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Coverage of the ISO 21500 Standard in the Context of Software Project Management by a Simulation-Based Serious Game

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Abstract. Bringing professional practice into the learning/teaching process is an especially difficult task in the scope of software project management and can turn into a challenge in the context of software process standards education. The ISO 21500 standard is an international reference standard that provides generic guidance and good practices in project management. In this paper, we perform a literature review in order to analyze the current studies related to the use of serious games for understanding, teaching and supporting the education of the ISO 21500 standard. Moreover, we propose ProDec, a serious game for software project management training, and provide a mapping between the different stages of the game lifecycle and the ISO 21500 standard applying its management processes in the context of software projects. As a result, we observe that in this context, ProDec is able to cover seven of the ten subject groups and almost 75% of the project management processes of the ISO 21500 standard.

Keywords: ISO 21500, Software Project Management, Serious Games, Teaching Standards, Simulation, Education

1 Introduction

Software engineering is a complex activity that requires a good integration of theoretical and practical information in order to create quality software (Clarke, O'Connor, & Leavy, 2016). To facilitate this activity, the software industry defines standards that provide guidance and processes with the goal to structure the activities and tasks for supporting the development of software. Within this discipline, software project management consists of applying knowledge, skills, tools, and techniques to

software project activities in order to meet the project requirements (Project Management Institute, 2013).

Software project management is an important field for succeeding in the development of quality software (ACM/IEEE-CS Joint Task Force on Computing Curricula, 2013). Although there are many international standards that provide best practices, guidance and support software project management such as the ISO/IEC 12207 (ISO/IEC, 2008) or the ISO/IEC 29110 (ISO/IEC, 2016) and project management in general such as the ISO 21500 (ISO, 2012), we can observe a crucial need for better understanding and training in them (Aydan, Yilmaz, Clarke, & O'Connor, 2017). Thus, practitioners need to be involved in a practical and realistic learning/teaching process that allows them acquiring more practical experience in software process to be enough experts to produce more quality software (Dorling & McCaffery, 2012).

This necessity moves trainers towards the development and use of methods and techniques to teach in a highly practical way, promote active learning and increase the motivation and the engagement of learners in software project management (Calderón & Ruiz, Coverage of ISO/IEC 12207 Software Lifecycle Process by a Simulation-Based Serious Game, 2016). In this context, games can be considered as a learning resource to train novice software practitioners and to allow them to learn from their own mistakes and acquire experience in a free-risk environment (Kosa, Yilmaz, O'Connor, & Clarke, 2016).

Regarding the ISO 21500 standard as a basic guidance for project management that can be applied in the context of software project management, we can observe that there is a lack of works for understanding, teaching or supporting the education of the project management processes of the ISO 21500 standard. For that reason the main contributions of this paper are: (i) providing a complete view of the current studies related to the use of serious games for understanding, teaching or supporting the education of the ISO 21500 standard, (ii) analyzing the coverage of the project management processes of the ISO 21500 standard by the gameplay's lifecycle process of a proposed serious game in the context of software projects and (iii) evaluating the idea of using the proposed serious game as a learning resource for supporting the education of the software project management processes.

The remainder of this article is structured as follows: Section 2 shows the related works of this study. Section 3 describes a simulation-based serious game and evaluates the coverage of the project management processes of the ISO 21500 in the context of software projects. Finally, section 4 summarizes the paper and presents our conclusions and future work.

2 Background

Several organizations have published best practices and standards to provide guidance and describe processes for supporting project management. For instance, the PRINCE2 method defined by AXELOS (AXELOS, 2017), the PMBOK guide proposed by the Project Management Institute (Project Management Institute, 2013)

or the ISO 21500 standard (ISO, 2012). In this work, we have decided to take the guidance and processes provide by ISO 21500 as a reference model because comparing with the other guides, it provides more general and basic guidance for project management. In addition, their processes do not need to be applied uniformly on all projects, the standard can be complied be adopting other recognized project management methods and it is well accepted on the international level by the industry and the scientific population.

2.1 ISO 21500

ISO 21500 international standard (ISO, 2012) aims to provide guidance for project management and a high-level description of concepts and processes that are considered to form good practice in project management. The standard is intended to be used by any type of organization as: (a) a reference in an audit; (b) a link between different project management and business processes; (c) a checklist to prove the knowledge and skills of project managers and project workers in executing projects; (d) a common reference between different methods, practices and models; (e) and a common language in project management.

Table 1. ISO 21500 processes.

Subject groups	Process groups				
	Initiating	Planning	Implementing	Controlling	Closing
Integration	P1. Develop project charter	P2. Develop project plans	P3. Direct project work	P4. Control project work P5. Control changes	P6. Close project phase or project P7. Collect lessons learned
Stakeholder	P8. Identify stakeholders		P9. Manage stakeholders		
Scope		P10. Define scope P11. Create work breakdown structure P12. Define activities		P13. Control scope	
Resource	P14. Establish project team	P15. Estimate resources P16. Define project organization	P17. Develop project team	P18. Control resources P19. Manage project team	
Time		P20. Sequence activities P21. Estimate activities durations P22. Develop schedule		P23. Control schedule	
Cost		P24. Estimate costs P25. Develop budget		P26. Control costs	
Risk		P27. Identify risks P28. Assess risks	P29. Treat risks	P30. Control risks	
Quality		P31. Plan quality	P32. Perform quality assurance	P33. Perform quality control	
Procurement		P34. Plan procurements	P35. Select suppliers	P36. Administer procurements	
Communication		P37. Plan	P38. Distribute	P39. Manage	

		communications	information	communications	

The ISO 21500 standard is structured in four clauses that define the scope, the terms and definitions and the project management concepts and processes, and an informative annex. The fourth clause of the standard identifies the recommended project management processes in a generic way, with the goal they can be used by any project in any organization or entity. In this section, the ISO 21500 identifies five process groups regarding the management perspective of a project: Initiating, Planning, Implementing, Controlling and Closing On the other hand, regarding the project management practices, the ISO 21500 identifies 39 processes divided into ten project management topics named subject groups. Table 1 shows these processes related to the process and subject groups where they take place.

2.2 ISO 21500 & Serious Games

As a generic standard that recommends best practices in project management, ISO 21500 should be considered in any project management curricula in order to provide a best education, more attached to the practice and more realistic, where learners can put into practice their knowledge acquisition within real-life scenarios (ACM/IEEE-CS Joint Task Force on Computing Curricula, 2013). However, regarding the software engineering scope, teaching international standards can turn into a challenge for both industry and university trainers (Aydan, Yilmaz, Clarke, & O'Connor, 2017).

In this context, the use of games and simulation-based experiences helps trainers to achieve these goals by supporting the knowledge acquisition within a risk-free environment. These games, are called serious games, are designed with a different purpose than entertainment and allow participants to experiment, learn from their own mistakes and acquire experience (Abt, 2002).

With the goal of providing a complete view of the current studies related to the use of serious games for understanding, teaching or supporting the education of the standard ISO 21500, we have performed a systematic review of the literature for identifying the relevant related studies. For that, taking into account Kitchenham and Charters guidelines (Kitchenham & Charters, 2007), we have performed the following steps:

a) **Search strategy**

First, we identified a set of key terms. Taking into account these key terms and their synonyms, we performed some initial pilot searches to test and tune the search string. Table 2 shows the different search strings defined.

Table 2. Search strings.

Search strings (SS)
SS1. "ISO 21500" AND "serious game"
SS2. "ISO 21500" AND game
SS3. "ISO 21500" AND (teach OR train OR educate)
SS4. "ISO 21500"

Using these search strings, we performed the search in the following digital databases: Wiley Online Library, ACM Digital Library, IEEE Xplore, ISI Web of Science, SCOPUS and SpringerLink. We adapted the different search strings to each digital database and restricted the search to title, abstract and keywords.

Figure 2 shows the results of applying the different search strings to each database. As we can observe, there are only reflected the data to four of the six selected databases. The reason is that SpringerLink and IEEE Xplore databases did not report any work with any of our search strings. Moreover, we can observe how the search string SS1 did not allow finding any study and the rest of the search strings allowed finding few studies. The search string that allowed finding more related

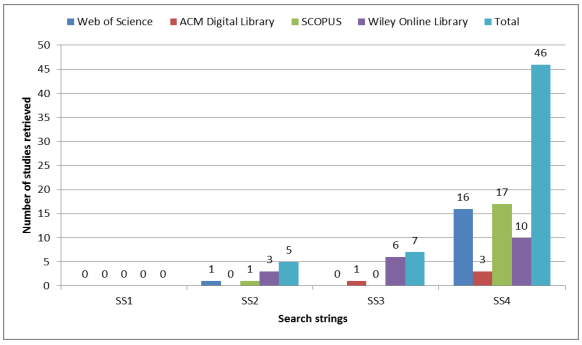

Figure 1. Number of studies retrieved.

studies was SS4 (46 studies), for that reason we decided to use it as the main search string of our review.

b) **Study selection**

After we retrieved the studies from the selected search string and deleted the duplicated studies, we performed a selection process based on two phases, through a test-retest approach.

In Phase 1, studies found during the search process were evaluated for their suitability based on the analysis of their title and abstract. In this phase, studies that were clearly irrelevant were excluded. Studies related to the use of games for understanding, teaching or supporting the education of the standard ISO 21500 were classified as possible select (PS) and the rest as non-selected studies (NS).

In Phase 2, studies identified as possible select during Phase 1 were exposed to a more thorough analysis that included reading the full text. This phase was done to ensure that the study in question definitely contained information that is relevant to the study.

Figure 3 represents firstly, the papers that were retrieved from each consulted database; secondly, the number of different studies that were collected from each

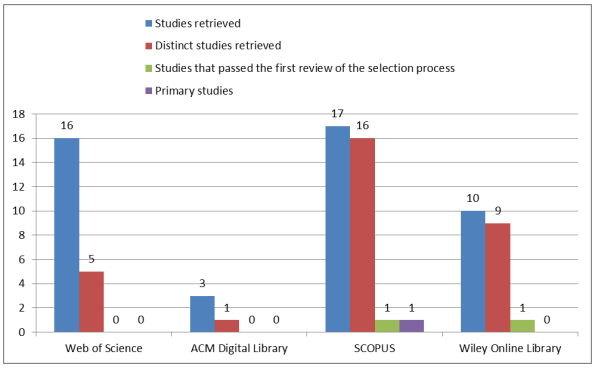

Figure 2. Evolution of studies retrieved in each digital database.

database after removing duplicates; thirdly, the number of studies that were collected from each database that passed the first review of the selection process. Finally, it shows the number of papers that were included as primary studies in our review.

c) Results

The selection process began with 46 studies and ended with only the work of Mesquida et al. (Mesquida, Jovanovic, & Mas, 2016) as suitable for our review. In this work, authors proposed the use of games as a technique to facilitate the implementation of the project management processes proposed by the ISO 21500 standard. Concretely, authors presented a specific game to facilitate the implementation of two project management processes of the ISO 21500 international standard (Mesquida, Jovanovic, & Mas, 2016). However, they do not introduce a serious game that allows teaching in the whole processes of the standard. Then, we can observe a lack of serious games as learning/teaching resources for understanding, training and supporting the education of the project management processes of the ISO 21500 standard.

For that reason, in this work, we take advantage of the features of a simulation-based serious game, called ProDec, to assess how it can be used for covering the project management processes of the ISO 21500 and supporting learners and practitioners in learning, understanding and practicing the project management processes of ISO 21500 standard.

3 Coverage of ISO/IEC 21500

In this work, we apply the guidelines of the ISO 21500 in the context of software project management with the goal to observe how ProDec can support the understanding and teaching of project management processes in software education. For that, in this section, we describe the main functionalities of ProDec related to the process and subject groups of the ISO 21500 and discuss how ProDec covers the different processes identified by the ISO 21500.

3.1 Game description

ProDec (Calderón & Ruiz, ProDec: a serious game for software project management training, 2013) is a simulation-based serious game to train and motivate in learning, understanding and practicing the principles of software project management. As a learning resource, its main goal is that players put into practice their knowledge related to the concepts and practices of software project management in a risk-free virtual environment where they take the role of a project manager.

Regarding its main functionalities, we can highlight that ProDec: (a) provides a training environment that allows learners to take contact with all the software lifecycle stages of a software project from its conception to its closure; (b) provides trainers with an environment for supporting players assessment through the gameplays of the game; (c) provides both, learners and trainers, with an environment

for game scenarios designing that allows them to create every project plan scenario they can think of; and (d) provides a learning/teaching environment that promotes learning by doing, active and social learning.

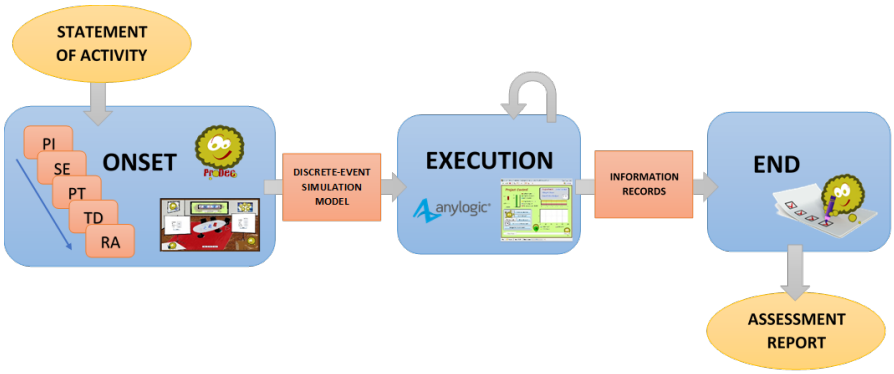

Figure 3. ProDec gameplay's lifecycle process.

On the other hand, as a game, its objective is that players be able to manage a software project in a successfully way, this involves to complete the project within the time and cost limits. In the contrary, the game is over when the project significantly overruns either the approved budget or the allocated time.

For that, as Figure 4 shows, starting from a statement of activity that defines the scope of the project scenario, players need to immerse in the gameplay's lifecycle process in order to win the game and get a final assessment report that allows them to learn from their own performance with ProDec. The gameplay's lifecycle process is composed of three main stages: Onset, Execution and End stage.

In the Onset stage, taking into account the statement of activity, players follow a process that guides them to create from scratch the game scenario that involves defining the project plan for the gameplay (see Figure 4). This process is made of five sequential sub-stages which are the following:

- *Project Information (PI).* In this sub-stage, players provide the general information of the project about its scope and features, such as the salary of the workers, the length of the project, the number of use cases, etc., that are necessary to begin the size estimation stage.
- *Size Estimation (SE).* In this sub-stage, players make the size estimation of the project using Albrecht's method (Albrecht, 1979) of function points-base estimation.
- *Project Team Definition (PT).* In this sub-stage, players define their project team. For this, they have to select their past work experience and some features for their personality based on the sixteen personality factors described by Cattell (Cattell, Eber, & Tatsuoka, 1988).
- *Tasks Definition (TD).* In this sub-stage, players define the tasks of the project based on PERT diagram (Moder, 1983), and enter, for each of them, the time data,

the budget allocated, and its predecessor tasks. Moreover, players have to allocate the personnel for each task.

- *Risk Analysis (RA).* In the last stage of the process, players make a quantitative risk analysis.

Once the project plan of the game scenario is defined, the game automatically generates a source code file with the equations of a discrete-event simulation model that simulates the execution of a project plan and allows players to start the Execution stage of the gameplay's lifecycle process. During the simulation of the project plan execution, the game allows players to practice their decision-making skills by controlling and monitoring the progress of the project execution in order to correct the potential deviations of the progress of the project.

Finally, when the simulation of the project plan ends, players immerse in the End stage of the gameplay's lifecycle process. In this stage, they perform the closure of the project and get an assessment report related to their performance during the gameplay.

We can observe how the gameplay's lifecycle process of ProDec can be easily mapped to the process groups defined by the ISO 21500. In the following subsections, we describe the different activities associated with each stage of the gameplay's lifecycle and discuss their mapping with the project management processes of the ISO 21500 standard from a software point of view.

3.2 Onset Stage

The process of a ProDec's gameplay begins with a Statement of Activity that establishes the objectives of the gameplay and provides players with the needed information about the scope and requirements of the project scenario involved in the gameplay. Table 3 shows the activities players need to perform for starting a gameplay and the project management processes of the ISO 21500 that the game is able to cover with these activities. Before starting a gameplay, players have to review the Statement of Activity (*A1*) and analyze all the information provided in order to develop the project charter and the project plans (*P1* and *P2*). Once players know the features of the project scenario, they can start the gameplay (*A2*).

Table 3. Coverage of ISO 21500 processes by the activities of the ProDec's Onset stage (I).

Activities of the Onset Stage		**ISO 21500 processes**
A1. Review the Statement of Activity.	A1.1. Identify the objectives of the gameplay. A1.2. Identify the scope and requirements of the project scenario.	P1. Develop project charter. P2. Develop project plans.
A2. Start the Gameplay.	A2.1. Select the type of gameplay. A2.2. Identify the players involve in the gameplay.	

During the Onset stage of the gameplay's lifecycle process, players are involved in a process that guides them to create from scratch the project scenario. This process is composed of six main activities that allow players defining the general information of

the project (*A3*), performing the size estimation of the project (*A4*), establishing the composition of the project team (*A5*), creating the schedule of the project tasks (*A6*), performing the risks analysis of the project (*A7*) and creating the project plan of the game scenario (*A8*).

In Table 4, we can observe these activities with all the sub-activities that players need to perform in order to create the project plan and define all the information related to the size, the project team, the tasks and the risks of the project scenario. Moreover, Table 4 maps the different activities of the Onset stage with the processes of the ISO 21500 standard that the game is able to cover through these activities. As we can observe the activity "*Define the Project Information (A3)"* allows covering the *"Develop project charter (P1)", "Develop project plans (P2)", "Identify stakeholders (P8)"* and *"Define scope (P10)"* processes of the ISO 21500 that belong to the Initiating and Planning process groups of the standard.

The activity "*Estimate the Size of the Project (A4)*" in which players have to perform the size estimation of the project, allows covering the "*Estimate resources (P15)"* and *"Estimate costs (P24)*" processes of the Planning process group of the ISO 21500 standard.

The process "*Establish project team (P14)"* of the Initiating process group and the process "*Define project organization (P16)"* of the Planning process group of the ISO 21500 standard are covered by the activity "*Define the Project Team (A5)"* in which players have to select and define the human resources for composing the work team of the project.

Through the activity "*Define the Project Tasks (A6)",* players define the schedule of the project tasks regarding the estimated start and completion dates, the assigned human resources and the dependency of the tasks. Therefore, through this activity players take contact with the following processes of the ISO 21500 Planning process group: *"Create work breakdown structure (P11)", "Define activities (P12)", "Sequence activities (P20)", "Estimate activities durations (P21)", "Develop schedule (P22)"* and *"Develop budget (P25)"*. Moreover, this activity also allows covering the "*Develop project team (P17)"* process of the ISO 21500 Implementing process group.

The activity "*Analyze the Project Risks (A7)"* allows covering the *"Identify risks (P27)* and *"Assess risks (P28)*" of the ISO 21500 Planning process group. Finally, the activity "*Create the Project Plan (A8)*" allows players to accept all the defined information and establish the project plan to be used in the gameplay scenario. Then, this activity supports the "*Develop project plans (P2)"* process of the ISO 21500 Planning process group.

Therefore, the activities of the ProDec's Onset stage allow players to take contact with the Initiating, Planning and Implementing process groups of the ISO 21500 standard.

3.3 Execution Stage

The second stage of ProDec gameplay's lifecycle process is the Execution stage. In this stage of the gameplay, players should perform three main activities with the goal

to simulate the execution of the project scenario and perform the control and monitoring of the project (see Table 5).

Table 4. Coverage of ISO 21500 processes by the activities of the ProDec's Onset stage (II).

Activities of the Onset Stage		**ISO 21500 processes**
A3. Define the Project Information.	A3.1. Define the context of the project. A3.2. Identify the companies that are involved in the project. A3.3. Establish the requirements of the project. A3.4. Set the features of the development company related to the salary, workday and effort values. A3.5. Establish the initial duration of the project.	P1. Develop project charter. P2. Develop project plans. P8. Identify stakeholders. P10. Define scope.
A4. Estimate the Size of the Project.	A4.1. Calculate the function points of each use cases. A4.2. Calculate the total function points of the project. A4.3. Estimate the workforce needed to perform the project. A4.4. Estimate the initial budget.	P15. Estimate resources. P24. Estimate costs.
A5. Define the Project Team.	A5.1. Select the human resources of the project. A5.2. Define the personality traits of each human resource that is involved in the project. A5.3. Define the experience of each human resource that is involved in the project. A5.4. Establish the composition of the work team.	P14. Establish project team. P16. Define project organization.
A6. Define the Project Tasks.	A6.1. Define the project tasks. A6.2. Estimate the duration of each project task. A6.3. Estimate the cost of each project task. A6.4. Allocate the human resources for each task. A6.5. Define the dependencies of the tasks. A6.6. Create the schedule of the project tasks.	P11. Create work breakdown structure. P12. Define activities. P17. Develop project team. P20. Sequence activities. P21. Estimate activities durations. P22. Develop schedule. P25. Develop budget.

A7. Analyze the Project Risks.	A7.1. Identify the project risks. A7.2. Make a quantitative analysis of the project risks.	P27. Identify risks. P28. Assess risks.
A8. Create the Project Plan.		P2. Develop project plans.

Once the players have ended the Onset stage, ProDec generates the simulation model that simulates the execution of the project plan and players can start its execution (*A9*). During the Execution stage, players have to direct, monitor and control the simulation of the execution of the project plan in order to success the project scenario (*A10* and *A11*). Therefore, they have: (a) to review and evaluate the progress of the project simulation against the project plan; (b) to identify the problems, deviations or risks that could be affecting the adequate progression of the project plan; and (c) to make decisions for correcting the potential deviations.

As we can observe in Table 5, through the activities of this stage, ProDec is able to cover the "*Direct project work (P3)*", "*Develop project team (P17)*" and "*Treat risks (P29)*" processes of the ISO 21500, which are related to the Implementing process group of the standard. In addition, ProDec allows players to take contact with the following processes of the ISO 21500 Control process group: *"Control project work (P4)", "Control changes (P3)", "Control scope (P13)", "Control resources (P18)", "Manage project team (P19)", "Control schedule (P23)", "Control costs (P26)"* and *"Control risks (P30)"*. Therefore, the Execution stage of the gameplay's lifecycle process of ProDec allows covering processes belong to the Implementing and Controlling process groups of the ISO 21500 standard.

Table 5. Coverage of ISO 21500 processes by the activities of the ProDec's Execution stage.

Activities of the Execution Stage		**ISO 21500 processes**
A9. Execute the Simulation of the Project Plan.	A9.1. Generate the simulation model of the project plan. A9.2. Start the simulation of the project plan.	
A10. Monitoring the Execution of the Project Plan.	A10.1. Review the Earned Value Analysis indicators. A10.2. Review the progress of the project in terms of tasks completion, duration and budget. A10.3. Review the motivation of the work team. A10.4. Review risks status.	P3. Direct project work. P4. Control project work. P5. Control changes. P13. Control scope. P17. Develop project team. P18. Control resources. P19. Manage project team. P23. Control schedule. P26. Control costs. P29. Treat risks. P30. Control risks.
A11. Control the Execution of the Project Plan.	A11.1. Evaluate project progress with respect to the project plan. A11.2. Identify the problems, deviations or risks that could be affecting the adequate progression of the project plan. A11.3. Make decisions (according to the game set of actions) to correct the potential deviations against the project plan with the goal of ending the project within the time, cost and quality established.	

3.4 End Stage

The last stage of ProDec gameplay's lifecycle process is the End stage. In this stage of the gameplay, players should perform three main activities with the goal to end the game (see Table 6).

First, players have to accept the completion of the project plan in order to end the simulation of the project (*A12*). Once they accept to close the simulation of the project, ProDec generates an assessment report that allows players to get the lessons learned from their performance during the game (*A13*). Finally, after getting the assessment report, players can close the project scenario, ending, at the same time, the gameplay (*A14*).

Table 6. Coverage of ISO 21500 processes by the activities of the ProDec's End stage.

Activities of the End Stage		**ISO 21500 processes**
A12. Close the Simulation of the Project.	A12.1. Accept the completion of the project plan.	P6. Close project phase or project.
A13. Collect the Lessons Learned.	A13.1. Get the assessment report of the gameplay. A13.2. Analyze the assessment report to get the lessons learned.	P7. Collect lessons learned.
A14. End the Gameplay.		P6. Close project phase or project.

Through the activities of this stage, as Table 6 shows, ProDec is able to cover the *"Close project phase or project (P6)"* and *"Collect lessons learned (P7)"* processes of the ISO 21500, which are related to the Closing process group of the standard. Thus, the End stage of the gameplay's lifecycle process of ProDec allows covering the Closing process group of the ISO 21500 standard.

4 Conclusions and Further Works

Bringing professional practice into the learning/teaching process is an especially difficult task in the context of software project management and can turn into a challenge in relation to software process standards education. According to many authors, the use of serious games, simulations and gamification strategies can help to overcome the difficulties and enable learners to acquire practical experience with real-life scenarios during their learning/teaching process.

The ISO 21500 standard provides generic guidance for project management and can be used by any type of organization, including public, private or community organizations, and for any type of project, irrespective of complexity, size or duration. In this paper, we have performed a systematic literature review to analyze the current works related to the use of games for understanding, teaching and supporting the education of the project management processes of the ISO 21500 standard. The results of our review allow us giving evidence about the lack of serious games for

supporting the education of the ISO 21500 standard and considering this topic as a research opportunity.

For that reason, we have analyzed how ProDec, a simulation-based serious game, covers the project management processes of the ISO 21500 standard in order to assess its suitability to be integrated as a learning resource for understanding, teaching and supporting the education of the project management processes of the standard in the context of software projects.

The game, through the activities that are involved during the gameplay's lifecycle, is able to provide coverage of the five process groups of the ISO 21500 standard. Moreover, ProDec covers the 100% of the processes involved in the Integration, Scope, Resource, Time, Cost and Risk subject groups and the 50% of the processes involved in the Stakeholder subject group. Therefore, ProDec allows taking contact with seven of the ten subject groups of the ISO 21500 standard and covering almost 75% of the project management processes of the ISO 21500 standard. On the other hand, the current version of ProDec is not able to cover the processes involved in the Quality, Communication and Procurement subject groups and the process *Manage Stakeholders (P9)* involved in the Stakeholder subject group.

We believe that the use of this kind of learning resources is beneficial for learners and helps them to consolidate their knowledge. The coverage of the standard allows us to consider that ProDec can be a helpful learning resource to be used within the learning/teaching process of the ISO 21500 standard in the context of software projects. Nevertheless, more research and evaluations in this scope are needed to consider ProDec as a potential tool for software project management process education. For that reason, we are currently working to perform evaluations of the educational effectiveness of ProDec with both, university students and industrial practitioners, with the goal to get the necessary feedback to improve ProDec and integrate it as a learning resource to support project management processes education in the context of software projects.

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