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A game-based learning method to teach project management – the case of the earned value management

Elina Jääskä^{1*}, Jaakko Kujala¹ and Kirsi Aaltonen¹

Abstract: The earned value management (EVM) is a project management method for monitoring and controlling project expenditure and progress. Teaching EVM is challenging as the method may appear theoretical, mathematical, and disconnected from the uncertainty of real-life projects. Educational games have been suggested as one method to influence students' motivation and to teach relevant skills with practice-based and intriguing approaches. This study examines how educational games can be used to teach complex project management phenomena. The research process of this study follows a one-group, posttest-only, quasi-experimental design. We conducted a quasi-experiment using an educational game and related learning activities designed to teach EVM to 39 university students. As part of the experiment the students wrote reflective essays of their perceptions and learning experiences, which were analyzed using qualitative content analysis methods. This data was complemented by students' feedback survey regarding the achievement of learning outcomes and presented as summative descriptive statistics. Our findings indicate that GBL methods are suitable for teaching and learning EVM, because they prepare learners to deal with project uncertainty, provide challenges and also repetition. Our findings indicate that learners' holistic project management understanding and skills improved, because the GBL solution demonstrated the importance of managing unexpected events, re-planning the project and making evidence-based decisions. This study provides new knowledge on how game-based learning (GBL) can be applied to teach and learn project management methods such as EVM.

Subjects: Engineering Education; Theories of Learning; Educational Research; Higher Education

Keywords: earned value management; educational games; game-based learning; project management education

1. Introduction

Projects and the projectification of society are present in the global economy and in our daily lives (Jacobsson & Jaloča, 2021; Jensen et al., 2016; Kuura, 2020; Schoper & Ingason, 2019). The phenomenon of projectification is visible in public organizations and companies, which initiate, plan, execute and control their work efforts through single projects or series of projects. Both



project leaders and project personnel need versatile project management understanding, competence, and skills to succeed in a projectified society where organizations and companies demand highly skilled project personnel to accomplish a specific goal, help improve project performance and outcomes (Ballesteros-Sánchez et al., 2019; Kaufmann & Kock, 2022). The jobs growth and talent gap identified in project-oriented job roles indicate that there is an urgent need of educated project managers in organizations (PMI, 2017). Consequently, education institutes need to develop their project management course offerings in order to educate and fill the identified competence gap. Challenges facing project management education include how to develop learners' critical thinking and interpersonal skills (not just their technical skills) and how to prepare project managers to deal with complex real-life project situations (Ramazani & Jergeas, 2015; Svejvig & Andersen, 2015; Winter et al., 2006). This study explores the use of game-based learning (GBL) methods to complement project management education. It uses the earned value management (EVM) method as a case example of challenging project management subject to teach and learn.

Monitoring and controlling processes, techniques, and tools enable the tracking, reviewing, and regulating of project performance (PMI, 2021). They help identify any deviation from the project management plan and recognize and plan for changes, both of which might be necessary to successfully complete a project. As part of the project monitoring and controlling process, a project manager needs to constantly know and frequently report the current status of a project. A project manager should be able to answer management's or stakeholders' questions, such as "How is the project proceeding compared to the planned schedule and budget?" "How much will the project cost in the end?" and "When will the project be completed?"

EVM method combines project scope, cost, and schedule management, enabling the calculation of cost and schedule variances and performance indexes (Anbari, 2003; Vandevoorde & Vanhoucke, 2006). It provides practices, methods, and tools to assess project performance and progress and to forecast the project outcome (PMI, 2019). With EVM, a project manager can analyze and visualize a project's status at various points in the project life cycle in order to manage project risks and changes with evidence-based decisions (Kwak & Anbari, 2012). EVM is recognized as an effective method for monitoring and controlling project performance by providing early indicators for eventual corrective actions, but despite this, its use has been relatively limited (Bryde et al., 2018).

Earlier research has identified various challenges with EVM education. Conceptualizing EVM is regarded as difficult because of the large amount of terminology and formulas (Jimenez & Beigh, 2020). In particular, learning EVM requires an understanding of how to cope with uncertainty and stochastic events that happen after the project planning phase, which may not be easy to teach (Vanhoucke & Shtub, 2011). Students also often lack opportunities to practice project management concepts and techniques taught in expository lessons (Anastasiadis et al., 2018; Ramazani & Jergeas, 2015; von Wangenheim et al., 2012). These challenges make it difficult for students to learn how to apply EVM in practice, which motivated us to conduct the GBL (Plass et al., 2015) study presented in this research paper.

Many project management educators face the challenge of how to educate and teach complex and abstract project management phenomena, such as EVM, in a concrete and enticing manner. Project management education research has recognized the potential of GBL methods to teach both the hard and soft skills required to manage conceptually challenging and complex project management phenomena (Boyle et al., 2016; Jääskä & Aaltonen, 2022; Jaccard et al., 2022; Rumeser & Emsley, 2022). Still, more understanding of how GBL methods contribute to students' engagement, motivation, learning, and impact is needed (Westera, 2015). This study aims to provide new knowledge about how GBL methods can be applied to teaching EVM to higher education students. We designed and conducted a quasi-experiment, where students' perceptions of learning were gathered and analyzed. To comprehend the effect of this educational experiment

on students' learning, we formulated the following research question: *How do students learn the earned value management using a game-based learning method?*

This paper explores and highlights factors related to how the use of an educational game affects students' understanding of the concept and application of EVM. We designed a learning solution that included a digital educational game called the Project Business Game (PBG). In spring 2022, we conducted classes for students on university level project management course. The research data were collected from a feedback survey and essays, which students wrote as the final assignment of the experimented learning solution.

The learning approach and insights are presented as follows. First, we briefly present the concept of EVM and educational games' effects on learning complex phenomena and methods of project management. We highlight the potential of GBL and present possible challenges identified in earlier studies. Next, we introduce our experimental research design and learning solution, which were formulated for the case of EVM teaching. Thereafter, we discuss the findings and present the educational implications derived from the observations and analysis of the students' perceptions. We conclude with our research limitations and suggestions for future research.

2. Theoretical background

2.1. The earned value management

The history of EVM dates back to 1967, when the method was introduced by the U.S. Department of Defense as an integral part of its cost/schedule control criteria system (C/SCSC), and later on, in 1972, it was formulated as a component of a C/SCSC implementation guide for military departments (Kwak & Anbari, 2012). EVM was first applied to public sector government and NASA space projects (Kwak & Anbari, 2012) and, subsequently, to complex construction projects. EVM has also been called earned value method, earned value project or performance management, and earned value analysis. It has been used as a project management method for more than 50 years. The Project Management Institute published simplified EVM terminology in *A guide to the Project Management Body of Knowledge PMBOK* in 1987 and in subsequent editions (PMI, 2021) and in a more detailed guide called *The Standard for Earned Value Management* in 2019 (PMI, 2019). In Australia, EVM has been codified as standards AS 4817-2003 and AS 4817-2006.

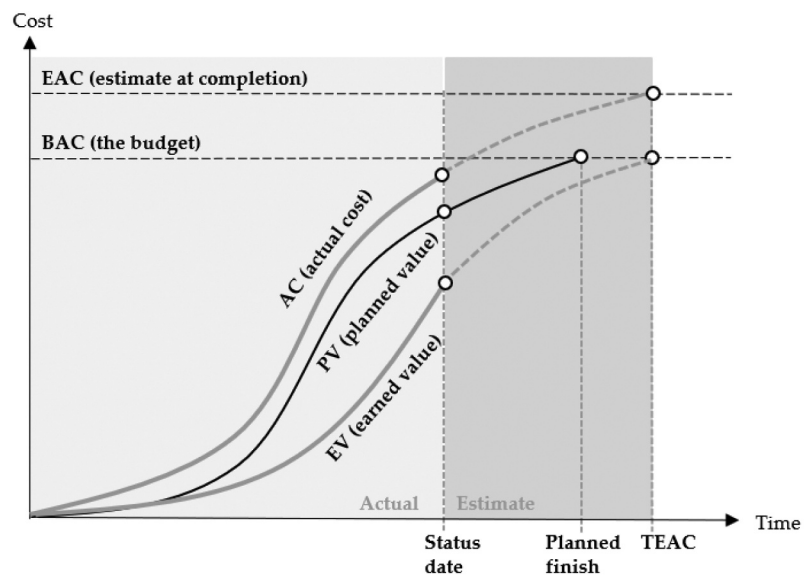
EVM is an important project management method and a powerful tool, which can be used to manage project scope, time, and cost by employing monetary units as measures (Acebes et al., 2014; Anbari, 2003; Fleming & Koppelman, 2010; Marshall et al., 2008). This method enables the calculation of cost and schedule variances and performance indexes to measure project performance and to forecast project costs and schedules at completion (Anbari, 2003). EVM was developed as a tool for project managers to help them comprehend whether a project was progressing according to the planned schedule or not and whether it was over or under budget (Czarnigowska, 2008). A project manager can utilize EVM to monitor, report, and communicate a project's status, to adjust a project's strategy and plans, and to organize and take corrective actions using early indications of a project's expected results (Anbari, 2003; Czarnigowska, 2008). Thus, EVM measures act as early warning signals for reacting and implementing changes at the right moment during a project, rather than too late.

Table 1 presents the most common EVM parameters and indicators and their purposes according to Anbari (2003) and Lipke et al. (2009).

Figure 1 illustrates the basic idea of EVM for project control in a visual format. An EVM graph, with the actual cost, planned, and earned value curves, helps to analyze the project status at a specific date and to forecast its cost and duration at completion (Czarnigowska, 2008). In the example shown in Figure 1, the project is over budget and behind schedule at the time of measurement (on the status date), because the actual costs are higher than the budgetary

| Table 1. EVM parameters, measures, and indicators | | |
|---|--|---|
| | Key parameters | Description |
| PV | Planned value | Budgeted cost of work scheduled (BCWS) |
| AC | Actual cost | Actual cost of work performed (ACWP) |
| EV | Earned value | Budgeted cost of work performed (BCWP) |
| | Performance measures | Description |
| CV | Cost variance (CV = EV - AC) | Volume of work done (i.e., earned) versus the actual cost, where a positive value is favorable |
| SV | Schedule variance (SV = EV - PV) | Volume of work done (i.e., earned) versus the volume of work planned, e.g., SV < 0 means that the work is behind schedule |
| CPI | Cost performance index (CPI = EV/AC) | Measures the budgetary conformance of the actual cost of the work performed, where a value greater than 1 is favorable |
| SPI | Schedule performance index (SPI = EV/PV) | Measures the conformance of the actual progress to the schedule, e.g., SPI < 1 means that the schedule efficiency is lower than planned |
| | Forecasting indicators | Description |
| BAC | Budget at completion | Planned cost of the project/work package |
| EAC | Estimate at completion | Cost estimate at completion |
| TEAC | Time estimate at completion | Total project/work package duration based on the actual performance up to a measurement point of the project |

Figure 1. An EVM graph.



costs (the planned value), and all the planned work has not been completed yet (the earned value is less than the planned value). As a consequence, the project will be completed later than planned and will be more expensive than budgeted for, assuming that the progress trend continues and corrective actions are not taken.

EVM has been regarded as particularly useful in large and complex projects. It is applied to different types of projects, such as engineering (Wei et al., 2016), construction (Balali et al., 2020; Bryde et al., 2018; Czemplik, 2014; Durga Sruthi & Aravindan, 2020; Proaño-Narváez et al., 2022), and software (Kamyabniya & Bagherpour, 2014; Sulaiman et al., 2006; Warburton, 2011) projects. However, there are known limitations when applying EVM in practice. For example, according to Hall (2012), the method does not distinguish between critical and non-critical project activities, variance in the performance of dependent tasks is hard to control, measures could be manipulated to appear positive, and the method requires plenty of up-to-date information, which might be difficult to reliably obtain from projects. The method is also criticized because it only considers the dimensions of cost and time and omits important performance measures, like quality and customer expectations (Hall, 2012; Hazır, 2015). Therefore, several researchers have further developed EVM by enhancing its capability as a project progress monitoring method (Acebes et al., 2015; Batselier & Vanhoucke, 2017; Chen et al., 2016; Hendiani et al., 2020; Naeni et al., 2011; Zohoori et al., 2019).

2.2. GBL in project management education

GBL methods, including educational games (also known as serious games), have been acknowledged as promising learning methods in higher education (Crocco et al., 2016), in engineering education (Udeozor et al., 2022), and in project management education (Calderón et al., 2018; Law, 2019; Petri et al., 2018). Prior results provide evidence that educational games may contribute positively to students' perceived learning. GBL as an instructional method may foster learning because of its ability to activate students with experiential learning and practice-based assignments (Barbosa & de Ávila Rodrigues, 2020; Rumeser & Emsley, 2019). Indirectly, GBL has an impact on learning by influencing students' motivation and interest (Hamari et al., 2016; Hartmann & Gommer, 2021; Jääskä et al., 2022; Martín-Hernández et al., 2021; Pando Cerra et al., 2022) as necessary preconditions for learning.

Non-digital games have previously been applied as part of EVM instruction (Jimenez & Beigh, 2020; von Wangenheim et al., 2012). The results have been encouraging from the perspectives of students' learning and motivation, but digital games have not been widely used in EVM teaching. According to the research on GBL's impact on science education, learning solutions with serious games were found to be more beneficial for knowledge transfer, gain, and retention compared to more conventional instruction methods (Riopol et al., 2019). We may assume similarities in science learning and EVM learning because both apply systematic quantitative and predictive models.

Despite the positive results regarding GBL methods used to teach project management and EVM, weaknesses, challenges, and a lack of research results have also been found regarding the effectiveness of the methods (All et al., 2016; Jaccard et al., 2022; Westera, 2019). One of the challenges is how to integrate gaming and learning in a pedagogically reasonable and purposeful way (Bado, 2022; Jaccard et al., 2022). Another issue is that learning the game mechanics and how to play take time prior to the actual gameplay (Jääskä & Aaltonen, 2022; Jaccard et al., 2022). Yet another problem in experience-based of a project management course at university level learning, such as GBL, might be that students play the educational games in a routine-like manner without achieving deep-level insights or internalizing the lessons (Westera, 2019). Therefore, the role of debriefing has been recognized as a culmination of the GBL process, where discussion and oral or written reflection deepen the learning and connection between the game content and curriculum (Bado, 2022; Boud, 1985).

3. Materials and methods

The research process of this study follows a one-group, posttest-only, quasi-experimental design (Kirk, 2009). In our study we conducted a quasi-experiment, where the students of the university

level project management course participated to the experiment (EVM learning solution with educational game and related activities). We did not apply pretest and had no control or comparison groups, which makes the nature of the experiment as one-group test. Posttest-only refers to research data collection method, where the data were collected post-game through student essays and feedback survey. Writing an essay was a final activity of our EVM learning solution.

Figure 2 illustrates the research process that was applied in this study. The five phases of the research process are explained together with references to chapters or sub-chapters, which contain more details of each phase.

The first phase of the research process is 1. *Experiment design*, where the learning solution design is aligned with the expected learning outcomes. Educational games were designed and implemented to support learning EVM with practice-oriented assignments. The learning package consisting of educational games and related activities was called as EVM learning solution and it is described in chapter 3.1.

In the next phase 2. *Quasi-experiment*, the students played the educational games (among other activities) to learn EVM individually, as a group and with the teacher to practice the EVM method with increasing difficulty built in the games. The basic idea of the GBL learning solution to teach and learn EVM is described in chapter 3.2.

In phase 3. *Data collection* the data collection was carried out. Each of the students reflected their learning of EVM and the game-based learning process by writing their perceptions into an essay. Writing an essay was a mandatory assignment but taking a feedback survey was voluntary. Students' feedback in essays and surveys were used as empirical data of this research as elaborated in chapter 3.3.

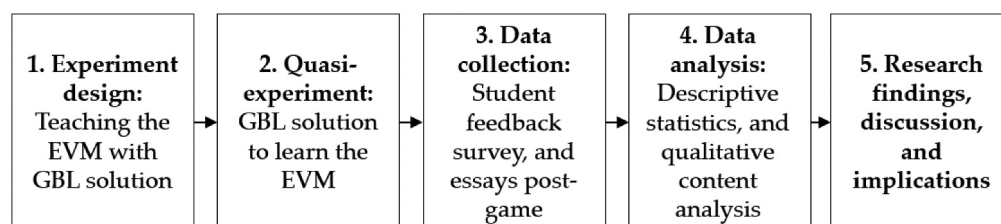
In phase 4. *Data analysis*, we applied qualitative content analysis method (Miles et al., 2014) to students' essay texts to identify and analyze their perceptions of the experimented GBL solution for learning EVM (chapter 3.4). The essay data were coded to identify patterns and to interpret the data. In the feedback survey, students subjectively evaluated with a numeric scale how the GBL method to learn EVM affected their competence. Their survey responses were reported as descriptive statistics which were used to validate the results of the qualitative data analysis and to provide an overall view of how the students themselves evaluated the achievement of the expected learning outcomes.

The final phase of the research process is 5. *Research findings, discussion and implications* are addressed in chapter 4. Findings followed by discussion and implications are presented in Chapter 5.

3.1. Experiment design: teaching EVM with a GBL solution

Teaching EVM was part of a higher education project management course, which introduced the basics of project management, such as scope, schedule, and cost management; project organization; and stakeholder management. Based on ten years of experience of teaching EVM to project management students, some pedagogical and practical issues were taken into account. First, EVM

Figure 2. Research process.



utilizes monetary values together with mathematical formulas, which may lead to a situation where students learn the formulas and are able to perform routine-like calculations of indexes, without understanding the meaning of them as project progress status indicators. Second, challenges exist in terms of teaching students to comprehend why and how to apply EVM to project monitoring, controlling, and estimating. Third, teaching how EVM charts are generated based on earned and planned monetary values and how to interpret the diagrams seems to be demanding. Overall, the challenge with the EVM education is that theoretical-level learning may have occurred, but deeper learning of how to flexibly apply the method for project management monitoring and controlling purposes may not have taken place. To change and improve the earlier practices of the EVM education, a GBL solution was designed for the experiment in this study.

To avoid the potential pedagogical flaws and practical challenges introduced in section 2.2, in our GBL experiment, we paid special attention to the meticulous design of our learning solution. We designed the learning to contain a suitable number of progressive challenges (Hamari et al., 2016) and a balance of ludic activities (the games) and knowledge transfer (lectures, feedback, debriefing) assignments (Giessen, 2015; Ravysse et al., 2017). Since the educational game we applied is fully configurable, we were able to tailor the game in coherence with the pedagogical objectives of an EVM learning solution. We set aside time to introduce the gameplay and for discussions with the teacher and peers during the online classes. We designed a post-game reflection activity to ensure that the students contemplated what they had learned from the in-game events and other learning solution assignments. Debriefing and feedback guided the students in situating their GBL experiences and perceived learning within a relevant context (Ravysse et al., 2017).

The learning solution design started with the definition of the expected learning outcomes. The nature of the learning outcomes is quite technical and specific because the method contains mathematical formulas and numeric and graphical analysis to explore project status and future progress. The expected learning outcomes were defined as follows: After the course module, the student is able to

- describe the concept of the earned value method (EVM) and its principles,
- calculate project performance indexes using EVM,
- apply EVM to compare a project's progress with its baseline budget and schedule, and
- estimate a project's total cost and schedule using EVM.

The GBL solution for teaching EVM was divided into phases, which aimed to develop an understanding of the subject matter based on the progressing complexity of activities and assignments. Four educational games built on a game platform were integrated into the learning solution, which also included a description of the learning outcomes, instructions, and supporting documents for both the teacher and students. The first three games were rather simple and short in duration. Their focus was on understanding the principles of EVM and how it can be applied to track project progress. In the fourth game, "Townhouse construction project," the focus was on how to manage a complex project and what the role of EVM is in the management of such a project. In this game, the aim was to provide learners with a realistic context to apply their project management skills.

We present the activities, methods, and sub-learning objectives of the EVM learning solution components in Table 2. The learning activities are numbered and presented in the same order as they were conducted in our experiment. Activities 1–3 are prerequisites for understanding EVM and playing the game (pre-game activities). Activities 4–7 are gameplay activities, and activity 8 is a post-game activity to reflect on the learning and learning experiences.

3.2. Quasi-experiment: GBL solution to learning EVM

The learning solution for teaching and learning EVM was explored by 39 students as part of a project management course at university level in spring 2022. EVM was taught as part of the

Table 2. EVM learning solution

| N | Activity | Description | Method | Sub-learning objective |
|----------|--|---|--|--|
| 1 | Project budgeting | Work Breakdown Structure and project budget calculations using the townhouse building project example | Individual assignment with MS Excel | Understand the concept of planned value |
| 2 | Introduction to EVM theory | EVM concept and principles | Teacher's lecture and reading materials | Understand the basics of EVM |
| 3 | Playing of EVM Game 1 | Game with a simple task network and EVM graphs | Teacher's presentation of the game (project task network, project progress, EVM indexes and graphs), voluntary gameplay individually | Familiarize oneself with the game mechanics, track conversion value calculations using variables and graphs as the project progresses |
| 4 | Playing of EVM Game 2 | Game with a simple task network and EVM graphs, cost and schedule changes | Teacher's presentation of the game, gameplay as a group assignment, discussion with the teacher and students regarding the game events after the gameplay | Learn to interpret EVM graphs, calculate cost and schedule performance indexes |
| 5 | Playing of EVM Game 3 (1st round) | Game with a simple task network requiring external subcontractor and material orders, EVM graphs, game events, such as questions for the players, cost and schedule changes | Individual assignment | Learn to make decisions, manage risks, apply EVM to analyze and inform about the project progress current status, total cost, and schedule |
| 6 | Playing of EVM Game 3 (2nd round) | The same as above | Teacher playing the game, and students making informed decisions in order to get the highest possible game score, debriefing discussion after the gameplay | Learn to analyze the project progress status and make project management decisions |
| 7 | Playing of Game 4 – Townhouse construction project | Game with a complex and long task network designed to simulate the schedule, cost, and risk management of a townhouse building project | Voluntary individual exercise | Learn to apply EVM to analyze the project progress and forecast the total cost and duration, learn to make decisions and manage risks |

(Continued)

| N | Activity | Description | Method | Sub-learning objective |
|---|---|--|-----------------------|---------------------------------------|
| 8 | Writing a reflection essay on learning outcomes | An essay of 600–1000 words to reflect how the learning outcomes were achieved and how the GBL solution contributed to learning EVM | Individual assignment | Contemplate EVM learning achievements |

intensive, five-credit (European Credit Transfer System, ECTS) project management course, which consisted of four contact days of online teaching, self-studying, assignments, and a final exam.

In this experiment, we used a non-commercial, university-built computer game environment. All the students received a similar treatment, so they were involved in three (or optionally four) gameplay activities to practice and learn EVM, as described in section 3.1. The game complexity increased, so the first games were rather easy, but the last one contained more challenges for the students. We used a digital educational game environment, which is completely tailorable and can be adapted to different levels of complexity, types of project management phenomena, and learning goals. Figure A1 in Appendix A illustrates the EVM learning solution portal, through which the project contract, expected learning outcomes, instructions, and games were delivered.

The idea of the game is that a student (or group of students) acts as a project manager and makes informed project management decisions to optimize the schedule, budget, and quality. The game is turn-based, where the turns simulate the project schedule, for example, in weeks. A player is supposed to reserve the required contractors, order materials, and allocate resources to project tasks at the right times to ensure the successful progression of the project. The simulated project includes a sequential task network, where task dependencies define the order in which they should be completed. As in real-life projects, stochastic events, problems, or changes within the game require informed actions and decisions from the player (project manager). Game events and risks may cause delays or extra costs, which can affect the project results. Figure 3 illustrates the user interface of the EVM game and the key functionalities.

Figure 4 shows an example of a game event, where a player needs to perform calculations using EVM to answer a question from the Chief Executive Officer of the company responsible for the fictitious project. The game provides immediate feedback for the student regarding their answer. Correct answers affect the game end score positively. Figure 5 shows an example of the game’s EVM curves, which are used to visualize and analyze project progress.

Figure 3. Example of the user interface of the EVM game.



Figure 4. Example of a player's game event.

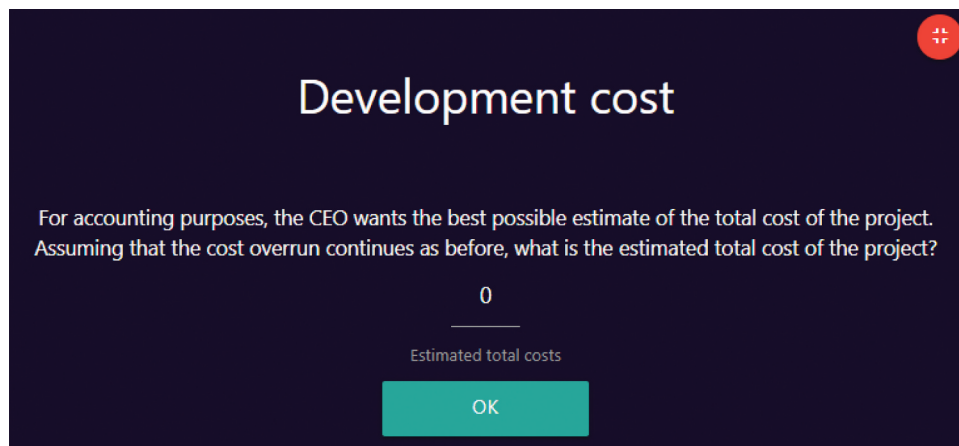
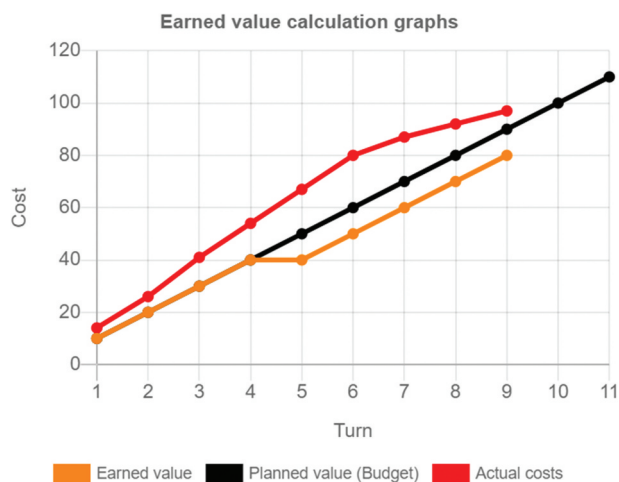


Figure 5. Example of an EVM graph from the game.



3.3. Data collection: student feedback survey and essays

Student feedback on the game and learning experience was collected with an online, post-game survey questionnaire after the gameplay sessions. The survey was voluntary, anonymous, and consisted of three sections: the background, a Likert-scale questionnaire, and open-ended questions. We received and analyzed 31 completed surveys. The background data were collected to understand the characteristics of the student sample. A symmetric five-point Likert-scale questionnaire was applied to gather data about the students' subjective experiences of achieving their learning outcomes.

At the end of the EVM module of project management course, the students were asked to write a reflective essay of 600–1000 words to contemplate what they had learned about EVM and how the educational game had contributed to their learning (Appendix B). Writing the essay was a mandatory assignment, and it was assessed with a weight of 30% in the course grading. In total, 39 essays written in the Finnish language were received, with an average length of approximately 580 words. Three of the documents were excluded from the analysis because of the students' absence from gameplay activities. The authors of this article translated the themes, categories, and illustrative quotations into English in the data analysis phase of the research process.

3.4. Data analysis: descriptive statistics and qualitative content analysis

The data from the Likert-scale questions of the student feedback survey regarding the achievement of the learning outcomes are reported as descriptive statistics with mean and standard deviation values (Boone & Boone, 2012). To analyze the student essays, we applied a qualitative data analysis method adopted from Miles et al. (2014), where we performed data condensation and coding to organize, sort, and focus on the most relevant data. To analyze the data and draw conclusions, we created graphs that illustrate the themes and categories observed in the essay texts, which are presented in section 4.3.

4. Research findings

4.1. Student sample

The analysis of the students' ($n=31$) background data indicated that the student sample in our quasi-experiment was rather homogenous. Of the students, 94% had a bachelor's degree, and they all had permanent jobs. The majority of them (68%) had less than two years or no experience of project management work. Of the respondents, 55% said that they had little or no experience of educational games or simulations, and 42% had played "some." Therefore, we can assume that GBL was a fairly new educational method for most of the students in the experiment. The average age of the students was 38.3 years old, and 83% of the respondents were male.

4.2. Descriptive statistics

In the online survey, the students subjectively evaluated how the educational method and learning solution affected their competence. Students were asked to use a five-category scale, ranging from "strongly disagree" (1) to "strongly agree" (5), to evaluate statements on whether the GBL solution had increased their ability regarding each of the four planned learning outcomes. The neutral category was defined as "neither agree nor disagree." The summative descriptive statistics are shown in Table 3, including frequency per Likert-scale category, mean, and standard deviation values. The overall student satisfaction in terms of achieving the learning outcomes was high, since the frequency of "agree" or "strongly agree" is over 70% for each of the learning outcomes, which is supported by the mean values of approximately 4.0 (of maximum 5.0).

4.3. Learning EVM with the GBL method

The following subsections consist of key findings from the students' essays structured according to the expected learning outcomes of our experiment with a GBL solution. The first-order categories are determined based on the students' learning perceptions, and these are synthesized into second-order themes (the students' lessons) in connection with the expected learning outcomes, as shown in Figure 6.

4.3.1. Describing the concept of EVM and its principles

We introduced the first three (pre-game) activities of the experimented learning solution in section 3.1. Project budgeting was taught and practiced as a pre-game orientation to project cost management practices. The project cost baseline was created by estimating costs for the project work package of building a townhouse, which was regarded as an "easy to understand" example for the students. The learning goal of this assignment was to introduce the concept of planned value to students.

The teacher gave a lecture about EVM prior to the first EVM game. Students mentioned in their essays that they regarded the lecture about EVM principles, terminology, and goals as an important precondition for learning the method later on with the games. As one student stated, "The introduction to basic terminology prior to the game aided my comprehension and helped me to play the game and succeed at it, which motivated me to learn the basics." Another student wrote, "The game itself did not teach the basics of project management or EVM, but these need to be studied beforehand to fully benefit from the game."

Table 3. Students' responses regarding how the GBL solution affects the achievement of learning outcomes (n = 31)

| The GBL solution increased my ability to: | Strongly disagree | Disagree | Neutral | Agree | Strongly agree | Mean | Standard deviation |
|--|-------------------|----------|---------|--------------|----------------|------|--------------------|
| Describe the earned value method concept and its principles | 0% | 3.2% | 16.2% | 64.5% | 16.1% | 3.9 | 0.7 |
| Calculate project performance indexes using the earned value method | 0% | 3.2% | 6.5% | 67.7% | 22.6% | 4.1 | 1.4 |
| Apply the earned value method to compare project progress against a baseline budget and schedule | 0% | 0% | 19.3% | 56.1% | 22.6% | 4.0 | 0.7 |
| Estimate a project's total cost and schedule using the earned value method | 0% | 3.2% | 12.9% | 54.9% | 29.0% | 4.1 | 1.4 |

The teacher played the first EVM game to demonstrate the budget and schedule variance, the reasons behind this, and the consequences in terms of EVM measures and graphs. In their essays, the students described how the first game effectively demonstrated the influence of stochastic events on the actual project costs and schedule. The following quotes from students illustrate this: *“The game made me think about the causes and effects of project events”* and *“The game demonstrated unexpected events, which are a part of real projects. The project budget is an estimate of the expected costs, and the realized costs may differ from them.”* According to descriptive statistics of students' own evaluation regarding how the educational method affected their competence, majority of them (81%) agreed or strongly agreed with the statement of *“The GBL solution had increased the ability to describe the EVM concept and its principles”*.

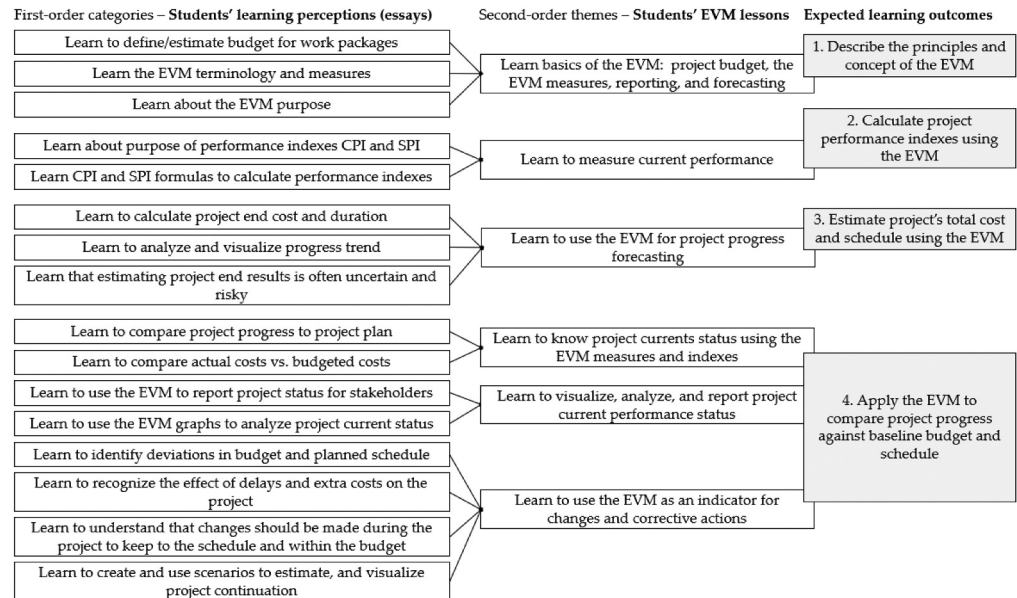
4.3.2. Calculating project performance indexes using EVM

After the introduction to the learning solution, students played the second game as a group assignment. The game dashboard contained schedule performance index (SPI) and cost performance index (CPI) values, which could be monitored and used when estimating the project end status with regard to the cost and schedule as the project proceeded. Students described how *“The game made me understand how schedule delays and extra costs affect projects and, consequently, performance indexes”* and *“When you know how to calculate performance indexes, you can estimate the current status of the project and whether it is behind or ahead of schedule and how the costs are looking.”*

The game activity network was similar to that of the first game. During the gameplay, the students were asked to input EVM measures and estimates for the total cost budget and duration of the project based on status date values. Students could use the EVM graph provided by the game to choose the correct values, but as the game proceeded, the indexes were no longer available. The students needed to find and learn the formulas for the SPI and CPI and calculate the values. This game event was regarded useful from a learning point of view. A student described how *“The best part of the game was when you had to calculate performance indexes from chart values, because it taught you the most.”* Another student recognized that *“The game questions forced one to learn how to calculate performance indexes.”* One of the students summarized this practical learning: *“The game helps one to internalize how the theory is connected to practice.”*

The calculation of performance indexes was required in Games 3 and 4 as well. In their feedback, several students mentioned that when there were many games or they were played multiple times, the repetition helped and forced them to memorize the formulas. As one student stated, *“When calculations needed to be done several times in sequential games, the basics of them stick in a learner's mind.”* Students also mentioned how, instead of “guessing” the project performance

Figure 6. Students' EVM lessons from the EVM learning solution.



and current status, they now have a tool that can be used to measure project performance for analysis, change, and reporting purposes: *"I will start applying performance measuring in my job. Often the calculations are done after the project end, but changes [in the project] should be made earlier on to keep to the schedule or to prepare for additional costs."* Descriptive statistics of students' own evaluation regarding how the GBL as an educational method affected their ability to calculate project performance indexes using EVM indicate, that 90% of the students agreed or strongly agreed with achieving this learning outcome.

4.3.3. Applying EVM to compare the project progress against the baseline budget and schedule
 Games 3 and 4 were designed and tailored to be more versatile than the first two games in order to challenge students to apply EVM. The games included activities where materials needed to be ordered and contractors reserved to accomplish the project tasks. Stochastic events affected the course of the games. Delays and additional costs were built into the learning solution to simulate what might happen in real projects. This assisted students in realizing the effect of unexpected events on project performance. For instance, one student described how *"The game concretized the performance indexes. For example, one could recognize how if an obstacle (like bad weather or a problem in the order/supply process) delayed the project work, the schedule performance index would fall."*

The EVM graphs played an important role in the learning solution. They visually and numerically assisted students in interpreting the current status of the project and in identifying trends to predict its future progress. This may have helped the students learn not only to analyze the graphical presentations of project cost curves, but also to use them in their own projects to visualize a project's current and future states for communication purposes. One student wrote, *"With EVM, the project manager can fluently monitor the project's progress and report to stakeholders."*

The students pointed out that the game questions made them understand the salience of knowing the project status (under/on/over budget and ahead of/on/behind schedule) at any point in time during the project and of being able to estimate its future progress using EVM. They realized that performance indexes are signals or triggers for making decisions, which affect the end results of the project. For example, a student stated: *"Based on performance index values, it is possible to make decisions that influence the project's total cost and schedule."* Another student

expressed how *“It is important that project managers identify schedule and cost aberrations so that corrective actions can be taken as early as possible.”* The deep learning of EVM is highlighted through the following comment: *“... even if 50% of the budget is spent, it does not necessarily mean that 50% of the budgeted value of the work performed (earned value) is achieved.”* One student corroborated this view: *“I learned that if the project is under budget (the planned costs), it does not necessarily mean that it is proceeding well, because the project might be behind schedule or the earned value might be lower than it should be.”*

The EVM games helped the students to create scenarios to forecast how the project would continue. They said they learned to observe and estimate how the project would proceed if the current trend of delays continued or if the rest of the project proceeded as planned from the status date onwards. A student wrote, *“Applying EVM to estimate the project end cost and schedule using different scenarios to project future progress was interesting. The project game and chart helped to concretize it.”* Descriptive statistics indicate that most of the students (79% agree/strongly agree) thought the experimented GBL method increased their ability to apply EVM to compare a project's progress with its baseline budget and schedule.

In the students' essays, there was also criticism directed at EVM as a method. Some students pointed out that EVM may not be suitable for agile project management. Another worry is the fact that the status date measures may not be up to date, because monetary values of the actual costs may not be available: *“EVM measures will not be accurate in real-life projects, because actual money data are not always available in real time.”* In their writings, the students also contemplated how, because EVM utilizes status date values, the status information can be misleading and inaccurate due to, for example, missing data. One student mentioned that *“... status date EVM indexes may indicate remarkable deviations from the project's plan, but the situation will usually plateau later on as the project proceeds. Because of that, it is difficult to know when there is enough data to make the right decisions”* and the *“project budget is just an estimate for costs, which vary on a daily/weekly basis.”*

4.3.4. Estimating the project's total cost and schedule using EVM

All the experimented learning solution games required that students were able to estimate the project end week and total costs. Students stated that they learned the formulas and how to utilize the EVM graphs, as described in sections 4.3.1–4.3.3. They recognized how project risks and unexpected costs could still affect the project's success and results. Students wrote that *“Forecasting the project results is uncertain and risky”* and *“You can apply EVM for end results estimation if you can evaluate whether the effect of potential problems is a one-off event or if it will continue influencing the project negatively.”* Based on students' own evaluation of achieving learning outcome, 84% of them (agreed/strongly agreed) with the statement of *“The GBL solution had increased the ability to estimate project's total cost and schedule using EVM”*.

4.3.5. Project management lessons

The reflective essay writing, as a post-game assignment and the last exercise of the experimented learning solution, turned out to be useful, also from a project management deep learning perspective. In addition to the findings on EVM learning, we synthesized the project management lessons in Figure 7 and elaborate on them in the following paragraphs.

The students expressed how, while studying EVM, they learnt that as a project manager they need to be prepared for unexpected events and risks and learn to tolerate uncertainty and to react accordingly at the right moment to get the project back on track again. The importance of knowing the project's situational status was highlighted in the following ways: *“Project monitoring and controlling is crucial, because project funding often depends on how [well] the project proceeds”* and *“The game concretized and helped us to realize that a lot of [stochastic] events may happen during the project's lifespan, and one should be prepared for them.”*

The students pointed out that cost and schedule corrections need thorough consideration because they may compromise customer satisfaction (the project scope) or the project’s product quality. One student wrote that “... it might be possible to accept deviations in quality to keep to the schedule and budget, but as a consequence there might be defects or faults in the end product.”

Many students mentioned how learning EVM provided them with a tool to make informed decisions regarding, for example, project resourcing, subcontractors, or scope changes. They wrote, “The game helped me to understand the benefit of ordering the materials [needed in the project] at the latest possible time” and “The project may proceed faster if new personnel are hired, but the project costs are increased by salary costs.” They recognized that their ability to determine and justify change proposals regarding managerial or steering group decisions had improved, which is necessary to ensure a project’s success. As one student expressed, “The earlier you can recognize project schedule and budgetary problems, the earlier you can propose corrections.”

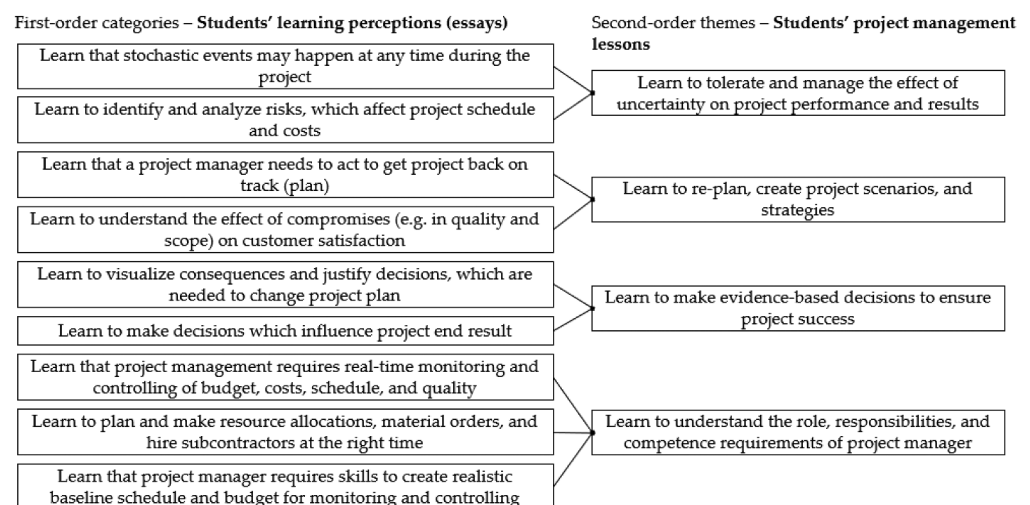
Students felt that the EVM learning solution made them realize and comprehend the responsibilities and skills required of a project manager when leading a project. They, for example, mentioned that “Project success depends on how professionally and well the project schedule and budget are planned” and “The project’s total cost and duration must be updated constantly during the project as any changes influence them.”

5. Discussion

This study applied a quasi-experimental research design to explore how students learned EVM as part of their project management course. An experimental GBL solution was designed and applied as an educational method. The study focused on investigating and reporting students’ learning perceptions, yielding a new understanding of GBL methods’ role in project management education and in learning EVM in particular. The effect of a GBL method on students’ learning was measured post-game with a reflective essay, which students wrote as a compulsory course assignment and as an inclusive part of the experimented learning solution.

EVM is a project management method, where project performance measures are used to understand the current status of a project’s progress and to estimate the project duration and cost at completion (Anbari, 2003; Bryde et al., 2018; Fleming & Koppelman, 2010). Teaching EVM may appear demanding, because the method may appear too conceptual and mathematical (Jimenez & Beigh, 2020), with a lack of opportunities for exercising theoretical learning (Ramazani & Jergeas, 2015; von Wangenheim et al., 2012). GBL has a lot of potential in project management education (Jääskä & Aaltonen, 2022; Jaccard et al., 2022; Riopel et al., 2019), but the

Figure 7. Students’ project management lessons from the game-based EVM learning solution.



effectiveness of the method needs more research-based proof (All et al., 2016; Law, 2019), such as that provided by this study. In particular, more research on the detailed mechanisms and learning paths through which students learn complex phenomena with GBL is still needed.

We built our GBL solution using a tailorable educational game platform, where EVM could be practiced through fictitious projects. We concentrated on mitigating potential pedagogical and practical flaws in our GBL solution design. First, the GBL solution had to challenge students (Hamari et al., 2016), second, enable knowledge transfer with interactive gameplay activities (Giessen, 2015; Jaccard et al., 2022; Ravyse et al., 2017), and third, be situated in a context through debriefing (Bado, 2022; Ravyse et al., 2017; Westera, 2019).

Our learning solution design presented increasing challenges for learners. Lectures, project budgeting exercises, and game demonstrations helped with orienting the students regarding the EVM theory and its purpose. Our educational games were tailored so that the first one was the easiest and the fourth game was the most difficult. The majority of the students regarded the games as being sufficiently challenging, but some students experienced the games as being too easy for higher education.

In their essays, the students discussed and contemplated their EVM lessons but also, on a more generic level, what they learned about project management. Their writings reveal that, in addition to just learning EVM, a more profound understanding of project management processes, practices, and competences was gained. For example, students pointed out that they had learned the following:

- to tolerate and manage the effect of uncertainty on project performance and results,
- to re-plan and create alternative project scenarios and strategies,
- to make evidence-based decisions to ensure project success, and
- to understand the role, responsibility, and competence requirements of project managers.

In summary, according to the students' opinions of the experimented learning solution and insights into achieving the expected learning outcomes, the GBL solution helped students to learn the EVM concept and how to apply it. The learning solution enhanced learning processes because it provided students with a learning environment to put theory into practice based on gameplay activities. The reflective essays, as a post-game activity, fostered learning, as the students were required to contemplate their perceived learning processes and the influence of the GBL method on achieving their learning outcomes. The survey results of the students' experiences of achieving the learning outcomes were reported as descriptive statistics in this paper, and they corroborate this insight.

5.1. Educational implications

The findings of this study suggest that GBL can be applied to facilitate EVM education. Based on our results, the learning of an important but rather complex theoretical method, such as EVM, can be fostered when students are able to apply and practice the method in a simulative game environment. EVM exercises with educational games may mitigate the challenge of understanding the usability of EVM as a practical tool for project management. We suggest that educational games are integrated into instruction so that pre-game and post-game activities are considered, designed, and seamlessly implemented as a significant part of learning solutions.

The key lessons learned and presented in the following section will help to understand and guide the design of a GBL solution to educate project management phenomena and practices. We assume that these lessons are not specific to teaching project management methods, like EVM, but can be applied to the design and implementation of other learning solutions outside of the scope of project management as well. Key lessons learned are:

- Ensure that the theoretical base for GBL learning is offered through, for instance, lectures, reading materials, and demonstrations as pre-game activities.

- Reserve enough time to teach the gameplay requirements, rules, and practicalities before the actual gameplay so that the learning focus will be on the game events rather than the game mechanics.
- Build challenges into the GBL solution: Increase the complexity of the GBL exercises and learning activities to gradually build knowledge, starting with easy assignments and games and varying between individual and group work assignments.
- Build repetition into the GBL solution: Repetition and applying games with varied assignments help students to memorize and learn.
- Include discussion and feedback as part of the instruction: Deeper learning regarding the subject may occur after the game session when the game events are discussed and contemplated together.
- Consider incorporating learning diaries or written reflections into the learning solution as post-game activities: Reflection on lessons and achieving their learning outcomes help students to repeat, think, contemplate, and consequently, internalize the learning subjects within a wider context.

5.2. Limitations and further research

The present study has some limitations, which may limit the generalization of the findings. Our EVM learning solution focused on teaching how schedule and cost performance indexes can be applied to monitor the current status and forecast the end results of a project. Performance indexes give situational information about a project's status, and the estimation of a project's end result assumes the continuity of the current trend. For future investigation purposes, more versatile game-based EVM learning solutions could be created to teach project monitoring and controlling. For instance, more measures and variance analysis could be incorporated into the learning solutions, and the games could be made more complex with challenging stochastic events and risks, which would require the trying out of different strategies to ensure successful project completion.

As a result of the quasi-experimental research design, we did not have a comparison or control group. Further research with a comparative design could be conducted to analyze the effectiveness of a GBL solution for learning EVM, where different learning methods are applied to similar student groups. Further research could also be performed to understand whether students' personal characteristics, such as gender, prior experience of games, educational background, work experience, and different learning styles and strategies, impact the results.

Our findings are based on students' subjective perceptions of learning EVM. The students' essays were assessed and affected the grading of the course, but we did not examine, for example, whether the students gave correct answers to the questions that the game asked or the game scores. Thus, we suggest that future research studies GBL solutions for learning project management phenomena and methods not only based on qualitative research, but also from learning performance perspectives. For example, qualitative or quantitative learning data from game events could be stored and analyzed to provide evidence of learning. Moreover, experiments with sample and control groups could be used, where assignments or course modules are assessed after different educational treatments for student groups.

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Appendices

Appendix A

Figure A1. The EVM learning solution in the PBG portal (teacher's view).

PROJECTBUSINESSGAME / LS20EN – EARNED VALUE MANAGEMENT
Dark Guest

LS20EN – Earned Value Management

You are working as a project manager for the design and implementation of an information system. Your task is to implement projects according to budget, in schedule, and follow project progress using earned value method.

Learning outcomes

- describe the principles and concept of earned value method
- calculate project performance indexes using earned value method
- apply earned value method to compare project progress against baseline budget and schedule
- estimate project's total cost and schedule using earned value method

The objective in this learning solutions is to learn how to use EVM method to manage and control project progress.

The learning solution includes three games:

- Game 1: Learn to follow project progress
- Game 2: Use EVM method to estimate how project will progress in future (estimate duration and total cost)
- Game 3: Demonstrate that you know how to use EVM method to analyze project progress and make decisions to improve project profitability

LS20EN – Earned Value (Game 1)

Play

| | | | | | |
|--------------|---|--------|------|--------------------|---|
| 0 | - | - | - | - | Available |
| Times Played | - | Points | Rank | Estimated Duration | ⓘ Status |

LS20EN – Earned value (game 1)

You work as a project manager in an information systems implementation project. Track conversion value calculation using variables and graphs as the game progresses. In this game, you cannot influence the progress of the project and the costs incurred. When you have completed the project, the customer will pay a fixed price of 150k€. If the project is delayed from the planned schedule, then you will have to pay a penalty of 5k € / week for the delay.

| | | | | |
|------|------|--------|-------------|--------|
| RANK | NICK | POINTS | GAME REPORT | POINTS |
|------|------|--------|-------------|--------|

Appendix B

Please write a short 1–2-page (600–1000-word) essay where you contemplate how you achieved the EVM learning outcomes. Think about each of the four learning outcomes separately.

1. Describe the concept of the earned value method and its principles
 - describe what you have learned during the course regarding the learning outcome
 - reflect on how the educational games and their events influenced the achievement of the learning outcome
2. Calculate project performance indexes using the earned value method
 - describe what you have learned during the course regarding the learning outcome
 - reflect on how the educational games and their events influenced the achievement of the learning outcome
3. Apply the earned value method to compare the project progress against the baseline budget and schedule
 - describe what you have learned during the course regarding the learning outcome
 - reflect on how the educational games and their events influenced the achievement of the learning outcome
4. Estimate the project's total cost and schedule using the earned value method
 - describe what you have learned during the course regarding the learning outcome
 - reflect on how the educational games and their events influenced the achievement of the learning outcome