Potentials of Applying Gamification in Teaching Project Management

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Abstract—Currently, gamification is applied in various contexts, especially in education area. In this paper, the principles of gamification are applied for improving the process of teaching Earned Value Analysis. Earned Value Analysis is a special technique, used in project management for evaluating the state of the project. This technique is taught in the course for graduate students and the existing teaching process can be improved for increasing student motivation and engagement. Our proposed solution is a computer game, which will help to gamify the learning of EVA.

Keywords—gamification, education, project management, Earned Value Analysis.

I. INTRODUCTION

Students' motivation during the learning process is very important to master the subject [1]. Motivation inspires and gives a goal that can be achieved through certain activities [2]. To increase students' engagement into the learning process, it would be useful to apply gamification as a teaching method. This would allow students to enjoy the learning process rather than simply solve problems that are presented in a form, which is not interesting enough [1]. Gamification can be used as a tool for education and business training [2]. The most important objective of gamification is to turn daily activities into learning opportunities by encouraging participants to think like in a game. A game is an independent unit that consists of elements, has a clear goal, a defined start and end, established winner status and the ability to overcome the challenge through several attempts [3]. Educational community explored the effectiveness of games as a learning tool, and one of the way of using games in education is gamification [4].

Graduate students of the Information Systems study programme at the Kaunas University of Technology have a course "Information Systems Project Management Technologies". The course curriculum focuses mainly on software project management, which is defined as the application of knowledge, skills, tools and methods for project tasks in order to meet project requirements [5]. Project cost control helps to ensure that the project does not exceed the budget and at the same time is not exceeding the duration or reducing the quality. The method for measuring such factors is Earned Value Analysis (EVA) [6]. One of the aims of the course is teaching to apply Earned Value Analysis. Teaching method used to explain how to solve EVA problems is not interesting enough, because the problems are presented to students as a simple calculation exercise, i.e. students calculate and write on a sheet of paper using presented formulas. Therefore, some students lack motivation to master the Earned Value Analysis. Our research focusses on applying gamification to the teaching process for increasing student motivation and engagement.

Five main principles of gamification can be distinguished: goal orientation, achievement, reinforcement, competition and fun orientation [7]. Gamification uses game elements that interact with each other to include the player in a game, motivate him or her to continue it [7] and teach them at the same time [2]. Werbach and Hunter [8] present three categories of game elements: components, mechanics and dynamics. Components are specific elements of the game, mechanics defines how the components act when a player is playing a game, and dynamics are the players interaction with mechanics, i.e. the players reaction to the mechanics of the system [9].

Most commonly used components are: points that are the main digital measure of success in a game and show player progress; levels that shows to players their progress during the game; leaderboards that show player progress as compared to rivals [7] [10]; badges that visual represent achievements; virtual goods that are game assets that you can buy for virtual or real money [8]. These core components realize mechanics of the game, which affect the players experience in the game [9], encourage player next action and participation in the game [8]. Various authors present basic elements of mechanics and most popular are feedback that is information about the player, how he is doing at the moment, challenges that are puzzles or other tasks that require effort to solve, rewards that are grades for achievements and chance that is a random element [8] which create a sense of uncertainty and interest [10]. Each element of mechanics is a way to achieve dynamics, for example, a randomly received award can affect emotions of the player - stimulate the sense of curiosity and happiness [8]. Authors present these elements of dynamics such as, emotions that are a player's experience and includes: curiosity, competitiveness, frustration, happiness [10], narrative that is a coherent and engaging storyline and progress that is a player's advancement, which increases when the player knowledge grows [8].

These game elements help to increase player engagement and motivation, makes the game fun, that's why they are used in the proposed game for teaching EVA. The main purpose of this paper is to define the strategy of applying analysed gamification methods and tools to the process of teaching Earned Value Analysis.

The rest of the paper is organized as follows. The second section analyses related work in the area of gamification in education, case studies on applying gamification in education and gamification of teaching Earned Value Analysis. The third section presents the proposed solution for teaching EVA. Lastly, the fourth section presents the conclusion and outlines the future work.

II. RELATED WORK

A. Methods of gamification in education

Methods of gamification must convey appropriate knowledge, which depends on the level of learner's understanding, so in order to avoid learner's frustration, it is necessary to choose the proper logic of the game operation [2]. Game must not cause anxiety or boredom, therefore, it is necessary to maintain a balance between these psychological states [9].

According to Karl M. Kapp [2] human knowledge is divided into declarative knowledge, when information can be learned only by remembering it (e. g. facts and concepts), conceptual knowledge, when information is learned by linking it with other information (e. g. definitions with concepts) and rules-based knowledge, when concepts or definitions have certain rules. Gamified learning process can help to teach starting with the basic facts and concepts, then proceeding to definitions and eventually the rules. There are some methods of gamification used to teach facts, definitions, concepts and rules. According to these methods there are game types suggested. Facts and definitions may be taught by using the *Association* method when a word or a term is linked to its definition. Suggested game types for this method could be *Sorting*, when a player needs to place content into the right place, or *Matching*, when a player has to associate an image or a fact to another image or a fact. The *Examples and Non-examples* method can be used to teach concepts when presenting content-related examples or non-examples and a game type suggested could be *Experiencing the Concept*. In this game type, the player can experience certain content that he learns. Rules may be taught by using *Provide Examples* method, which illustrates the rule in action. It is an appropriate method for conveying cause and impact relationships. The second method for teaching rules is the *Role Play* method, in which the player plays a role that must apply certain rules to specific situations. For these methods the game type suggested could be *Board Games*. Board games allow a player to apply the rules using questions with multiple choice answers, that requires for rules to be set or applied in certain situations.

B. Case studies on applying gamification in education

Gamification is used in various environments. In this research, the solutions of gamification in educational process are analysed in more detail. Various researchers have applied gamification to their activities aiming to analyse the effects and benefits of gamification in learning contexts.

Scientists of the Brazilian Federal University of Santa Caterina, led by Prof. Dr. Christiane Gresse von Wangenheim [11] developed a board game, named "Deliver!" with the objective to teach students in project management courses to monitor and control a project using Earned Value Analysis. The total game duration is around 90 minutes and, ideally, there are four players in pairs playing on one game board. Each pair has to plan project's human resources, duration, costs and the results of the planning has to be documented in the project plan. During the game, each pair rolls a dice simulating the execution of the project. Depending on the number of the dice rolled, the pair should take a risk card or advance on the game board in spaces. At each milestone between project phases, the pair must monitor and control the project execution using EVA. The winners are the ones who arrive on the game board space "delivery" without running out of money.

The game has been applied in the Software Project Management course at the Federal University of Santa Catarina. The research showed that the game had a positive effect in learning process because it engaged students in the lecture. Christiane Gresse von Wangenheim states that this teaching method can complement the student's learning process. Professor Guillermo Montero Fernández-Vivancos [12] uses this game at project management courses at the University of Seville. According to student feedback, the game helps to increase students' interest and motivation during the lectures.

Dicheva, Irwin, and Dichev [13] provide the OneUp Learning Platform that supports the use of gaming elements in training courses. This platform is customizable for each course because it allows to configure course structure, game elements and create challenges. Platform uses these game elements: points that are divided into skill points, challenge points and activity points, badges that are given for mastery of skills: "Novice", "Journeyman", Expert" and "Master", levels that unlock new challenges, leaderboards, avatars, virtual currency, feedback and freedom to fail. There is a bank of rules in which teacher can add the desired rules. An anonymous study was carried out involving 15 participants (students and lecturers). During the study, participants were assigned tasks that depended on the type of participant. Participants also had to answer the questions and submit their observations. The results of the surveys demonstrated that the OneUp Learning platform could successfully motivate and involve students.

Researchers of the University of Valladolid [14] apply gamification in a parallel programing course. This course is extensive and students often lack the motivation to learn, so it was decided to gamify the course in order to increase students' interest and engagement. Separate students' groups must create a program that is evaluated according to the execution time. It is decided to use the leaderboards. Gamified course uses awards, which are delivered using the Moodle platform. They are rewarded for well-written program and also for attending the course. They also use badges as rewards: bronze, silver and gold. The Tablón system was created to gamify the learning process, which allowed to control the execution of the students' program code and ranking the students' programs in the leaderboard accordingly. Tablón system was also used to assess and rank students by the program source code correctness and execution speed. Student activity and behaviour data was also logged. The usefulness and engagement of Tablón was measured and the leaderboard for competitiveness, students' satisfaction and marks was analysed. The results of the study showed that the course was successful in terms of student motivation, interest, learning and final grades.

Ryder and Machajewski [15] developed an app named "UIC German" for gamification of the German language teaching. Students can create their avatar, perform various tasks, receive points for them and view leaderboards. Students who have accumulated a lot of points can exchange them for the certain bonuses. This app supports the import of Duolingo results, in which points are assigned. Duolingo – gamified free language-learning platform created by professor Luis Von Ahn and his graduate student Severin Hacker [16]. Duolingo is publicly available since 2012 and has over 300,000 users, and since 2016 offers 59 different courses for 23 languages. This system uses the following game elements: virtual currency, called Lingot, leaderboards, levels and badges. Huynh, Zuo, and Iida [16] claim that badges are the most important element of gamification, because they are combined with the content of the training course and are used to increase the player's motivation in language learning.

Based on the related work, only the EVA board game "Deliver!" is the most suitable for teaching Earned Value Analysis. The other analysed solutions use gamification elements more extensively than "Deliver!", but they are not suitable for EVA teaching. Only some of the features in analysed case studies can be tailored to the EVA teaching process. Unlike the EVA board game, the proposed teaching process will be computerized. We are planning to use points, levels, badges, leaderboard and virtual currency for teaching EVA. Duration is also important in gamification of teaching. The EVA board game "Deliver!" has the shortest duration, as it is intended to play the game during a lecture. As the OneUp Learning Platform and the parallel programming course gamified the entire course of a particular subject, the duration of the training is a semester, since most of the time, university courses last one semester. The duration of using the "Duolingo" is uncertain as the students learn independently, not in the university, therefore, the duration depends on the student. The duration of the single proposed EVA learning game may be short, like the EVA board game, but the game will be used to gamify the whole learning process, which is planned to take about 3 weeks. All computerized solutions gamified the entire course, however the main aim of our research is not gamifying the course but gamifying only the EVA learning process.

C. Gamification of teaching Earned Value Analysis

To find out how to utilize gamification for teaching EVA, it is first necessary to analyse the basic formulas of EVA and EVA teaching process itself. According to PMBOK guide [5], the purpose of Earned Value Analysis is to evaluate the project current and final results by linking the calculation of three main metrics for each project activity. Planned value (PV) is the work budget, which is planned to spend on certain activities over a certain period. Actual cost (AC) is the money spent on certain activities performed over a certain period. Earned value (EV) is the value of performed activities. These three metrics are used together to determine whether an activity is being executed as planned [5]. By using these metrics, variances and performance indicators are calculated. Cost variance (CV) estimates the difference between the budgeted costs and the actual cost of the work performed [6]. Schedule variance (SV) compares the planned work with the actual work performed [6]. Cost performance index (CPI) shows how effective the project costs

are spent [17]. Schedule performance index (SPI) shows how to effectively use project time [17]. Project execution indicators values show how scheduled work and budget are followed [17].

Assessment of the likely quantitative result is applicable for project duration and cost [5]. Estimate at Completion (EAC) shows the final cost of the project, if the current project performance is going to continue, and Estimate to Complete (ETC) indicates the costs required to complete the project [17].

By calculating these metrics, we can find out, which project's tasks are on schedule, and which are behind it, which tasks are over budget and which are on it. Thus, it is possible to evaluate the situation for each project's task separately and the overall condition of the project. Students in project management course solve EVA problems by calculating these metrics, and gamification of the problem solving process can help to increase their engagement into the learning process. At present, EVA metrics calculation tasks are presented as simple exercises, which students solve manually on the sheet of paper. Theory and formulas of EVA are introduced to the students and using that information, students must calculate necessary metrics for filling in the missing values in a table. These values are later used for defining the state of the project.

Rory Burke [18] presents a systematic method for filling the EVA table. In EVA table columns have EVA metrics and the rows contain project tasks. Available project data (planned budget, percentage complete, actual cost) are presented at the intersection of the rows and columns. The EVA table is filled in a particular order: at first, PV and EV for each project task are determined and then the rest of the metrics for each project task are calculated. Finally, the values of PV, EV and AC columns are aggregated and based on the results obtained the values of SV, CV and EAC are calculated for the entire project.

In our analysed project management course, students use the similar method for filling the EVA table. The table is presented to the students to fill in the calculated EVA metrics. Overall work PV, performance plan to this day, AC and real performance percentage to this day are given in the table. After calculating the metrics and completing the table, students write conclusions about the project status and situation of the project tasks (e.g. which tasks are behind the schedule or over the budget). The problem with this learning process is that some students lack motivation to master the Earned Value Analysis and thus are not prepared enough for the exam. The EVA presentation in another form can help increase students' motivation. To gamify learning of EVA, it would be useful to apply such gamification elements as points and levels. These game elements show players progress and give feedback to the player about his performance. It would be useful for the students to solve EVA exercises for which they would receive points that increase their level in the game. Points can be assigned for solving the exercises and after completing all exercises, students should be able to move to the next level. Other useful game elements are badges, which represent player achievements, so during EVA learning process students would receive badges like rewards for the correct answers or achieved levels. It is important to show student's progress in comparison with other students, in order for the students to compete with each other. Leaderboard can be formed based on the number of points

collected by each student. The virtual currency can be used as a means for buying desired items in the game, which would give some advantage to the player.

III. DEFINITION OF THE PROPOSED GAME STRUCTURE FOR TEACHING EVA

In this paper, we are presenting the proposal for developing the game for learning to solve EVA problems. The game and the elements of the gamification are designed to gamify the learning process in order to increase student motivation and interest. The proposed EVA game has such gamification elements as points, levels, leaderboard and badges. These elements ensure, that the main principles of gamification are used, such as rewards for students' achievements and competition.

EVA gamification system is implemented as an online website that is accessible through the browser so that students can learn individually. The main functionality of the proposed game encompasses starting a game, rolling a dice, solving problems and filling EVA table, as presented in UML use case diagram for EVA gamification system in Fig. *1*.

Fig. 1. EVA gamification system use case diagram

The proposed game is structured into two parts. The first one is preparation, when student chooses a project and selects tasks, milestones and resources for the selected tasks. Students can choose tasks, milestones and recourses from the existing list because this game is intended for monitoring and controlling an existing project, not for developing a new project plan. During the second part of the game – the project execution, students carry out their projects by rolling a dice.

The main elements of the game (as presented in class diagram of EVA gamification system entities in Fig. 2) are the project, its resources, tasks, milestones and risk cards, used during the project execution. The information about students and their achievements is also stored (Fig. 2).
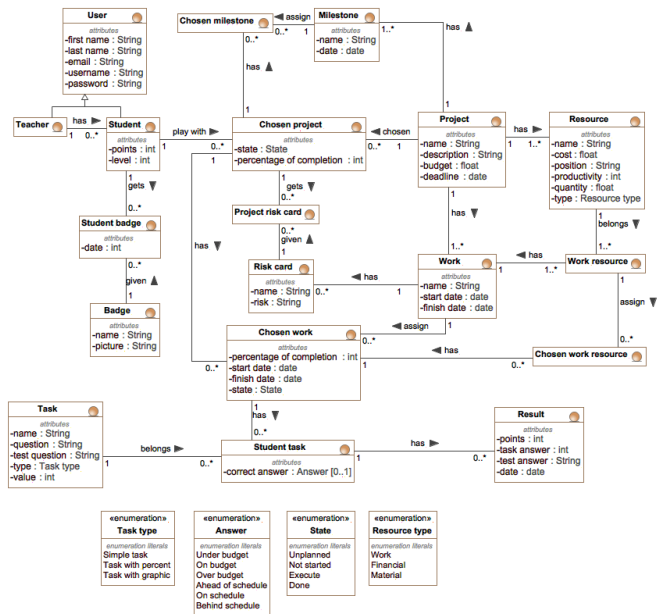

Fig. 2 EVA gamification system entity model

During the game, student sees a game board, a dice, risk cards and a Gantt chart that illustrates a project schedule (Fig. 3). The game board consists of cells that show where the player is, and the percentage of project finished.
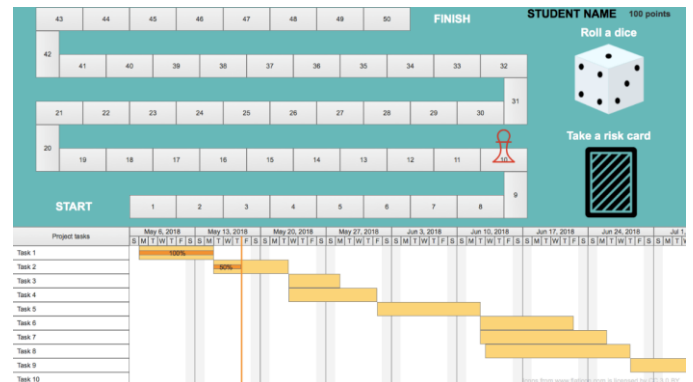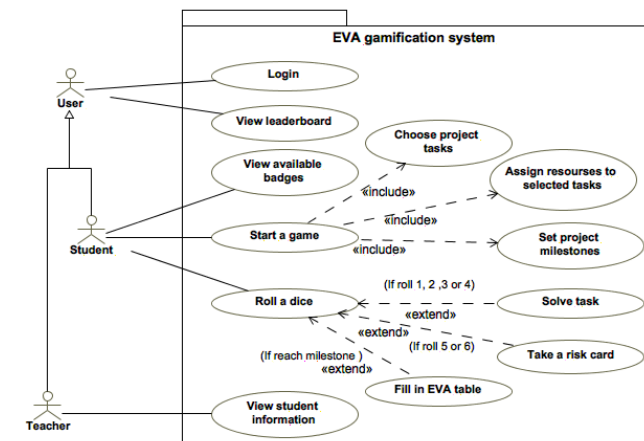

Fig. 3 EVA gamification system user interface

The project execution starts with rolling of a dice. If the score of 1, 2, 3 or 4 are rolled, student moves as many cells as the dice points and at the same time the part of the project in the Gantt chart is executed as much as the percentage of the cells in the game are passed. The percentage of actual tasks performance depends on the level of resource productivity that is assigned to the task. If the level of productivity is low, it will have a lower performance percentage and if the level of productivity is high, it will result in a higher percentage of performance.

When the game figure stops on the cell, the EVA task is given to student. There are several types of tasks. The simple task is when one of the EVA metrics is given to calculate. The formula and existing EV, AC and PV values are given, and the student must choose the correct metrics and drag them to the empty formula spaces, according to which the required value should be calculated. The task with percentages is when student

is given only the budget of the task, how much the work is planned to accomplish and how much it is actually done in percent. EV and PV must have calculated by percentages (AC is always given). The other requested metrics are calculated like in a simple task. The task with graphs is when EVA graphs with EV, PV, and AC information are presented, and according to them, the required metrics should be calculated. The student receives points for the correct answer of the task, but if the answer is incorrect, the number of student's points is decreased. If the task is to calculate PV, CV, SPI or CPI and get the correct answer, then the test question with the answer variants is given afterwards. The test question checks the students' understanding whether the task is ahead of the schedule, or is over the budget etc.

If rolling the dice results in the score 5 or 6, student takes a risk card. Risk card is related to the duration or budget of a particular task, for example, the task's duration or budget has decreased. Student has to decide what to do after taking a risk card. He can choose to change the duration of the task, add or remove the resources.

Once the player has reached the milestone, he has to complete the entire EVA table. When the player selects the field in the table, the corresponding formula and the possible values are given. The student solves this task by similar principle as a task of one cell.

During the game, students earn points and after collecting the required amount of points students' game level increases. They also receive badges to collect. Badges can be obtained for the percentage of performance of the project (25%, 50%, 75% and 100%), the first time of well-calculated CV, SV, CPI, SPI, EAC and ETC, completed milestone (EVA table), reached level and getting into one of the first three places in the leaderboard.

These game elements are used to meet one of the principles of gamification – awards for achievement, when players are evaluated for achievements and receive rewards. The second applied principle of gamification is competition, therefore the leaderboard is used, so the players are able to view each other points and compete with each other. In addition, for stimulating the competition, the students at the top of the leaderboard will receive the teacher's predefined encouragement.

IV. CONCLUSIONS

Gamification is a new way of using game elements to engage students and increase their motivation to learn Earned Value Analysis. Although there exists a game for teaching EVA, it is non-computerized. Our proposed solution is a computer game, which, along with the elements of the game, will help to gamify the learning of EVA. We have presented the structure and main principles of the game. In the further research, the gamification of the EVA will be experimentally tested in student learning process, to assess the effects of game and game elements on the EVA learning process.

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