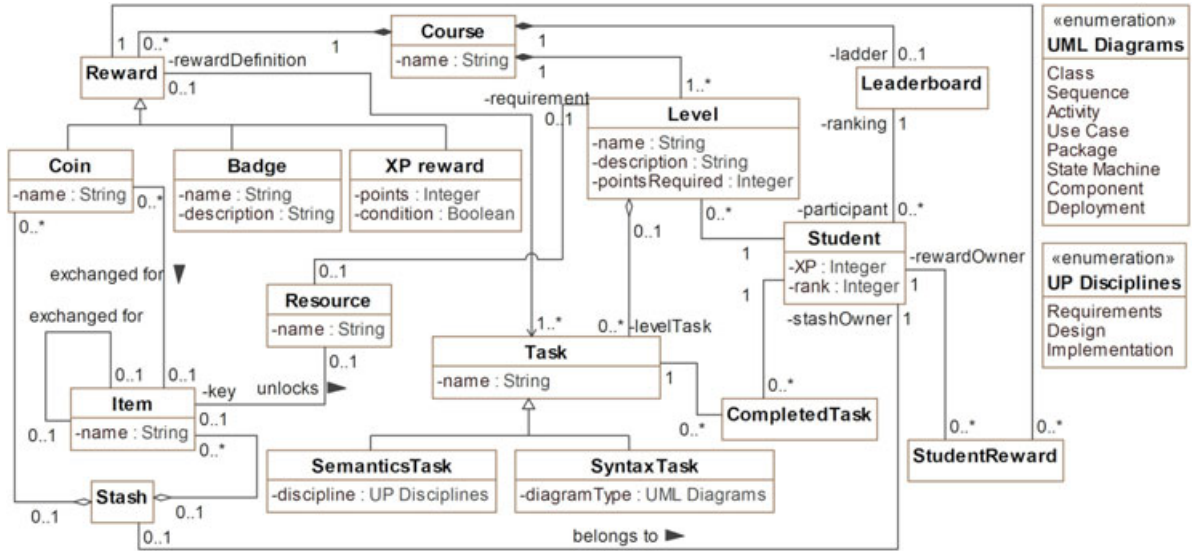

FIGURE 2 The metamodel of the gamified UML modeling course

3 | THE GAMIFIED UML MODELING COURSE

3.1 | Structuring the UML modeling course for introducing gamification

The first step for introducing gamification into the UML learning course was implementing a new level-based course structure. This structure ensures that a gradual unlocking of the course contents depends on levels. The levels in our course are divided into two groups. The first one is used for teaching the syntax of the UML diagrams—more specifically, the principles of notation. Level 1 is dedicated to teaching the notation of Class and Use Case diagrams, Level 2 to Activity and State Machine diagrams, Level 3 to Class diagrams extended with Robustness stereotypes, Level 4 to Package and Sequence diagrams, and finally, Level 5 to Component and Deployment diagrams. Level 1 is prerequisite for all other levels in the course. The other level group is used for teaching the semantics of the UML diagrams. More precisely, it focuses on the application of above mentioned diagrams in specific domains based on the Unified Process methodology. The levels of semantics are based on the UP engineering disciplines, namely, Requirements, Design and Implementation. The basic structure of levels and their order is presented in Figure 1. The icons used in Figure 1 (and in Figures 4–7) are based on the icons made by Freepik from Flaticon.com.

The principles of structuring the gamified course are specified in the course metamodel presented in Figure 2. The metamodel also defines the types of gamification elements used in the course. Rewards are appointed to the students of the Course for completing the Tasks. These rewards can be in the form of experience points (XP reward), Badges and Coins. Coins can be exchanged for the Items, which can be later used for unlocking the Resources of the Course (in our gamified course implementation, the Resources were the example UML models for three different domains). Both Items and Coins are stored in Stash, which belongs to the Student. The Course also has its Leaderboard, which ranks Students by the amount of the collected experience points.

3.2 | Implementation of the gamified course

The gamified UML modeling course was implemented in a Moodle learning environment [17]. For implementing the

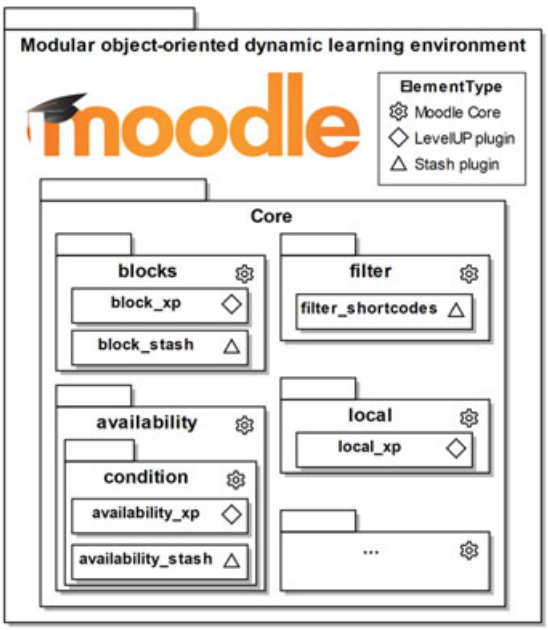

FIGURE 3 Gamified course implementation in Moodle platform with additional plugins

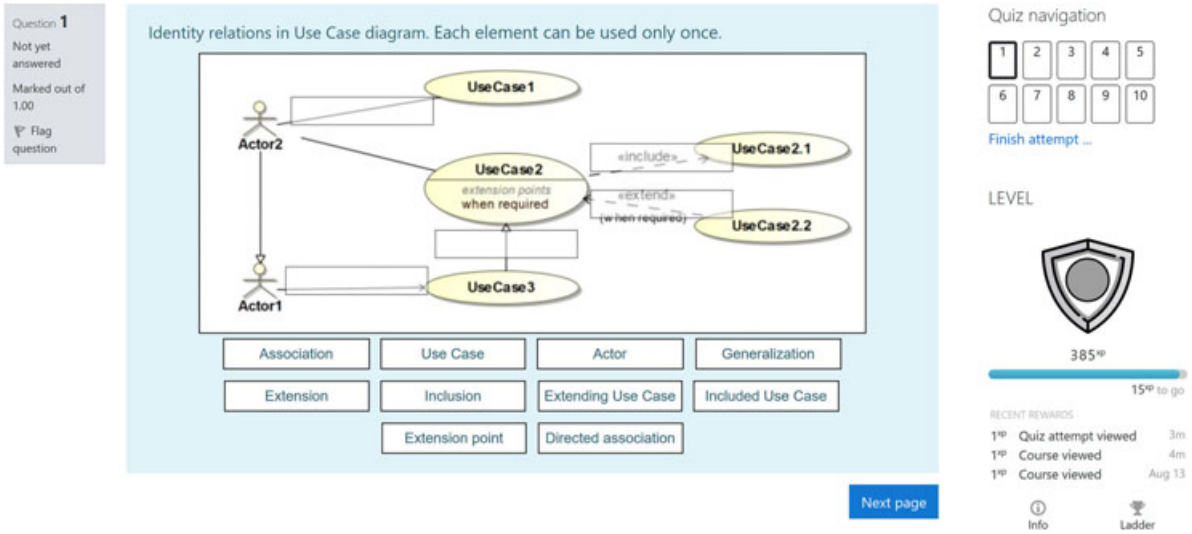

FIGURE 4 An example of a gamified course task

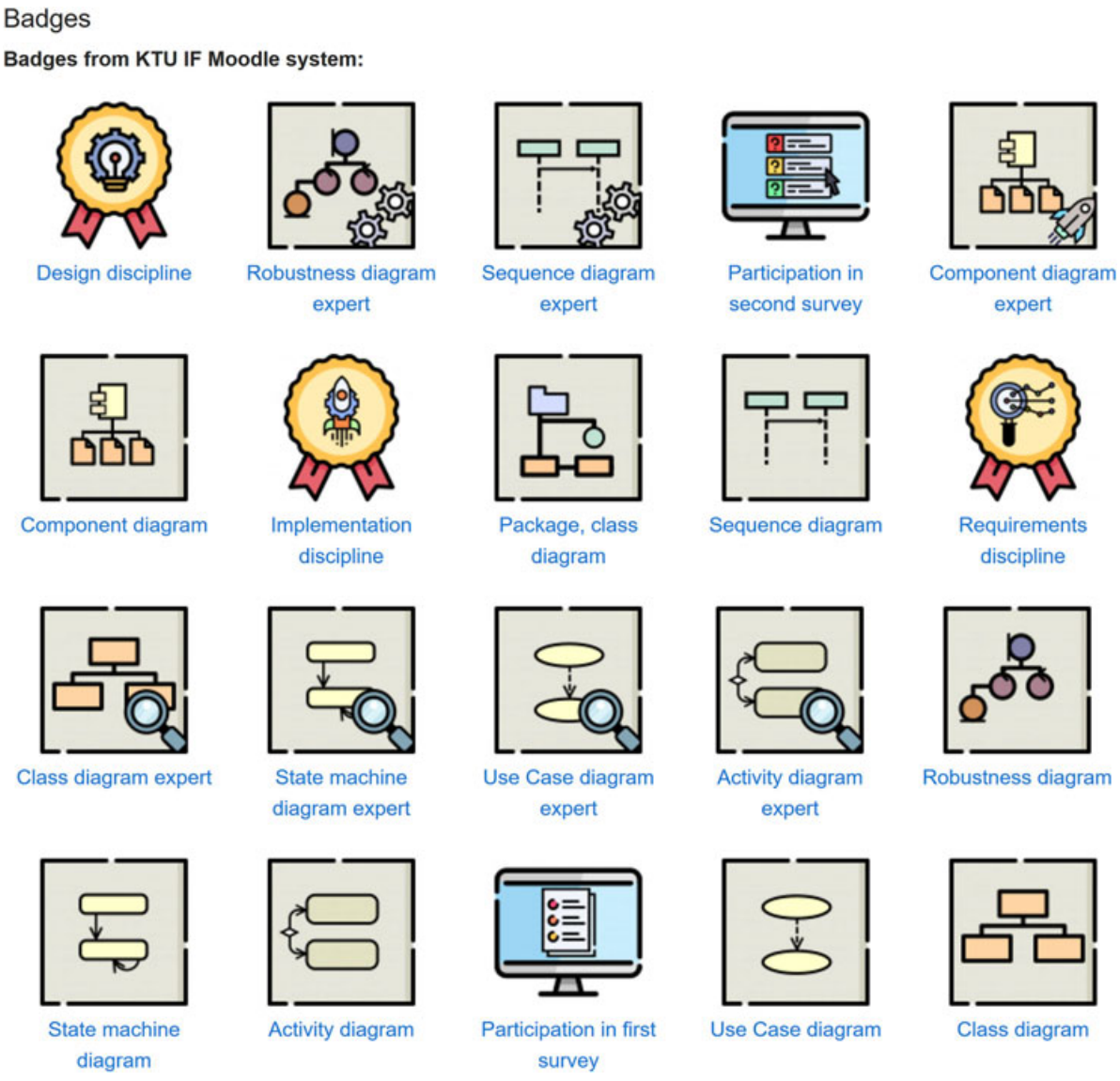

FIGURE 5 The representation of badges in the gamified course

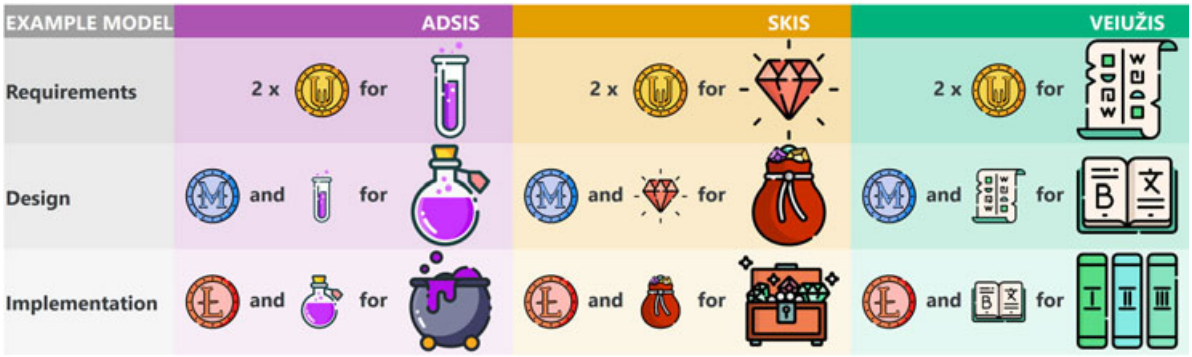

FIGURE 6 The representation of trading rules in the gamified course

proposed course structure and introducing gamification elements, in addition to basic Moodle functionality, two plugins were installed and configured: Stash [11] and Level up! [15]. In Figure 3, the principles of deploying plugins in Moodle environment are presented.

In our gamified course, all tasks for the levels were implemented as tests. A typical view of the gamified course test question is depicted in Figure 4. Each test was composed of five or more questions, and after finishing the test, the student would be presented with a reward and an evaluation of the attempt. In this particular case (as presented in Figure 4), a student is attempting a Use Case syntax test, where he/she has to answer a question about the use case diagram. Students can be presented with several types of questions: drag and drop, matching, embodied answers in text, true or false, etc. The course contains eleven tests (eight for syntax levels and three for semantics), which encompass a set of 193 questions (129 for syntax and 64 for semantics levels).

Locking of resources and activities in the course is based on the Moodle availability rules. The lockable content limits students so they are not overwhelmed by an extensive amount of information from the beginning of the course. By performing activities in the course and by gathering experience points, students gradually unlock new levels and functions.

For a successful completion of a syntax task, a student is rewarded with 100 experience points and a badge (an excerpt of the badge list of the gamified course is presented in Figure 5). A successful completion is considered to be achieving the minimum grade required to pass the test (85% in

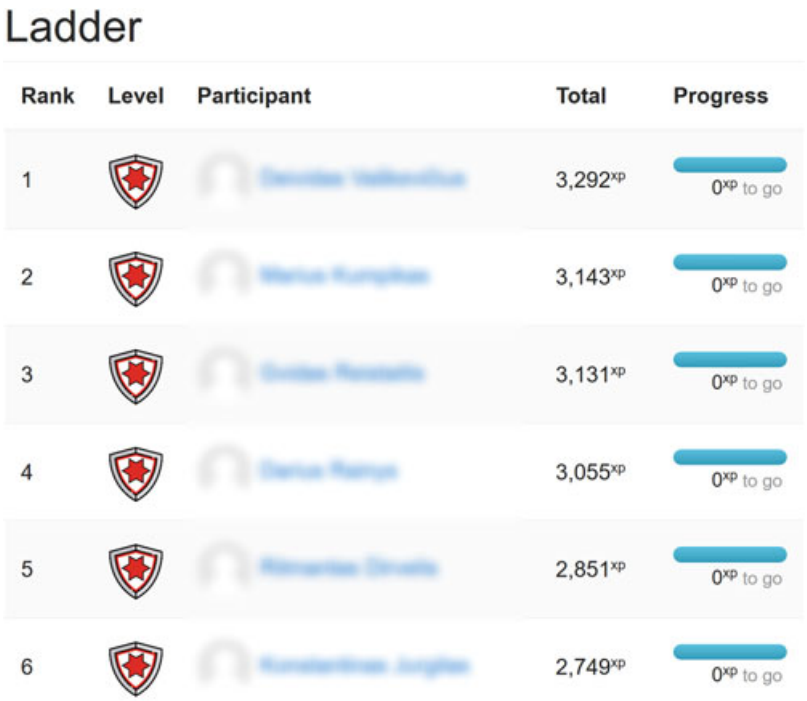

FIGURE 7 A fragment of the leaderboard in the gamified course

TABLE 1 The questions from the questionnaires for measuring students' general and gamified course intrinsic motivation

		Questionnaires	
No.	**IMI question group**	**General intrinsic motivation**	**Gamified course intrinsic motivation**
1	Interest/Enjoyment	I enjoy studying	I enjoyed studying the gamified course
2	Interest/Enjoyment	Studying is fun to do	The gamified course was fun to do
3	Interest/Enjoyment	Studies do not hold my attention at all	Gamified course activities did not hold my attention at all
4	Interest/Enjoyment	I would describe studying as interesting	I would describe the gamified course activities as interesting
5	Perceived Competence	I think I am pretty good at studying	I think I did pretty good at gamified course activities
6	Perceived Competence	I think I do pretty well studying, compared to other students	I think I did pretty well at the gamified course activities, compared to other students.
7	Perceived Competence	After studying for a while, I feel pretty competent	After working on the gamified course tasks for a while, I feel pretty competent
8	Perceived Competence	Studying is an activity that I can't do very well	Completing gamified course tasks was an activity that I couldn't do very well
9	Effort/Importance	I put a lot of effort into studying	I put a lot of effort into gamified course activities
10	Effort/Importance	I don't try very hard to do well at studying	I didn't try very hard to do well at the gamified course activities
11	Effort/Importance	It is important to me to do well at studies	It was important to me to do well at gamified course activities
12	Value/Usefulness	I believe that this studying is of some value to me	I believe that the gamified course was of some value to me
13	Value/Usefulness	I would be willing to enroll again because it has some value to me	I would be willing to participate in the gamified course again because it had some value to me
14	Value/Usefulness	I think that studies helped me to better understand modeling with UML	I think that the gamified course helped me to better understand modeling with UML

our gamified course). Regardless of the completion status, student is always rewarded with 20 experience points for attempting the task.

For a successful completion of a semantics task, the student is rewarded with 200 experience points, virtual currency (in the form of coins) and a badge. The coins can be later exchanged into items, which unlock access to a specific resource (Figure 6). The resources in our course are UML model examples for different domains. They are useful for the students as samples for their laboratory work in the course.

After the completion of each task, the student is immediately informed about his/her progress. Students' progress in the course is indicated by their level and experience points, and is displayed on the leaderboard (Figure 7). Students' expertise in the UML modeling course is reflected by their collected badges and items.

The implemented gamified course structure is customizable. It can be adapted to different versions of the Unified Process and other UML diagram types by extending the set of levels, adding badges, introducing new rewards, and implementing additional tasks.

4 | EXPERIMENT SETTING AND RESULTS

4.1 | Participants and the procedure of the experiment

The third-year software engineering students in the Faculty of Informatics at Kaunas University of Technology have a course called "Software Systems Analysis and Design Tools." A major part of this course curriculum covers UML modeling subjects. Students' UML modeling knowledge is assessed during the midterm exam and two laboratory assignments. During spring semester 2018, in addition to the main traditional course, the students were invited to participate in the gamified UML modeling course. The participation in the gamified course was non-mandatory, and the gamified course was only a supplement to the main course material. Even though the main course had all the required material for studies, the main purpose of the developed gamified course was to provide additional learning opportunities, which would help students to better understand UML

TABLE 2 The statistics of the UML modeling evaluation scores

Value	Mean	Std. deviation	Median	IQ range
2017 (non-gamified)	3.863	0.527	3.833	0.633
2018 (gamified)	4.053	0.516	4.066	0.666

modeling. The gamified course was not included in the grading system of the main course.

Students were proposed to voluntarily register for the gamified course and in total, 137 out of 172 students of the main course registered for the gamified course. For determining whether the implementation of gamification in the UML learning course was successful, two hypotheses were formulated:

> *H1: Gamification of the UML modelling course will have a positive influence on students' grades.*

> *H2: Gamification of the UML modelling course will have a positive influence on students' intrinsic motivation.*

For testing H1, students' grades were collected for analysis. We used two samples of students' grades from the course "Software Systems Analysis and Design Tools." One sample was non-gamified, from the spring semester 2017 (when only traditional course material was used in the teaching process), and another gamified, from the spring semester 2018 (when the gamified course was proposed in addition to the main course material). The main course curriculum material remained unchanged between 2017 (non-gamified year) and 2018 (gamified year). Grades of non-gamified year students, when students did not have access to supplementary gamified material, and the grades of gamified year students were compared to determine the effects of the gamified course.

Each year, students in the main course were expected to complete two laboratory assignments and a midterm exam. Based on their grades, UML modeling evaluation score was calculated for each student and its value compared between 2017 and 2018. As the purpose of our research was to measure the effects of gamification on the entire group of students, all students' grades from spring semester 2018 were collected, regardless whether the student has registered in the additional gamified course or not.

Furthermore, the grades of two prerequisite courses (i.e., "Fundamentals of Information systems" and "Databases") were collected as well. Courses were selected based on the fact that students were given a tasks of modeling in UML. Later, this data were used for the linear regression model to compare the academic results of the groups from the two different years.

For testing H2, during spring semester 2018, students were asked to answer two questionnaires (pre and post), which were used to measure students' general intrinsic motivation (pre) and intrinsic motivation of the gamified course (post). By the term "general intrinsic motivation" we refer to the overall students' intrinsic motivation during their undergraduate studies, and, by the term "intrinsic motivation of the gamified course" we refer to students' intrinsic motivation while participating in the activities of the gamified course. The questionnaires were developed using the Intrinsic Motivation Inventory (IMI) scale [28]. Four of seven IMI scale groups were selected: Interest/Enjoyment, Perceived competence, Effort/Importance, and Value/Usefulness. Altogether, 14 questions were included in each questionnaire (Table 1). The first questionnaire measured students' general motivation. The invitation to complete the first questionnaire was sent out to the students at the beginning of spring semester 2018. The invitation to complete the second questionnaire was sent out at the end of spring semester 2018, and it contained questions about the gamified UML modeling course, in which they took part during the semester. The questions in each questionnaire corresponded to one another, but inquired about different subjects of motivation (general vs. the gamified course, e.g., "*I enjoy studying*" vs

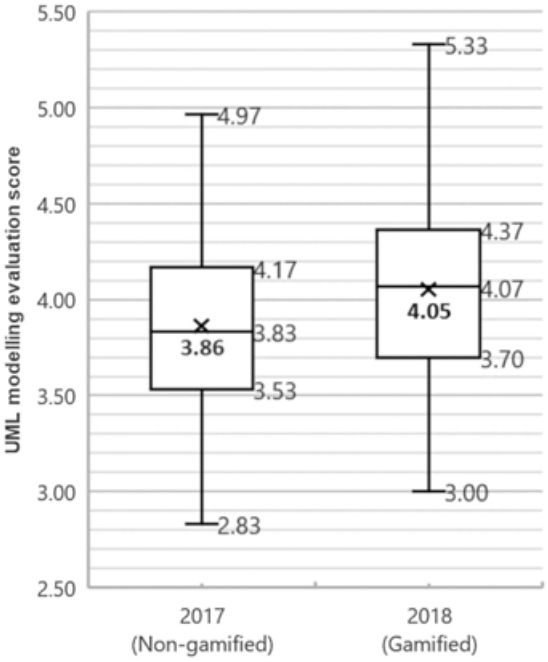

FIGURE 8 The boxplot diagram of the UML modeling evaluation score

TABLE 3 The results of the linear regression model

Variables	Coefficient	Std. Error	*t*-ratio	*p*-value
	$R^2 = 0.102$			
const	1.984	0.555	3.571	0.0005
ISLB	0.125	0.088	1.420	0.1574
DBLB1	0.051	0.041	1.245	0.2147
DBSU1	0.094	0.036	2.585	0.0105
Gamified	0.305	0.084	3.622	0.0004

TABLE 4 Cronbach's alpha scores for the IMI scale items

IMI scale question group	General Cronbach's alpha	Gamified Course Cronbach's alpha	Number of items
Interest/Enjoyment	0.894	0.885	4
Perceived competence	0.689	0.724	4
Effort/Importance	0.772	0.632	3
Value/Usefulness	0.751	0.672	3
Total	0.911	0.874	14

"*I enjoyed studying in the gamified course*"). Both questionnaires were anonymous, and a total of 89 responses were collected for the first questionnaire at the start of the semester. Despite the fact that the students were not too enthusiastic to fill out the questionnaire at the end of semester, 50 responses were collected for the second questionnaire.

5 | DATA ANALYSIS

The first hypothesis (H1), which states that the gamification of the UML modeling course will have a positive effect on students' grades was tested by comparing the sets of calculated UML modeling evaluation scores (non-gamified set from 2017 and gamified set from 2018). The scores were later tested for normality by Shapiro–Wilk W test. Both sets of data were normally distributed (p-value for 2017 is 0.089 and p-value for 2018 is 0.793) and Student's t-test was chosen for testing the H1 hypothesis.

The means of students' score for gamified and non-gamified groups were significantly different: $t(180) = -2.400$, the calculated p-value is 0.008. There was a statistically significant increase in the mean of students' scores (Table 2, Figure 8).

The comparison of central tendency in evaluation scores distribution between students of different years does not consider the students' knowledge level. For that reason, regression analysis was performed. For finding the relation between variables, a linear regression model (Ordinary Least Squares) was used to model the data set (Table 3). Variables included students' grades from prerequisite courses: a combined grade for laboratory work assignments (ISLB) in the course "Fundamentals of Information systems," a grade for laboratory assignment (DBLB1) and a problem-solving task grade (DBSU1) in the course "Databases."

Ten percent of variance scores around the mean were successfully modeled (R-squared = 0.102). Student UML modeling evaluation score increased by a coefficient of 0.305 (p-value = 0.0004).

For confirmation of the second hypothesis (H2), which states that gamification of UML modeling course will have a positive influence on students' intrinsic motivation, their

TABLE 5 The statistics of questionnaires: G, general questionnaire (89 respondents); C, gamified course questionnaire (50 respondents)

Group	Median	IQ range	Mann–Whitney U test p-value
Interest/Enjoyment			0.000000001
G	4.250	1.875	
C	6.000	1.562	
Perceived competence			0.000000076
G	4.750	1.375	
C	5.750	0.812	
Effort/Importance			0.002697060
G	5.000	1.666	
C	5.500	1.000	
Value/Usefulness			0.000000005
G	4.666	1.666	
C	6.333	1.000	
Total			0.000000003
G	4.500	1.428	
C	5.857	1.000	

motivation was measured with the IMI scale-based questionnaires. A total of 139 responses were collected, 89 for the first questionnaire and 50 for the second questionnaire. The collected responses were checked for internal scale consistency by calculating questions group Cronbach's alpha (Table 4) to determine whether the responses can be averaged out in each group. Although gamified course questionnaire groups had lower consistency, none of the groups had Cronbach's alpha lower than 0.6, indicating that the scale is consistent and can be compiled to their averages in each question group [18].

Later, the compiled averages were tested for normality by the Shapiro–Wilk W test. The general questionnaire was normally distributed (p-value = 0.243). Since the distribution of the gamified course questionnaire was not normal (p-value = 0.001), a non-parametric Mann–Whitney's U test was chosen to check for median equality. The summary statistics of each IMI questionnaire are presented in Table 5. The mean of the first questionnaire is lower than that of the gamified course, and the means of the question groups are lower too. IMI scale scores for two of the questionnaires are provided in a box plot diagram in Figure 9.

The distribution of the IMI score of general questionnaire was significantly different from the gamified course IMI score: Mann–Whitney U = 5.843, p-value = 0.000000003.

The difference between data is significant enough to confirm hypothesis H2, stating that the gamified course increased students' intrinsic motivation. The biggest change is in the Interest/Enjoyment group (1.47 points), while the smallest change is in Effort/Importance group (0.556 points).

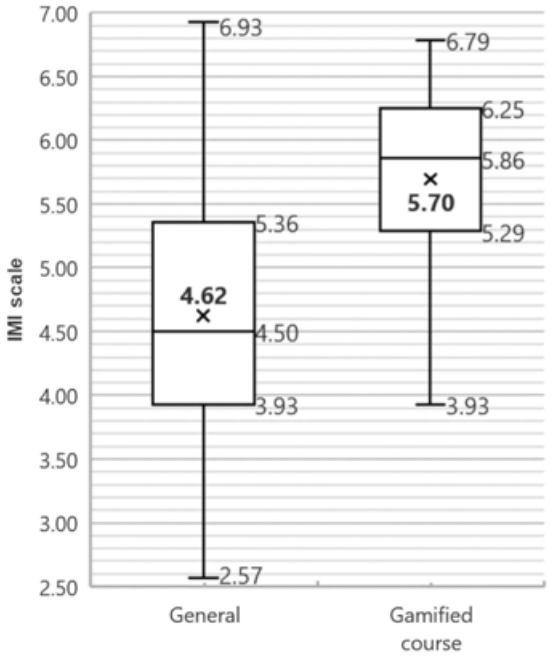

FIGURE 9 The boxplot diagram of the general IMI and the gamified course IMI

5.1 | Discussion

The confirmatory data analysis shows that gamification significantly improved students' intrinsic motivation and the average student assessment score. Similar results can be noticed in related case studies [2,3,12,14]. Ibanez et al., [12] confirmed the hypothesis that students' C-programming language knowledge improved while using the Q-Learning-G system. Buckley and Doyle [3] observed a significant difference in students' knowledge as a non-direct consequence of using a gamified tax system. Buckley and Doyle [3] also tried to measure the effect of student motivation and observed a positive correlation between intrinsic motivation to know and participation. Unfortunately, only a limited number of case studies have yet tried to measure the effects of gamification on students' motivation. Generally, student scores or grades are used to measure the effect of gamification. Although our experiment settings and environment differ from other case studies on applying gamification in higher education [2,14], data analysis in these and other case studies [9] shows that a positive influence of gamification on student grades can be observed often.

6 | CONCLUSIONS

As the UML modeling course curriculum encompasses an extensive amount of learning material and is difficult to study, gamification was proposed to facilitate the learning process and to increase students' engagement and motivation. A gamified course structure was developed. It was based on levels and gradual unlocking of the course content. Levels in the gamified course were separated into an UML diagrams syntax group and a semantics group thus ensuring that students learn not only the notation of diagrams but also their application in the process of software development. Other gamification elements that were introduced into the course were a leaderboard, badges, virtual currency and a trading system. The principles of introducing gamification were specified in the course metamodel, which defined gamification elements, their relationships, and depicted the generic structure of the course.

The gamified course was implemented on Moodle platform. As basic Moodle functionality was not sufficient for supporting required gamification elements, additional plugins were installed. The gamified course was configured according to the principles that are specified in the proposed metamodel.

During the spring semester 2018, an experiment was carried out using the implemented gamified course. A total of 137 students registered in the gamified course. The effect of gamification was measured by testing two hypotheses. The first hypothesis stated that gamification of the UML modeling course will have a positive influence on students' grade average. The hypothesis was tested by comparing student

grades between a gamified year course from 2018 and a non-gamified one from 2017. The results confirmed the hypothesis as average students' scores improved considerably: gamified course student average is higher by 0.3 points (out of 5.3) overall, compared to previous year students. The second hypothesis stated that gamification of UML modeling course will have a positive influence on students' intrinsic motivation. It was tested and confirmed by comparing student intrinsic motivation based on SDT IMI scale, as a significant positive difference was observed in students' intrinsic motivation: the motivation increased by 1.07 points in a scale from 1 to 7.

In the future, the gamified course can be improved by extending the functionality of Moodle with capabilities to validate UML diagram elements and provide extensive feedback on uploaded model files.

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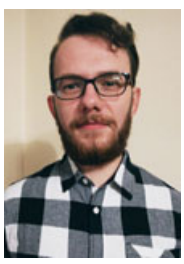

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