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DELIVER! – An educational game for teaching Earned Value Management in computing courses

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ABSTRACT

Context: To meet the growing need for education in Software Project Management, educational games have been introduced as a beneficial instructional strategy. However, there are no low-cost board games openly available to teach Earned Value Management (EVM) in computing programs.
Objective: This paper presents an educational board game to reinforce and teach the application of EVM concepts in the context of undergraduate computing programs complementing expository lessons on EVM basics.
Method: The game has been developed based on project management fundamentals and teaching experience in this area. So far, it has been applied in two project management courses in undergraduate computing programs at the Federal University of Santa Catarina. We evaluated motivation, user experience and the game's contribution to learning through case studies on Kirkpatrick's level one based on the perception of the students.
Results: First results of the evaluation of the game indicate a perceived potential of the game to contribute to the learning of EVM concepts and their application. The results also point out a very positive effect of the game on social interaction, engagement, immersion, attention and relevance to the course objectives.
Conclusion: We conclude that the game DELIVER! can contribute to the learning of the EVM on the cognitive levels of remembering, understanding and application. The illustration of the application of EVM through the game can motivate its usefulness. The game has proven to be an engaging instructional strategy, keeping students on the task and attentive. In this respect, the game offers a possibility to complement traditional instructional strategies for teaching EVM. In order to further generalize and to strengthen the validity of the results, it is important to obtain further evaluations.

1. Introduction

Project management (PM) is the discipline of planning, executing, monitoring and controlling resources to successfully complete a project. It is a key factor for delivering successful projects on time and within budget. In recent years, all business sectors, including the software sector, have increasingly recognized PM as a core competence [1,2]. As a consequence, the need for project managers has never been greater than today [3]. Many organizations are looking for trained project managers, who can fill the gap between executive managers and the "techies". As this occurs, the need for PM education and training in the software sector grows. Project managers have long been trained on the job with little formal training on PM [4–6]. Many project managers take on their job reluctantly and unprepared [7]. Especially, in computing courses, PM is still considered a minor topic [8], taught as only one of several topics in software engineering classes. To compensate for this lack of formal PM education, a vast variety of professional training courses are offered and certifications, such as, PMP – Project Management Professional (http://www.pmi.org) are demanded for PM professionals.

Another issue is the way in which PM is typically taught. Expository lessons are still the dominant instructional technique [9]. They are adequate to present abstract concepts and factual information. But, they are not the most suitable for higher-cognitive objectives aiming at the application and transfer of knowledge to real-life situations [10]. On the other hand, practical constraints regarding class duration and instructors' effort usually limit the

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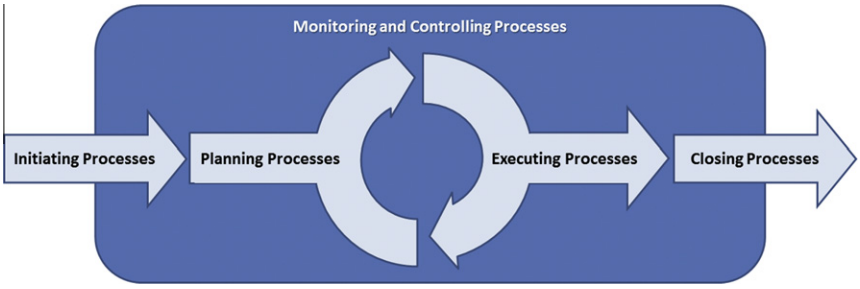

Fig. 1. Basic project management phases [2].

possibilities of students to exercise the concepts and techniques [11]. Therefore, it remains a challenge to teach students in a compact, but effective and motivating way.

In this context, serious games have become an alternative offering various advantages [9]. They can help to reinforce basic concepts. Games can also contribute to teach higher-cognitive competencies illustrating their application and relevance with acceptable training time and instructor load [12]. And, building on the engaging nature of games, they can make learning more fun, if not easier [13].

In this context, we developed an educational board game DELIVER! to support the learning of Earned Value Management as an important part of teaching PM in computing courses.

2. Background: Earned Value Management

Project management is the application of knowledge, skills, tools and techniques to project activities to meet the project requirements. Basic phases of the PM life cycle include: project initiation, planning, execution, monitoring and control and closing (Fig. 1) [2].

In relation to the focus of this paper, monitoring and controlling processes are required to track, review and regulate the progress and performance of the project (monitoring) and to identify areas in which changes are required and to initiate the corresponding changes (controlling) [2]. Their key benefit is that project performance is observed and measured regularly to identify variances from the project plan. It includes monitoring and control of work progress, schedule and costs, in order to measure, compare and analyze schedule performance (e.g., comparing actual start and finish dates with planned ones) as well as budget performance variations in the actual spending.

One of the most prominent techniques to monitor and control projects is Earned Value Management (EVM) [14]. It can play a crucial role in answering management questions, such as, if the project is behind schedule, over budget, what the remaining work is likely to cost, etc.

EVM allows the indication of performance variances and indices based on the planned values in the project plan baseline and actual work performed and cost (Fig. 2).

EVM includes the following key dimensions:

- PV – Planned Value is the authorized budget assigned to the work to be accomplished for an activity or work breakdown structure component.
- AC – Actual Cost is the total cost actually incurred and recorded in accomplishing work performed for an activity or work breakdown structure component.
- EV – Earned Value is the value of work performed expressed in terms of the approved budget assigned to that work for an activity or work breakdown structure component.

Using these key factors, variances and/or performance indicators with respect to time and cost can be calculated:

- Schedule Variance (SV) is a measure of schedule performance calculated by: $SV = EV - PV$.
- Cost Variance (CV) is a measure of cost performance calculated by: CV = EV – AC.
- Schedule Performance Index (SPI) is a measure of progress achieved compared to progress planned on a project. $SPI = EV/PV$
- Cost Performance Index (CPI) is a measure of the value of work completed compared to the actual cost or progress made on the project. $CPI = EV/AC$

EVM can also be used for forecasting:

- EAC – Estimate At Completion forecast for work performed at the budgeted rate. This method accepts the actual project performance to date as represented by the actual costs, and predicts that all future work will be accomplished at the budgeted rate. $EAC = AC + BAC - EV$ with BAC – Budget At Completion.

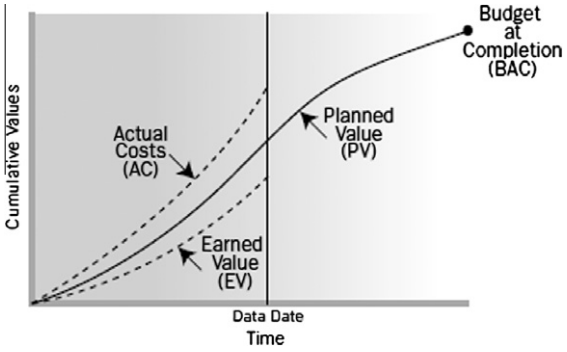

Fig. 2. Overview on EVM key dimensions [14].

These measures support project monitoring as shown, for example, in Fig. 3.

Providing these measures by integrating work progress, schedule and cost information, EVM is a valuable tool for project monitoring and control.

2.1. Teaching EVM in computing courses

A course on PM is considered a part of any kind of undergraduate computing program [8]. Learning objectives of such a course, among others, include enabling the students to monitor and control projects, presenting EVM as a performance monitoring method. On the undergraduate level, it is expected that students acquire EVM knowledge on the cognitive levels of remembering,

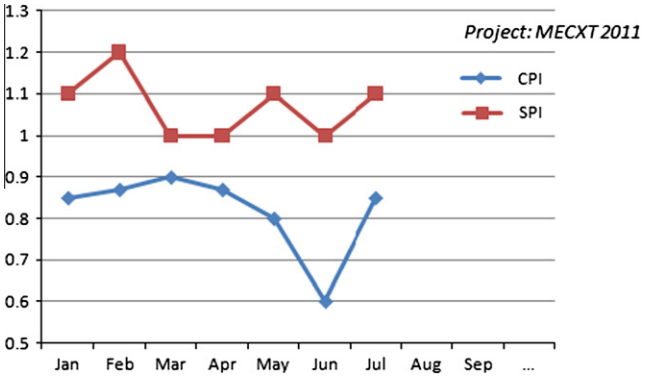

Fig. 3. Example of Cost and Schedule Performance Indexes. The performance indexes reveal that the project has been on schedule but over cost since early in the project. A large deviation of cost performance happened in June.

understanding and applying in accordance to the revised version of Bloom's taxonomy of educational objectives [15] (Fig. 4).

At the end of the instructional unit on project monitoring and control, students should be able to:

- Name key concepts and indicators related to EVM and to remember the respective formulas (remembering).
- Differentiate between types of indicators and to interpret their meaning (understanding).
- Calculate indicators and use them to monitor projects in concrete situations (applying).

2.2. Instructional strategies for teaching EVM

Instructional strategies determine the approach a teacher may take to achieve learning objectives. In general, we can differentiate five categories of instructional strategies as illustrated in Fig. 5 [16].

And, although direct instruction, such as, expository lectures, is still the most commonly used, experiential learning, is being recognized as a powerful instructional strategy. Experiential learning is the process of making meaning from direct experience [17]. Examples of experiential learning strategies include simulation, role-playing and serious games among others.

Game based learning [18,19] deals with game applications that have defined learning outcomes. A game can be defined as "any contest (play) among adversaries (players) operating under constraints (rules) for an objective (winning, victory or pay-off)" [19]. Educational games (or serious games) are specifically designed to teach people about a certain subject, expand concepts, reinforce development, or assist them in drilling or learning a skill or seeking a change of attitude as they play [20].

Slowly, games are also adopted for PM in computing courses. They range from computer games (SimSE [21], SESAM [22], Incredible Manager [23], etc.) including second life simulations [24] to card or board games [25]. Yet, single-player computer-based simulation games are still predominant. Most of these allow users to take the role of a project manager and make decisions about processes and resource allocation to see how these affect project success. On the other hand, educational board games are becoming increasingly popular as they are very involving leading to a sense of excitement, fun and learning due to the live interaction of the players.

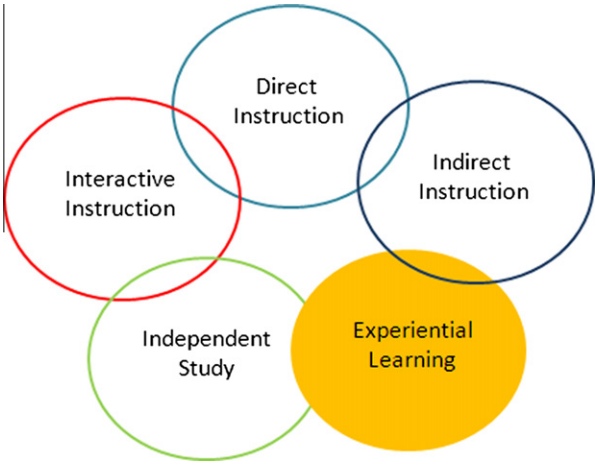

Fig. 5. Categories of instructional strategies [16].

And, although, EVM has become a prominent PM technique, there are very few educational games for teaching EVM. An initial systematic literature review on educational software engineering games did not identify any game for teaching EVM [12]. Broadening the search scope, we identified only two board games for teaching EVM, based on a search on Google in June 2010 with the search term <"board game" "earned value management" "project management" teaching education training> (returning a total number of 79 results):

- Project Risk Game (http://www.successfulprojects.com/Store/ProjectRiskBoardGame) focusing mainly on teaching risk management, but which can be enhanced to also cover EVM.
- Earned Value and Risk Management Simulation (http://www.projectauditors.com/Training/Earned_Value_Simulation.html) focusing on teaching project management tools and components including scope management, time management, cost management (including EVM) and risk management.

Besides these games, there exist also other experiential learning objects, such as simulations, e.g., The Herding Cats® Project Simulation (http://www.projectsolutions.com/PSCCompany/class_descriptions/Games/ilt_Herding.htm).

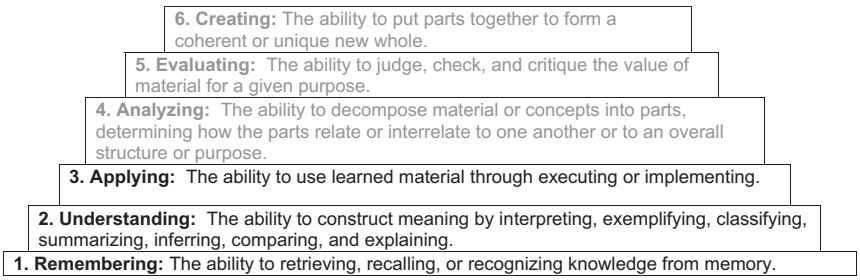

Fig. 4. Revised version of Bloom's taxonomy of educational objectives [15].

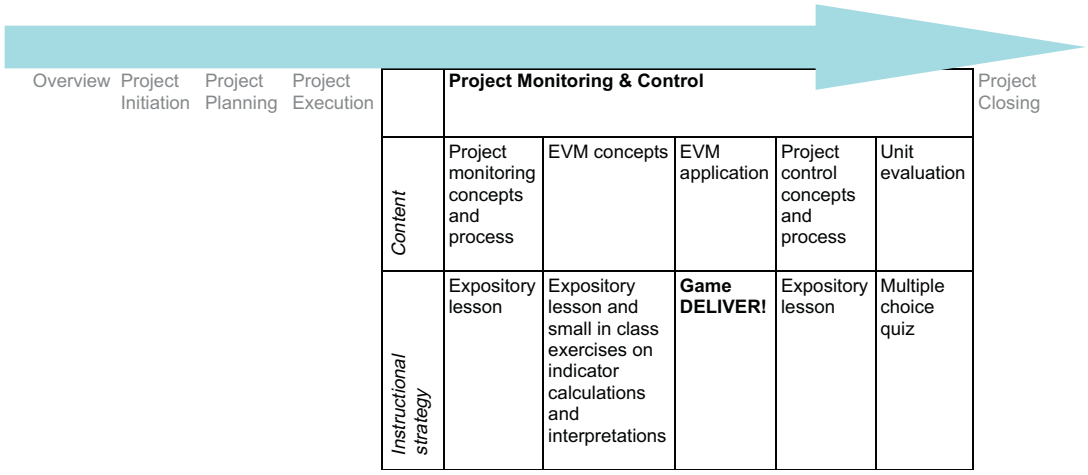

Fig. 6. Exemplar outline of instructional unit on project monitoring and control.

These experiential learning objects are typically commercial games or simulations available in English language. They are mostly outlined for a 1 to 3-day professional training course. However, we identified a need for a low-cost board game to teach EVM in one lecture (90 min) as part of a course at a public university in Brazil. To address that need, we developed a different board game DELIVER! focusing on EVM in the computing context.

Table 1
Steps of the game flow.

Phase	Duration (min)
Explanation of the activity	15
Project planning	10
Project execution and monitoring and control	50
Debriefing	15
Total	90

3. Description of the game DELIVER!

DELIVER! is a board game to teach Earned Value Management in monitoring and controlling the execution of a software project. The game is intended to be used as part of a PM course (either as part of a university course or professional training). It is targeted to teach students in computing programs, including computer science, information system or software engineering courses. It is intended as a complementary strategy in an instructional unit on project monitoring and control (Fig. 6).

A pre-requisite for the application of the game is that the students have a basic understanding of PM and EVM taught beforehand, e.g., through expository lessons.

The purpose of the game is to reinforce EVM concepts and to exercise the application of EVM. After the game session, students are expected to be more able to remember the names of key indicators and formulas (remembering) as well as to differentiate and interpret indicators (understanding). Students should be able to calculate and interpret performance indices to track project

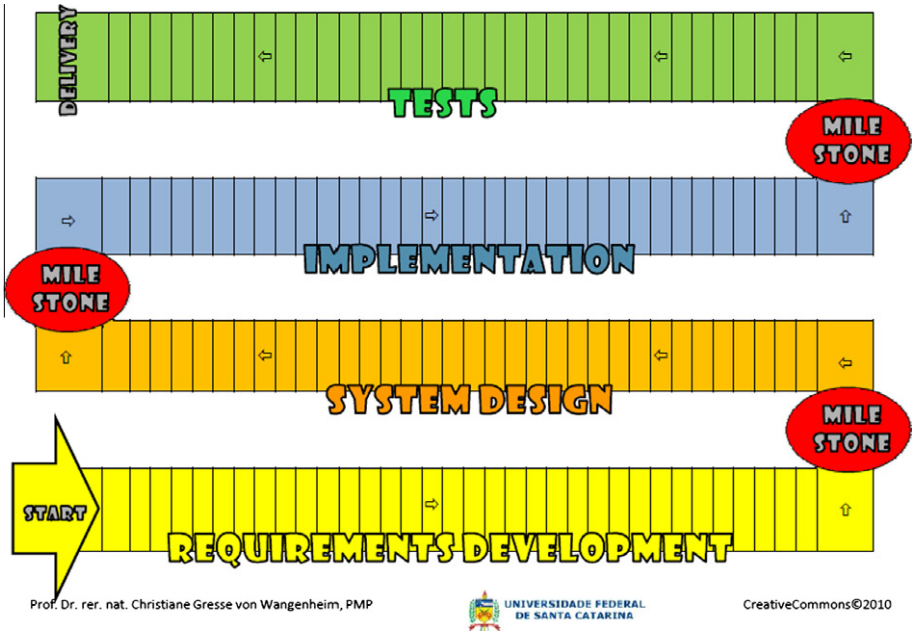

Fig. 7. Game board.

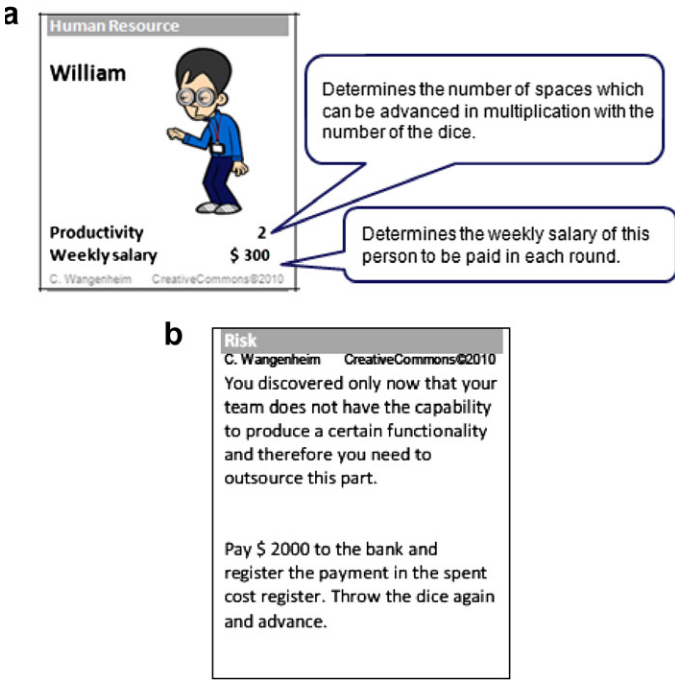

Fig. 8. (a) Human resource card and (b) risk card.

progress and to calculate and interpret estimate at completion (applying).

3.1. Game flow

Ideally, the game is played in groups of four pairs of players on one game board. The total duration of the game play is about 90 min divided in four steps as presented in Table 1.

The objective of the game is to be the first to deliver the results of the software project to the customer (arriving at the delivery space on the game board (Fig. 7)) without running out of financial resources during execution.

3.2. Phases of the game flow

In the beginning the instructor explains the game objectives and flow.

Then, the participants start planning by acquiring project team members from a pool of available human resources (Fig. 8a). Human resources can only be acquired/dismissed at this point of time or at a milestone during project execution.

Human resources are characterized by their productivity level and their weekly salary. The productivity level determines the number of spaces the project team will advance in each game round by multiplying it with the dice number. Project duration is then estimated by the players through the number of expected game rounds. Each game round counts as 1 week. The total number of activity units to be worked until delivery is fixed for all groups of players defined through the number of space on the game board. Typically it takes about 7–10 game rounds to finish the project arriving at the delivery space.

The weekly salary of the allocated resources has to be paid at the end of each game round.

Project costs are estimated considering the salaries of the chosen human resources and the estimated duration (=number of game rounds), within the total approved budget of $20,000. In addition, the participants can also plan a management reserve for unknown risks.

The results are documented in the project plan, identifying duration estimates (no. of game rounds), costs of human resources and management reserve. Summing up the total project cost, the BAC – Budget At Completion is calculated (Fig. 9).

During the game execution, the pairs of players advance on the game board, simulating the execution of the project by throwing a dice. If the dice number is between 1 and 4, they multiply the number with the sum of the productivity factors of their human resources and advance the corresponding number of spaces on the board. Potential risk factors occur when throwing the dice number 5 or 6. In this case, a risk card has to be taken (Fig. 8b), following its instructions.

Each game round, all pairs of players have to pay the weekly salary of their human resources.

At each milestone between project phases, the pair of players has to monitor and control the project execution using EVM. At this point, they must hold a status meeting analyzing the project performance (SPI – Schedule Performance Index and CPI – Cost Performance Index) and make a prediction (EAC – Estimate At Completion) (Fig. 10). Based on the monitored performance, they may dismiss or acquire human resources. In this case, the project plan has to be updated.

The winner is the pair of players who first delivers the project to the customer arriving at the space Delivery without running out of money during project execution.

Debriefing is directed to reflect on the usage of EVM to track the progress of the project, including discussion questions, such as:

PROJECT PLAN

Time planning

	Requirements Development	System Design	Implementation	Tests
No. of weeks *= no. of game rounds*	3	3	3	3

Cost planning

Items	Requirements Development	System Design	Implementation	Tests
Human Resources per phase *= no. of weeks * Sum of weekly salary of all team members*	4.200	4.200	4.200	4.200
Management reserve per phase	500	500	500	500
TOTAL per phase	4.700	4.700	4.700	4.700
PROJECT TOTAL (BAC - Budget At Completion)				18.800

Fig. 9. Example of project plan.

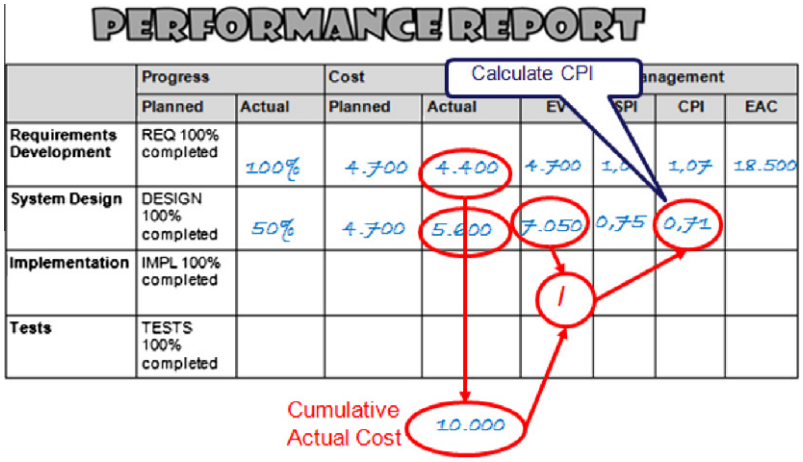

Fig. 10. Example of the calculation of CPI in the performance report.

What do the performance indices reveal? How did your project perform regarding the performance indices? Why did this happen (e.g., why did you spend more than planned? Why did the execution take longer than planned?

In a second part of the debriefing, the objective is to briefly reflect on the activity as a learning opportunity, discussing questions, such as: What did you learn through this activity? How can you apply this in your daily work?

3.3. Game components

Game components include:

- Slides for the explanation of the game
- Template for project plan, register of costs spent and status report (one per pair of players)
- Game board (one per group of four pairs of players)
- Instruction sheet (one per group)
- Game pawns (one for each pair of players)
- Dice (one per group)
- Money in notes of $100, $500 and $1000 (70 of each denomination per group)
- Human resource cards (one set of 24 cards per group)
- Risk cards (one set of 33 cards per group)

Game components are available in English and Brazilian Portuguese under the CreativeCommons licence at the web site http://www.inf.ufsc.br/~gresse/subpaginas/ProjectManagementTeaching.html.

4. Application and evaluation of the game

The game has been applied in the Software Project Management course (*INE5617 – Gerência de Projetos*) of the undergraduate program on Information Systems and the Software Project Management course (*INE5427 – Planejamento e Gestão de Projetos*) of the Computer Science undergraduate program at the Informatics and Statistics Department at the Federal University of Santa Catarina – UFSC during the second semester 2010 (Fig. 12).

The objective of both courses is to provide students with an understanding of key concepts and processes in managing software projects. This includes an instructional unit on project monitoring and control, including EVM. This unit is initiated with expository lessons on basic concepts and processes and the EVM method. Then, in order reinforce the concepts and the calculation of performance indicators as well as to motivate and teach its application, the game DELIVER! is played (Fig. 6).

4.1. Definition of the evaluation

The general objective is to evaluate the quality of the educational game. Due to a lack of a commonly accepted definition on the quality of educational games, we define a high-quality game as one that has clearly defined educational goals, motivates students to study and promotes the learning of curricular content through activities that are fun, enjoyable and challenging (based on a review of the benefits of educational games [26]). Thus, a game does not only have to be didactically appropriate and promote learning, it must also be able to motivate students to study and provide a pleasant experience.

Accordingly, our evaluation objective is to analyze the game DELIVER! with respect to its quality (including motivation, user experience and its contribution to learning) in the context of a PM course in an undergraduate computing program.

Table 2
Overview on Kirkpatrick's four-level model for evaluation [27].

Evaluation level	Description	Examples of evaluation tools and methods
1. Reaction	Evaluates how the students felt about the training or learning experience	Happy-sheets; feedback forms; verbal reactions; post-training surveys; ...
2. Learning	Evaluates the increase in knowledge or capability (before and after)	Assessments and tests before and after the training; interviews or observation
3. Behavior	Evaluates the extent of applied learning back on the job-implementation	Observation and interviews over time to assess change, relevance of change and sustainability of change
4. Results	Evaluates the effect on the business or environment by the trainee	Long-term post-training surveys; observation as part of ongoing, sequenced training and coaching over a period of time; measures, such as, re-work, errors, etc. to measure, if participants achieved training objectives; interviews with trainees and their managers, or their customer groups

For the evaluation of the game, we apply Kirkpatrick's Four Levels of Evaluation [27], a popular and widely used standardized framework for the evaluation of training and learning. Based on this model, our evaluation focuses on level 1 (Table 2).

Adopting this research strategy, the evaluation objective is assessed based on the students' perceptions through questionnaires after the game application. Such an approach is typically used to measure variables difficult to observe directly, such as beliefs, motivational states, expectations and emotions [28–30]. Therefore, it is considered adequate to measure user experience and motivation [30–35]. Measuring learning effectiveness in this way may be controversial. Asking learners for their reactions may gather valuable information. However, the information can often be biased and untrustworthy [36]. Although literature on this issue is arguable, there is evidence that self-assessment can provide reliable, valid and useful results [37,38]. And, although an experimental research design could provide more valid results, it also may suffer several threats to validity, such as, differences between the difficulty of pre/post test, teacher's assessment or the control of external factors [37,39]. Therefore, evaluation from the student's perception represents a simple, quick and less intrusive alternative to obtain feedback.

4.1.1. Evaluation measures

Using GQM [40], the evaluation objective is hierarchical decomposed based on a literature review of the respective quality factors [26] into the sub-components motivation, user experience and learning. The subcomponent motivation is decomposed based on

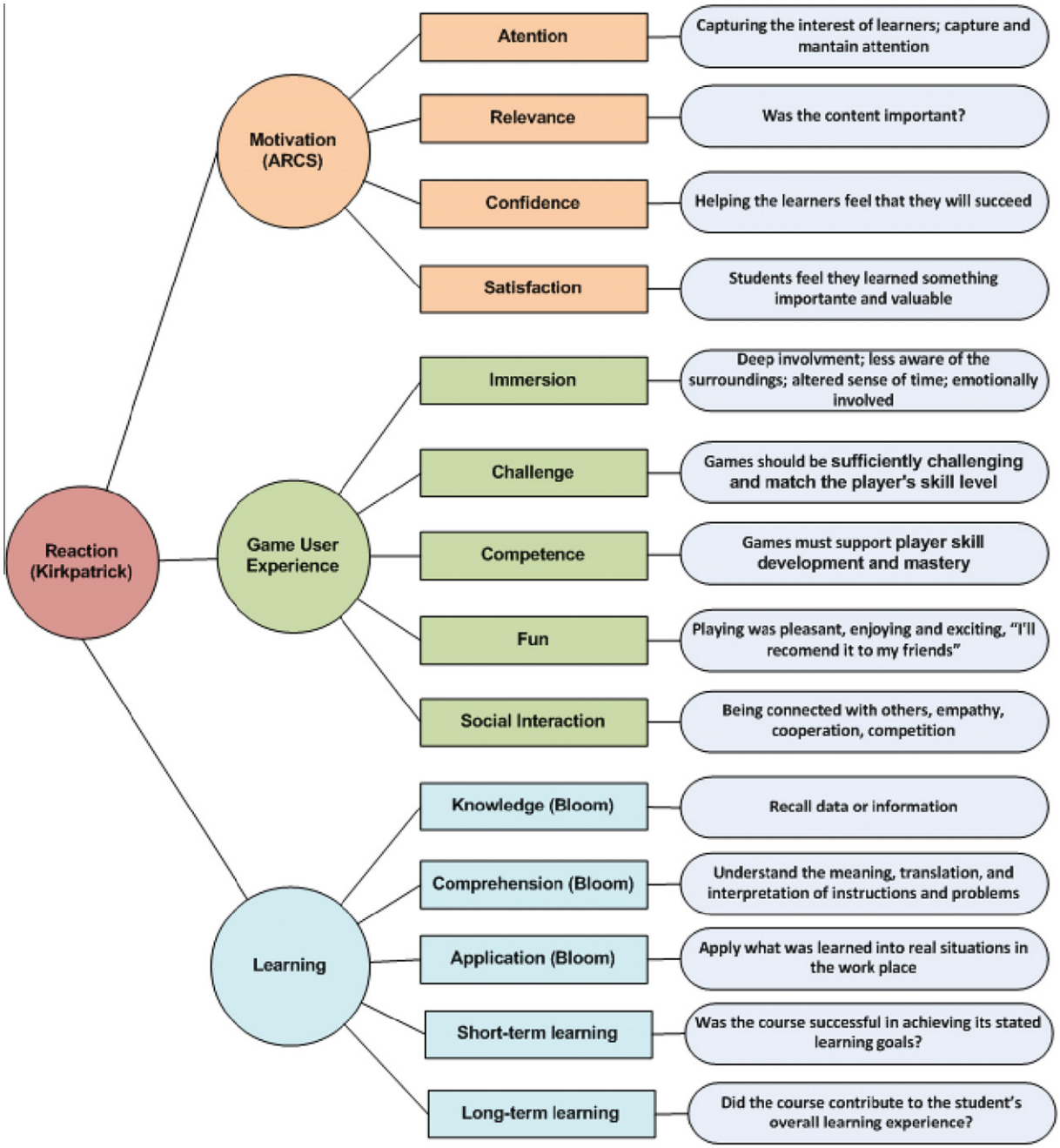

Fig. 11. Evaluation model.

Fig. 12. Students playing DELIVER!

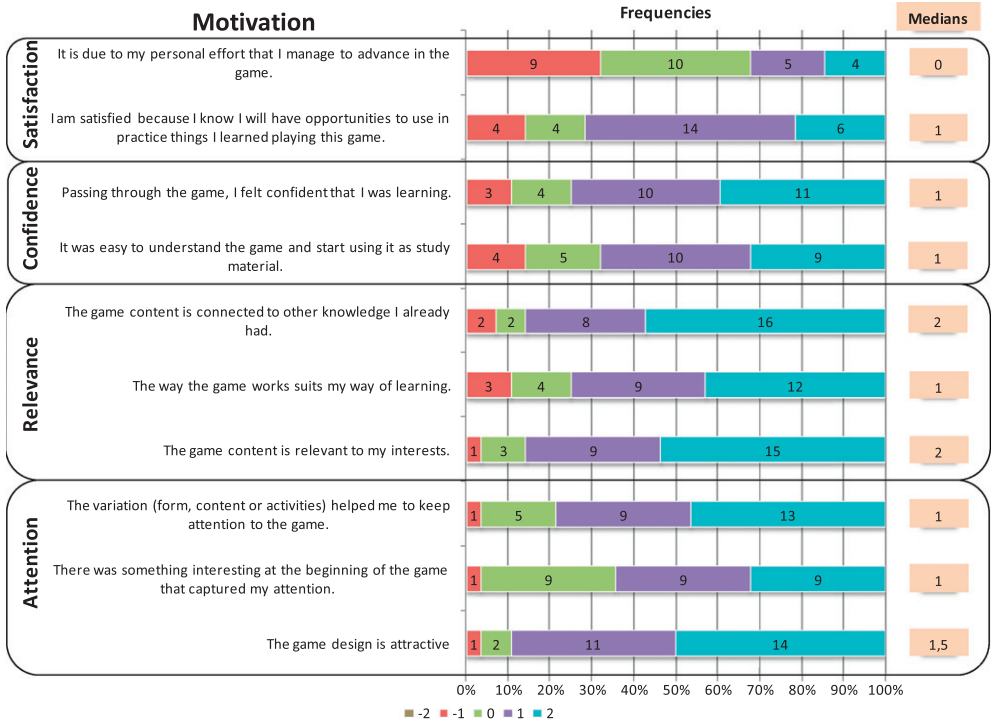

Fig. 13. Frequency diagram and medians of answers with respect to the sub-component motivation.

the ARCS model [41], which defines four categories to represent motivation in instructional design: attention, relevance, confidence and satisfaction. The subcomponent user experience (UX) covers the interaction of the individuals with the game, considering thoughts, feelings, pleasure and other perceptions that result from the interaction [42]. It involves the following dimensions: immersion, challenge, competence, fun and social interaction [30–32,35]. The subcomponent learning is measured in relation to the first three levels of Bloom's taxonomy (knowledge, comprehension and application) [15]. It includes two dimensions with respect to

short-term and long-term learning based on the assessment model of Sindre and Moody [43]. Each of these subcomponent is further refined in measures, resulting in the theoretical evaluation model presented in Fig. 11.

4.1.1.1. Research hypothesis. The basic hypothesis is that the educational game contributes positively to achieving the learning objectives of the instructional unit, motivates students and promotes a pleasant user experience.

4.1.1.2. Research strategy. The selected research strategy is based on the evaluation objective and practical restrictions typical to instructional units in university courses. Here, we chose a case study design [44] for the evaluation that allows an in-depth research of an individual, group or event [45]. The general study design is a one-shot post-test only design. The case study begins with the application of the treatment (educational game), and then a questionnaire is applied to the learners in order to collect the respective data.

Adopting this strategy of research, the evaluation objective is assessed based on the students' perceptions through questionnaires after the game application focusing on Kirkpatrick's level 1. This research design has the advantage that the evaluation can be performed without a lot of extra effort in a relative unintrusive way during the normal flow of the instructional unit.

4.1.1.3. Instrumentation. For the data collection, we used a standardized questionnaire [46], which has been developed based on the defined theoretical evaluation model (Fig. 11) [46] customizing and unifying existing standardized questionnaires [30–32,34,35,43]. The questionnaire consists of a total of 27 fixed items divided into three subscales and eleven dimensions (Table 3). As part of the development of the evaluation framework the questionnaire has been evaluated in terms of validity and reliability [46].

The response format for each of these items is based on a Likert scale with response alternatives ranging from strongly disagree to strongly agree on a five points scale ranging from −2 to 2.

In order to capture feedback on learning related to the three levels of Bloom's taxonomy (knowledge, comprehension and application) based on the learner's perception, the additional questions have been defined with respect to the specific instructional objective of the game (Table 4). The learners respond these questions by rating their perceived level of contribution of the game to their knowledge on a 4-point scale ranging from 1 – no contribution to 4 – strong contribution.

The research has been formally approved by the ethics commission of the Federal University of Santa Catarina (Certificate No. 1065/2010).

Table 3
Dimensions and items of the questionnaire.

No.	Item	Dimension
Sub-component motivation		
1	The game design is attractive	Attention
2	There was something interesting at the beginning of the game that captured my attention	Attention
3	The variation (form, content or activities) helped me to keep attention to the game	Attention
4	The game content is relevant to my interests	Relevance
5	The way the game works suits my way of learning	Relevance
6	The game content is connected to other knowledge I already had	Relevance
7	It was easy to understand the game and start using it as study material	Confidence
8	Passing through the game, I felt confident that I was learning	Confidence
9	I am satisfied because I know I will have opportunities to use in practice things I learned playing this game	Satisfaction
10	It is due to my personal effort that I manage to advance in the game	Satisfaction
Sub-component user experience		
11	Temporarily I forgot about my daily; I have been fully concentrated on the game	Immersion
12	I did not notice the time pass while playing; when I saw the game had already ended	Immersion
13	I felt myself more in the game context than real life, forgetting what was around me	Immersion
14	I was able to interact with others during the game	Social interaction
15	I had fun with other people	Social interaction
16	The game promotes moments of cooperation and/or competition between the players	Social interaction
17	This game is appropriately challenging for me, the tasks are not too easy nor too difficult	Challenge
18	The game progresses at an adequate pace and does not become monotonous – offers new obstacles, situations or variations in its tasks	Challenge
19	I had fun with the game	Fun
20	When interrupted at the end of the class, I was disappointed that the game was over	Fun
21	I would recommend this game to my colleagues	Fun
22	I achieved the goals of the game applying my knowledge	Competence
23	I had positive feelings on the efficiency of this game	Competence
24	I would like to play this game again	Fun
Sub-component learning		
25	How much do you think the game contributed to your learning in this course?	Short-term learning
26	How efficient was the game for your learning, comparing it with other activities of the course?	Short-term learning
27	Do you think the experience with the game will contribute to your professional performance in practice?	Long-term learning

4.2. Application and data collection

The application and evaluation has been conducted in the second semester 2010 in two courses INE5617 – Project Management and INE5427 – Project Planning and Management at the Informatics and Statistics Department of the Federal University of Santa Catarina. All students of the courses present in the respective lectures have been selected for participation, totaling 28 participants, 15 students from the INE5617 course and 13 students from the INE5427 course. Although being courses from different programs, the students have a similar background. Both courses are taught in the same semester of the courses (7. Semester).The instructor has been the same in both classes, being also the author of the game.

The total duration of the application of the game took about 90 min (duration of one lecture at the UFSC) and is, therefore, considered adequate, as it is possible to play the game during one lec-

Table 4
Collecting feedback on the games' contribution to learning.

Concepts	Remember the concepts/ methods	Understand how the concepts/ methods work	Know to apply the concepts/ methods
Earned Value Management			
Cost Planning			
Cost Monitoring and Control			

Instruction: Assign a rating from 1 to 4 for your perceived level of contribution of the game with respect to each of the listed concepts (1 – no contribution, 4 – strong contribution).

ture. In total, we spent less than US$ 5 for the material required (paper, copies, dices, etc.) for each group of eight players, which can be reused in future applications (with exception of the copies of the project plan and report templates).

4.3. Analysis and results

In order to try to obtain a greater accuracy and statistical power by increasing the sample size, we studied the combined results of the application of the game in both courses. Therefore, we performed a joint analysis, accumulating the data from the individual case studies into one dataset. As both applications were conducted in parallel by the same instructor in similar contexts under the same conditions, we consider them as one "large" case study. Such a procedure is applicable in this specific case, as the data of the individual studies is similar and homogeneous enough to be combined. We also regard the personal background of the participants in both studies comparable.

We analyzed the collected data through frequency diagrams in order to identify which are the most positive and negative aspects of the game with respect to each sub-component/dimension.

4.3.1. Sub-component: motivation

In general, the motivational aspect of the game has been evaluated positive by the students (Fig. 13). Especially, the items attractiveness of the game, relevancy of game content and connection of the game content to previous knowledge are the highest rated. On the other hand, the item establishing that the success of the game depends on the players effort is the lowest rated one, indicating that, through dice throwing, the game introduces an element of chance.

All items related to the dimension attention have been rated high. However, considering that nine participants rated their opinion towards the item "there was something interesting at the beginning of the game that captured my attention" as neutral (0), indicates a potential opportunity for improvement.

Concerning the dimension relevance, all items have been rated high, including two of the highest rated items. This indicates that the relevance of the game content seems in fact to be related to the instructional unit and that the relevance becomes easily clear to the students.

Both items related to the dimension confidence are rated moderately, indicating, that the game rules present a certain degree of complexity and that maybe the explanation of the game dynamics can be improved to facilitate their understanding.

Regarding the dimension satisfaction, the item expressing that the success of the game depends on the effort of the player and is not decided by chance (e.g. dice throwing), has received the lowest rating of the items of this sub-component with nine participants rating this item with −1 and 10 with 0. This indicates that, although, games typically include such a chance element, in an educational game, such an influence may be considered negative as game results may depend more on luck than on the knowledge of the players. Satisfaction of the participants related to the game in terms of usefulness in practice is evaluated acceptable.

4.3.2. Sub-component: user experience

In general, the game has been considered fun and has provided a positive experience for the students, with an emphasis on immersion and social interaction. And although, again all items have been rated by more participants above than below zero, there exists a certain degree of variation between the ratings (Fig. 14).

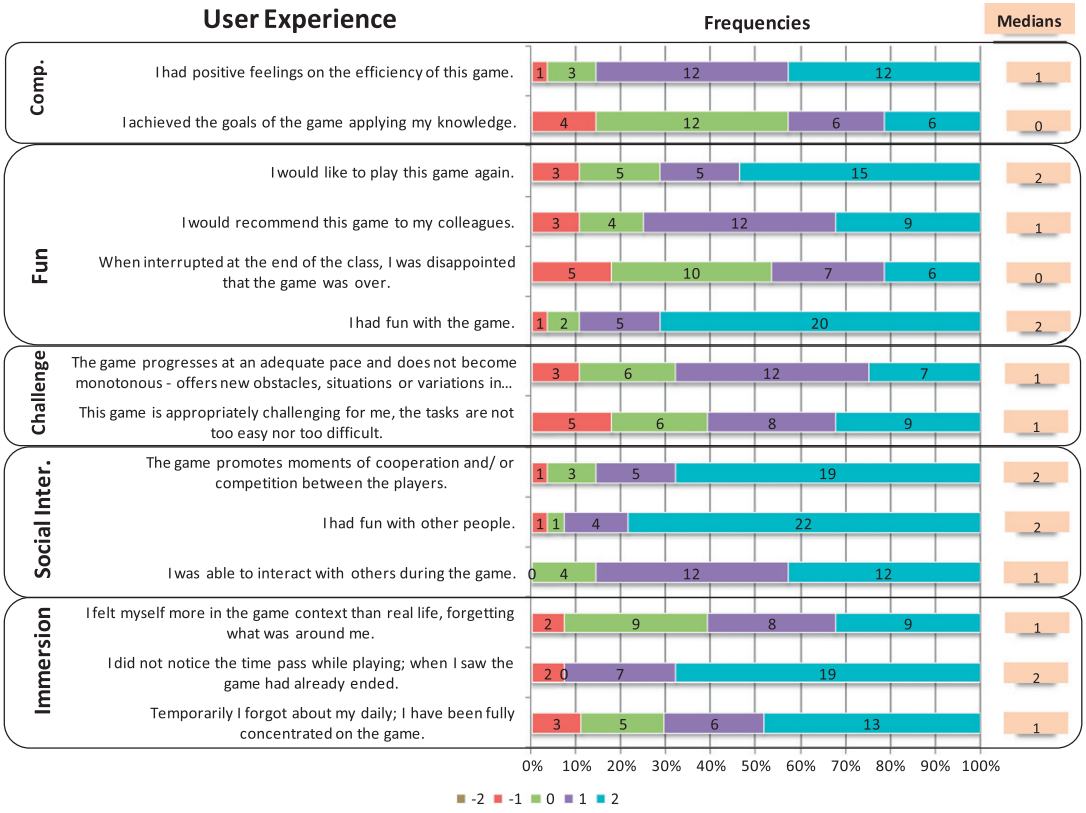

Fig. 14. Frequency diagram and medians of answers with respect to the sub-component user experience.

The dimension immersion has been rated quite high, indicating that the game dynamics allow the participants to immerse into the game context and forget the time passing.

The dimension social interaction has been the highest rated dimension. Twenty-two of the 28 participants rated the item that they had fun playing the game in pairs. These results can also be confirmed through informal comments of the students, who expressed their positive impression on the fact that the game stimulated them to get to know their collegues and that these contacts have been maintained even beyond the specific course. It was also a surprise that this kind of social interaction was even more valued by students from the course of the computer science program, which had less contact to their collegues until this point than the students of the course of the information systems program.

The dimension challenge received a moderate level of agreement in assessing if the game moves at an adequate pace and whether the game is appropriately challenging.

Regarding the dimension fun, the participates rated the item "I had fun with the game" very high (20 participants rated this item with 2). This may indicate that the game itself is in fact fun to play. This has been confirmed also by the indication that many participants would like to play the game again. On the other hand, the item "When interruped at the end of the class, I was dissapointed that the game was over" has received one of the lowest ratings of this sub-component. However, this may also express a normal behavior of students eagerly awaiting the end of class.

Regarding the dimension competence, the participants rated the item on if they achieved the goals of the game moderately.

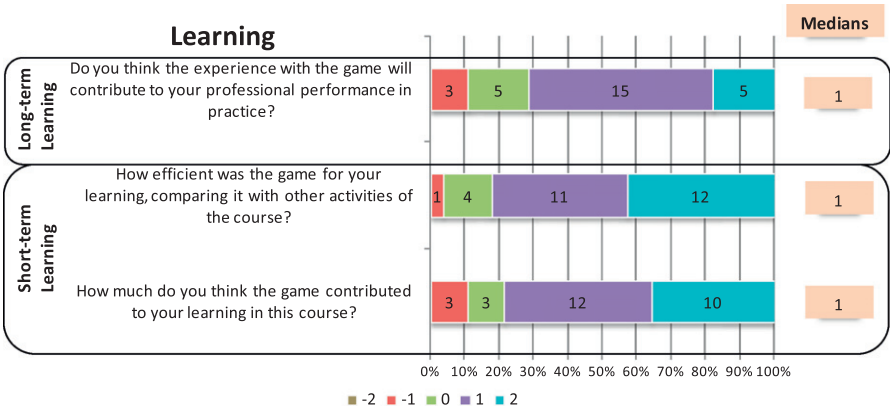

Fig. 15. Frequency diagram and medians of answers with respect to the sub-component learning.

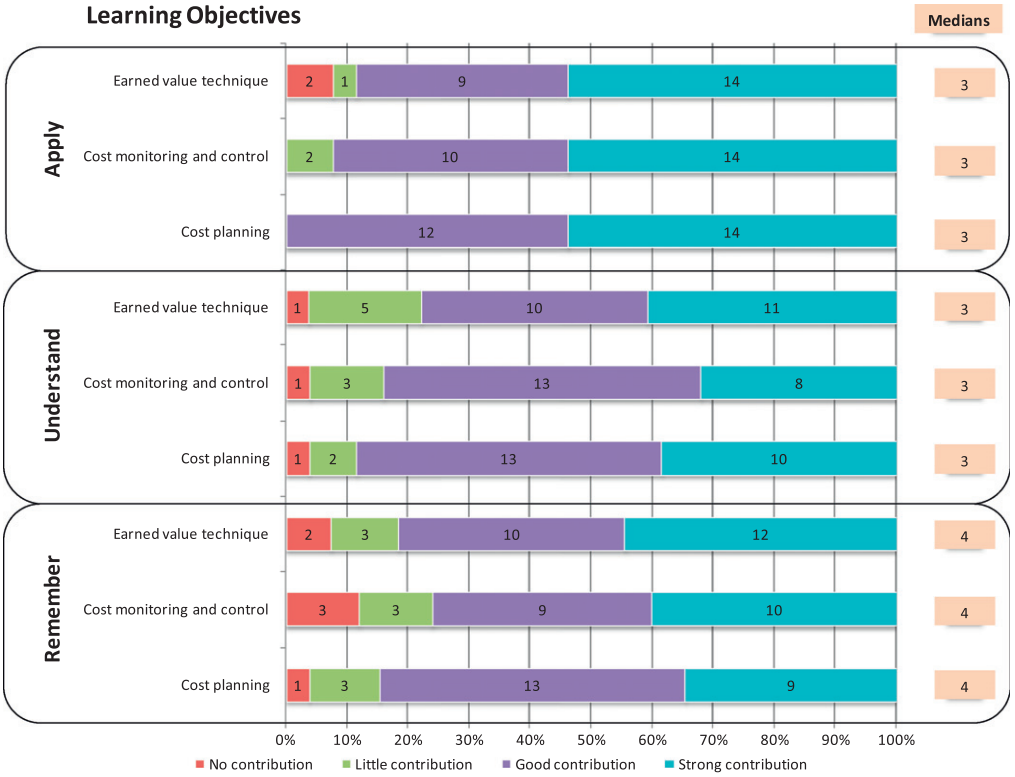

Fig. 16. Frequency diagram and medians of answers with respect to the feedback on learning.

Yet, the efficiency of learning process through the game has been rated highly.

4.3.3. Sub-component learning

In general, the students also rated the learning aspect of the game high (Fig. 15).

The majority of the participants rated the contribution of the game to their learning process in this course with 1 or 2, indicating that the game provides a valuable contribution to the course. The question on the efficiency of the game on the learning process was rated even higher; expressing that playing the game may also be an efficient way to teach the respective concepts and their application. The question on the game's contribution to their professional performance in practice was rated moderately but expressed a positive expectation.

This feedback has also been confirmed through the questions on learning related to the three levels of Bloom's taxonomy (Fig. 16). Here, the application level received the highest ratings with respect to all three concepts covered by the game. This indicates that the students perceived that the game helped them in learning how to apply cost management and the EVM method. In addition, it also has been highly rated on the remembering and understanding level, apparently, also reinforcing knowledge on these lower cognitive levels.

4.4. Threats to validity

The one-shot case study design applied in this research can cause various problems with respect to the validity of the results. One of the problems is a lack of baseline on the actual knowledge of the students before playing the game as a basis to make a comparison and record differences. This is further aggravated by the fact there is no control group with which to compare the identified effects. In this study we opted to conduct case studies instead of formal experiments in order to maintain minimal interruptions of the normal flow in the instructional unit. This, on the other hand, reduces the validity of the results obtained, yet, in the present situation represented the only possible way to run an evaluation in practice.

And, although, students' knowledge is assessed by a quiz at the end of the instructional unit and by a final exam at the end of the course, it is not possible to infer any significant results from a comparison of the quiz/exam results to the participation in the game. This is due to the fact that the quiz/exam is not exclusively related to EVM and consequently only few questions are directly related to EVM not allowing the derivation of statistical significant conclusions.

In addition, the fact that the application has been run with a small set of participants and within the same department by the same instructor reduces the possibility to generalize the results.

There may also exist various threats related to construct validity. Due to practical constraints, running the study as part of an academic lecture, learning effects have been assessed only on level 1 in accordance to Kirkpatrick's Four Levels of Evaluation [27] based on a self-evaluation of the perceived learning effect of the participants. However, this might not adequately capture the real learning effect. Especially, as we intend to measure knowledge on the application level, it may not be sufficient to evaluate if the game helped the participants to learn competencies to such a degree that they are able to apply the newly acquired knowledge in their professional environment.

Another possible threat is that aspects, such as, game appropriateness and engagement are difficult issues to measure and were captured through subjective measures. To counteract this threat to validity, the questionnaire items have been derived systematically based on existing standardized measurement instruments and have been evaluated in terms of validity and reliability as part of this research [46]. Following DeVellis's guide for scale development [29], we examined the questionnaire with respect to the correlation among items, item-scale correlations, item variances and coefficient alpha.

4.5. Discussion

The obtained results provide a first indication that the game DELIVER! can provide a positive contribution to the learning of EVM. Based on a self-assessment of the students, the game helped to reinforce and teach the calculation of performance indicators as well as it illustrated and motivated the usage of EVM. We also observed an additional learning outcome as the students perceived the low estimation precision in the beginning of a project and its increase throughout its execution.

In general, the evaluation of the game has been very positive with ratings above zero by the majority of the students. The evaluation of the game also confirmed the hypothesis that the educational game highly motivates the students and provides a very positive experience. The students participated actively in the game and expressed that playing the game was an enjoyable experience. Especially, the social interaction provoked by the game has been commented very positively.

The game design was considered attractive dealing with relevant content connected to the instructional unit and previously acquired knowledge. The students also demonstrated and confirmed a high degree of immersion and fun throughout the game.

And, although the game requires a certain amount of explanation upfront (on how to plan and specifically on how to report the status), the complexity of the game rules has been considered appropriate and all students were able to play the game at first try. Yet, aspects, which received lower ratings and, which may indicate opportunities for improvement, include a reduction of the dependence on luck (by throwing the dice) as well as the pace and the appropriate presentation of challenges throughout the game.

Due to the fact that no evaluation data could be encountered on the learning effects of the other identified board games for teaching EVM, it is not possible to compare the obtained results to other similar games.

5. Conclusion

In this paper, we present a board game for teaching Earned Value Management as part of project management courses in undergraduate computing programs. On the cognitive level, the learning objective of the game is to reinforce EVM concepts and to teach the competency to apply basic EVM calculations covering the cognitive levels remembering, understanding and application.

An evaluation of the game in project management courses at computing programs at the Federal University of Santa Catarina based on the students' perception indicates the potential of such a game to contribute to the learning of EVM. In addition, the study indicated the very positive effect of the game's application on the social interaction, engagement, immersion, attention and relevance to the course objectives.

From a practical point of view the game offers a low-budget alternative instructional strategy that can easily be applied during a lecture within the classroom. The game, of course, does not substitute, but complements other instructional strategies, such as, expository lessons, to be adopted beforehand to present basic concepts of EVM.

Based on the positive feedback, the game is currently being integrated permanently in the course syllabus. In order to widen the evaluation results, we are also planning to repeat the evalua-

tion within these courses as well as in cooperation with other instructors to broaden the variation of application contexts.

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