

An Instructional Feedback Technique for Teaching Project Management Tools Aligned with PMBOK

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Abstract. The management of contemporary software projects is unfeasible without the support of a Project Management (PM) tool. In order to enable the adoption of PM tools in practice, teaching its usage is important as part of computer education. Aiming at teaching PM tools, several approaches have been proposed, such as the development of educational PM tools. However, such approaches are typically limited with respect to content coverage and instructional support. In this context, an important technique is the provision of instructional feedback, which is essential in order to help the students to learn based on the evaluation of their own actions. In order to take advantage of this technique, this article proposes its employment in an Instructional Unit, being integrated into the PM tool dotProject+, providing automated feedback based on the project plan being developed with the tool. This technique has been evaluated through a series of case studies.

Keywords: project management; PMBOK; project management tool; dotProject; feedback; teaching; learning.

1. Introduction

Project Management (PM) is crucial for the success of software projects, being necessary to properly manage the project resources and its constraints in order to meet the project requirements (PMI, 2013a). Currently, PM is an extensive discipline, being organized in knowledge areas in accordance with the PMBOK guide (PMI, 2013a),

which is widely accepted by industry and professionals in this area (Mishra and Mishra, 2013; Car *et al.*, 2007). Moreover, considering the complexity of contemporary software projects, their management is unfeasible without the support of a software tool (Fabac *et al.*, 2010). In this context, a PM tool is a software system that may support the PM process. Examples of PM tools include proprietary alternatives, such as MS-Project and Oracle Primavera, as well as open-source alternatives, such as project.net and dotProject (Pereira *et al.*, 2013). Besides the existence of stand-alone solutions, today web-based PM solutions are required in order to facilitate the collaboration and information sharing among project stakeholders (Fabac *et al.*, 2010). Yet, most web-based PM tools do not support the PM process as defined by PMBOK (Pereira *et al.*, 2013), limiting the assistance to just some part of it (Mishra and Mishra, 2013), such as schedule development, risks identification, cost estimation, among others (Car *et al.*, 2007). In this context, the open-source PM tool – dotProject has been enhanced to be aligned with PMBOK processes, creating dotProject+ as a low-cost and web-based alternative (Gonçalves and Wangenheim, 2016a).

Thus, besides teaching knowledge on PM and interpersonal skills (PMI, 2013a), PM education should also cover the usage of PM tools, as considering the need to adopt some PM tool for managing software projects in practice, professionals need to know how to use them. Consequently, an important competency of project managers and/or Software Engineering (SE) professionals is the usage of PM tools (PMI, 2013a; IEEE, 2014), and the demand for teaching this competency is addressed by the ACM/IEEE curriculum guidelines for Computer Science (ACM and IEEE, 2013).

Currently, for the teaching of PM tools there are two alternatives – using a professional PM tool, such as MS-Project or dotProject, being developed for the support of PM in practice, yet do not provide further educational support (Car *et al.*, 2007). On the other hand, some specific PM tools have been developed for teaching, such as ProMES and ppcProject (Salas-Morera *et al.*, 2013; Reid and Wilson, 2007). Yet, these tools are focused strongly on teaching and are not made for managing real software projects, demanding the student to learn some professional PM tool during their professional tasks (Gonçalves and Wangenheim, 2015a).

Furthermore, it is not sufficient to just have a PM tool with educational features, as in order to effectively teach this competency a complete Instructional Unit (IU) is required. An IU is a set of classes and instructional materials, designed to teach certain learning goals in a specific educational context (Hill *et al.*, 2005), including a PM tool as part of the IU's materials. Some IUs have proposed the adoption of educational PM tools (Salas-Morera *et al.*, 2013; Reid and Wilson, 2007), which typically offer several exercises to be solved by students, and also automate student answer evaluation. In this way, these tools may assist in the teaching of part of the IU's content, delivering exercises to students according to their progress, and also assist with the immediate evaluation of student performance.

However, previous researches (Gonçalves and Wangenheim, 2015b) have identified that these existing IUs are rather focused on specific parts of the PM process, addressing mostly time and human resource (HR) management. Thus, in order to provide a more comprehensive support, improvement opportunities include the coverage of all PM

knowledge areas, the enhancement of professional PM tools for education, as well as the adoption of more effective instructional strategies (Gagne *et al.*, 1992).

As an attempt to improve the teaching of PM tools, the IU PiMENTO (Project ManagemEnt TOols) (Gonçalves and Wangenheim, 2016a) has been developed, focusing on initiating and planning process groups. Among its materials this IU uses an enhanced version of one of the most popular open-source tools for PM, dotProject (<http://dot-project.net>), providing support for the initiating and planning process groups in full alignment with PMBOK (PMI, 2013a). Moreover, even though this PM tool is designed for professionally manage software projects, it was also enhanced for educational purposes. Also, as part of the IU's materials the PM initiating and planning process has been modelled, being presented in a set of slides for the content explanation in class. The educational strategy of this IU consists of expositive lectures and practical classes, in which students initiate and plan a software capstone project. In these practical classes, students utilize a PM tool in computer labs to realize their assignments.

Furthermore, in order to improve students' learning and motivation it is important to also enhance instructional techniques, such as instructional feedback (Kleij *et al.*, 2012; Kretlow and Bartholomew, 2010). Instructional feedback provides a response to students' actions while doing the practical exercises, indicating how they may correct or improve them, in order to achieve the IU's learning goals (Kleij *et al.*, 2012). This feedback is normally provided manually by the instructors (Gagne *et al.*, 1992). However, giving individual feedback to each student may become impracticable due to the demanded effort (Kretlow and Bartholomew, 2010). For this reason, instructors are often only able to provide a superficial feedback to students, or some generic feedback to the class as a whole (Gagne *et al.*, 1992; Kretlow and Bartholomew, 2010). Thus, a practical alternative for providing a customized and individual feedback is automatizing its delivery to students with the assistance of a software tool (Chua and Balkunje, 2012).

There are many ways to design an instructional feedback technique, varying the definition of the proper moment to deliver a message or how to approach the students (Kleij *et al.*, 2012; Kretlow and Bartholomew, 2010). For example, for some instructional activities immediate feedback may be suitable to assist students when carrying it out; however, it may also interrupt their attention. Likewise, a feedback approach may explicitly highlight students' mistakes or providing explanations about the content, but leaving the students to find their errors by themselves.

Some of these techniques already have been adopted by previous studies (Chua and Balkunje, 2012), proposing feedback messages to be elaborated by instructors, other students, or even by a software tool. When the feedback message is elaborated by the software itself, it is usually automatic delivered to students (Vivian *et al.*, 2015). However, even tools providing an automatic evaluation of the PM tool usage by students, still do not fully explore the instructional feedback potential, presenting just simple messages, normally highlighting students mistakes, but without providing explanations about how to improve or examples that may assist in their understanding (Gregoriou *et al.*, 2010). Moreover, none of these approaches have been customized for teaching PM aligned with the PMBOK (Gonçalves and Wangenheim, 2016b), lacking the coverage of several PM

knowledge areas. Additionally, none of the previous studies includes the introduction of some instructional feedback technique in a professional PM tool, focusing rather exclusively on educational tools, diminishing the potential contribution of such techniques to the actual students' demands.

In this context, this article presents the design of an instructional feedback technique integrated into an IU for teaching PM tools, and its implementation as an add-on module as part of dotProject+. It provides students with recommendations, examples and explanations about the PM initiation and planning process, based on their interaction with the PM tool functionalities. For example, when students are carrying out risk planning, they receive feedback messages presenting risk examples, explanations about risk management strategies, or feedback messages criticizing their mitigation and contingency plans. The contribution of such a technique is evaluated through a series of case studies, applying the IU in four undergraduate computing courses during 2016.

Section 2 introduces the main concepts related to this article, and Section 3 presents related studies, including existing IUs that employ some instructional feedback technique for teaching PM tools. Section 4 presents the research methodology adopted in this study. The study is defined in Section 5. Section 6 presents the PiMENTO IU and introduces the proposed instructional feedback technique. The evaluation of the proposed technique is defined in Section 7 and its execution is presented in Section 8. In Section 9 the collected data is analyzed and discussed, presenting the conclusions in Section 10.

2. Background

2.1. Project Management

Project Management (PM) organizes project activities and its resources in order to meet the project objectives. According to the PMBOK (PMI, 2013a), the PM process is structured in 5 process groups, from initiation to closure (Fig. 1).

As a first step to improve the teaching of PM tools, this study targets the first process groups: initiating and planning. The initiating process group addresses processes for

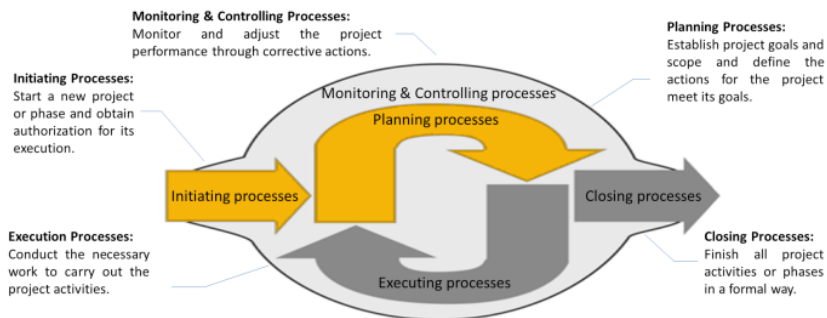


Fig. 1. PM process groups (PMI, 2013a).

Table 1
PM knowledge areas (PMI, 2013a)

Knowledge area	Processes to:
Integration	Identify, define, combine, unify, and coordinate PM processes and PM activities.
Scope	Ensure that the project addresses the entire work and meets all its requirements.
Time	Plan and control the activities that will be carried out during the project so it concludes within the deadline.
Cost	Plan, estimate, and control project costs, so it concludes within the approved budget.
Quality	Define the responsibilities, goals and quality policies so the project meets the needs that have initiated it.
Human Resource	Organize and manage the project team.
Communication	Ensure the generation, collection, distribution, storage and final destination of project information.
Risk	Identify, monitor and control the project risks.
Procurement	Buy or contract products, services or any resources that are not available as project internal resources.
Stakeholder	Identify and manage the stakeholders and their expectations.

specifying project goals, justifying the need for the project execution, defining its milestones and outcomes, as well as obtaining the commitment of the stakeholders. Its main output is the project charter, which has to be approved by the project sponsor, ensuring that the necessary resources will be available for the project execution.

The planning process group covers processes for elaborating the project plan, a document defining all necessary information to carry out the project. This project plan should not be limited to document the project activities and its resources, but also addresses several other topics, such as project costs, risks and procurement demands, covering all PM knowledge areas (Table 1), which are essential to properly manage a software project (PMI, 2013a; Car *et al.*, 2007; Salas-Morera *et al.*, 2013).

The PM process defined by PMBOK includes relevant PM techniques for software projects, being among the most adopted approaches in software industry (Eastham *et al.*, 2013). Its relevancy for software projects is also highlighted by Project Management Institute (PMI), creating an extension of PMBOK for software (PMI, 2013b), detailing particularities of PM techniques application in this context.

Conducting the PM process may be very complex and demand considerable resources of an organization. To assist in its execution, many PM tools have been developed, taking advantage from technology for supporting its execution.

2.2. Project Management Tools

Currently, there are a wide variety of PM tools with diverse functionalities and characteristics, such as MS-Project, Primavera, dotProject, Project.net, etc. (Mishra and Mishra, 2013). Their functionalities, for instance, may support the whole PM process or just some activities related to only one PM knowledge area, for example, registering and tracking work hours (Cicibas *et al.*, 2010). The scope of the provided functionalities

may influence in the usage of these tools for teaching, as they may limit the content to be addressed. In this context, analyzing existing open-source PM tools the widest (yet not complete) support is provided by dotProject (Pereira *et al.*, 2013). Moreover, none of these open-source options offers any educational support to assist students and/or instructors when utilized in classroom (Mishra and Mishra, 2013; Cicibas *et al.*, 2010). However, being open-source, these tools may be customized to meet educational demands. On the other hand, proprietary alternatives, such as Oracle Primavera, provide a complete support for the PM process, but, besides requiring monetary investments, they also do not include any educational support (Fabac *et al.*, 2010).

Moreover, in terms of platform, there exist stand-alone tools (mono-user and accessed via desktop) or web-based tools (multi-user and accessed via web browser). In practice, a web-based PM tool has to be used in order to properly manage a software project, due to its support to the collaborative work and the sharing of information (Fabac *et al.*, 2010; Pereira *et al.*, 2013; Bhattacharya, 2013). However, the adoption of a web-based PM tool requires this tool to be installed on a web server and Internet access during classes.

Today in practice in the IT industry, composed mainly by Small and Medium Enterprises (SMEs) (The Standish Group, 2015), with limited resources, open-source and web-based PM tools are a feasible alternative (Mishra and Mishra, 2013). Thus, commonly PM tools adopted by such organizations are: dotProject, GanttProject, RedMine, among others (Mishra and Mishra, 2013; Pereira *et al.*, 2013; Cicibas *et al.*, 2010). Hence, the teaching based on such tools is a reasonable choice to better prepare students for their professional tasks (Bhattacharya, 2013).

2.3. Teaching of PM Tools

Knowing how to use PM tools is a necessary competency for project managers (PMI, 2013a) and, as described in the Software Engineering Body of Knowledge (SWEBOK) (IEEE, 2014), it is also important for SE professionals. The need for its learning is also addressed by the ACM/IEEE curriculum guidelines for Computer Science (ACM and IEEE, 2013), specifying that students have to learn how to use a PM tool to develop a project schedule, to allocate human resources, to perform risk analysis, to monitor the project performance, etc.

Typically, IUs for teaching PM tools include activities in which students have to solve problems applying some PM technique with a tool (Gonçalves and Wangenheim, 2015b). Among these techniques typically are (PMI, 2013a; Car *et al.*, 2007; Reid and Wilson, 2007):

- Critical Path Method (CPM): to identify project activities that cannot be delayed without affecting the deadline.
- Program Evaluation and Review Technique (PERT): to calculate the estimated effort to carry out an activity based on three estimates (worst case, most common case, and best case).
- Earned Value Analysis (EVA): to measure project performance and progress in an objective manner.

Table 2
Addressed PM knowledge areas and process groups by the PM techniques typically taught (PMI, 2013a)

	Integra- tion	Scope	Time	Cost	Qua- lity	HR	Commu- nication	Risk	Procure- ment	Stake- holder
Initiating	-	-	-	-	-	-	-	-	-	-
Planning	-	-	CPM, PERT, RL	-	-	RACI, RL	-	-	-	-
Executing	-	-	-	-	-	-	-	-	-	-
Monitoring & Controlling	-	EVA	EVA	EVA	-	-	-	-	-	-
Closing	-	-	-	-	-	-	-	-	-	-

- Resource Leveling (RL): to adjust start and finish dates based on resource constraints, with the goal of balancing resource demand and availability.
- ACI Matrix: describes the participation by various agents and their roles in completing project activities.

These activities typically involve the use of some professional PM tool (Car *et al.*, 2007), or even some educational PM tool (Salas-Morera *et al.*, 2013; Reid and Wilson, 2007). However, the teaching of PM tools should not be limited to the execution of specific PM techniques (Table 2), but addresses its general usage, covering the PM process as defined by PMBOK.

Thus, the teaching of PM tools should address the usage of functionalities to support all process groups and knowledge areas, enabling the student to learn cognitive competencies up to the application level following Bloom’s taxonomy (Bloom, 1956) in order to be able to use a PM tool effectively. In this respect, several IUs rather seem to take students only up to the remembering and comprehensive level (Salas-Morera *et al.*, 2013; Reid and Wilson, 2007; Gonçalves and Wangenheim, 2015b), due to their instructional strategy basically relying on theoretical lectures, not involving any hands-on activities using a PM tool.

In addition, beyond the practical use of PM tools in the classroom, its teaching can be improved by the employment of instructional feedback as an important technique for student learning (JangHyeon *et al.*, 2002).

2.4. Instructional Feedback

Learning is the result of the human capability to acquire, transform and evaluate information based on the experience, causing a permanent change in his behavior (Bruner, 1977). Learning may occur at any time, even during daily situations, influenced by random events. However, for a controlled learning, teaching is introduced, providing means for the systematic development of competences (Bruner, 1977; Branch, 2009). This



Fig. 2. Gagne events of learning (Gagne *et al.*, 1992).

teaching/learning process can be divided in events as proposed by Gagne *et al.* (1992) (Fig. 2).

An important event in the learning process is the provision of feedback for stimulating student reflection about their own actions (Schilling, 2015). It provides information to students, criticizing their way of acting and thinking, consequently promoting their learning (JangHyeon *et al.*, 2002). This technique promotes learning through errors, using students' mistakes to concentrate the provided explanations exactly on topics of the IU content, towards which students present learning problems (Schilling, 2015; Bilal *et al.*, 2012).

There are different techniques to promote feedback, in accordance to the adopted instructional strategy (Branch, 2009), defining the feedback goal (assist students to improve their responses or marking it), how to approach students (providing extra explanations or highlighting their mistakes), and also the moment to deliver the message to students.

Feedback may have different goals, being formative or summative (Segers *et al.*, 2008). Formative feedback is designed in order to instruct students during an activity, assisting in its improvement before the delivery. On the other hand, summative feedback is given at the end of an activity, and is normally used for grading (Segers *et al.*, 2008; Martens *et al.*, 2010).

In relation to how students will be approached by a feedback message, it may be provided by verification, informing whether the student response is correct or not, or by elaboration, providing information assisting in the improvement of student response, but not necessarily judging its correctness (Segers *et al.*, 2008). A feedback technique may also focus on different aspects of student response correctness, as it may be positive (highlight the students correct responses), negative (highlight the students mistakes), or constructive (not only informing if a certain response is wrong or incomplete, but providing means for the student to improve it) (Kleij *et al.*, 2012; Kretlow and Bartholomew, 2010).

Feedback may be delivered immediately after some student action, or delayed, sometime after the conclusion of an activity (Scheeler *et al.*, 2010). Yet, the moment of delivering feedback is typically related to the adopted communication channel, which may vary from computer-based to oral or written by the instructor (Bilal *et al.*, 2012; Martens *et al.*, 2010). There are different manners in which an instructional feedback can be delivered to students. An instructor can provide individual feedback to each student, or provide a general feedback to the class as a whole.

Specifically when teaching PM tools, immediate and automated feedback has been an interesting alternative, due to the constant demand of interaction between students and the tool's functionalities (JangHyeon *et al.*, 2002; Schilling, 2015; Ojiako *et al.*, 2011). In order to know if such functionalities are being completely (i.e. addressing all PM knowledge areas) and correctly utilized (including the correct information), instructional feedback is an important technique for learning (Gagne *et al.*, 1992; Gregoriou *et al.*, 2010). In this context, students can receive feedback messages during their interactions with the PM tool, aiding them to execute the PM process, and avoiding stagnation in specific parts of the process. Being automated, it is expected that students receive the feedback messages at the right moment, addressing the content properly. A further advantage is that in such feedback does not depend on the instructor availability, neither his/her constant analysis of students' behaviour.

3. Related Studies

In order to identify existing IUs for the teaching of PM tools involving some instructional feedback technique, we conducted a Systematic Literature Review (SLR) (Gonçalves and Wangenheim, 2016b). We searched for studies published in academic journals and conference proceedings in relevant digital libraries. Yet, only few relevant studies were found, indicating that, despite the existence of a reasonable amount of studies about the teaching of PM tools, only very few report the adoption of some instructional feedback technique.

Gregoriou *et al.* (2010) introduce an interesting feedback technique, which is included in an IU for teaching PM techniques, such as CPM, PERT, and RACI matrix, focusing on exercises carried out in the educational PM tool – ProMES. The adopted instructional feedback technique delivers feedback messages immediately after each submitted response. These messages are focused on highlighting the students' mistakes, following the negative feedback approach. As a result, students became aware of their errors, and tried again to find another solution. Students indicated that the feedback technique was helpful, along with the feature that highlights the existing problems without revealing the right answer. It was highly appreciated, since they had the opportunity to try again until they produced the correct result. Yet, the impact of the feedback technique remains vague as only an ad-hoc evaluation has been reported based on verbal comments of the students on its contribution to their learning.

The instructional feedback techniques reported by other studies may be classified into two categories. One type of techniques evaluates students' decisions when running

simulations of the execution of a project plan (Chua and Balkunje, 2012; Gregoriou *et al.*, 2010; Rodriguez *et al.*, 2006). In these studies, feedback is automatically delivered after each simulation, reporting issues with regard to the trade-off between project time, cost, scope, and quality. Additionally, they adopt the elaboration feedback approach, suggesting possible improvements that the students could make before a new simulation. Likewise, the verifying approach is adopted, indicating whether students' actions are correct or not. This kind of feedback is normally presented by visualizing progress tracking, based on EVA indicators (Souza *et al.*, 2015) or remaining time and budget. In the reported studies these feedback techniques were typically evaluated by case studies, collecting data via questionnaires after the lectures. The findings of these studies highlighted the positive impact of the instructional feedback, especially in relation to student motivation.

A second category of studies focuses on instructional feedback provided through communication channels of collaborative PM tools (Vivian *et al.*, 2015; Tachikawa *et al.*, 2013; Xiao *et al.*, 2008), such as wiki, forums, chats, or shared whiteboards. In this case, the instructional activities demand the usage of these communication channels to promote discussions while managing a software project. PM decisions and rationales are discussed and registered by some students, while others analyse and comment them. Consequently, the feedback is elaborated by students themselves, promoting collaborative learning (Caballé *et al.*, 2010), where the instructor acts as a mediator, evaluating the promoted feedback and interfering when students are not able to evaluate, wrongly criticize, etc. This technique, thus, demands considerable effort from instructors in order to monitor students' evaluations. These studies also were evaluated through a case study, collecting data through system logs. Findings demonstrate that the students may evaluate the effectiveness of actions of their peers, through the discussion of the results and even find alternatives for improvement.

The processes addressed by these IUs are rather focused on time and HRs management. IUs either request the students to elaborate project plans or to analyse existing ones. Additionally, the communication knowledge area has also been superficially addressed by some studies, due to the adoption of collaborative PM delivering project artefacts to specific stakeholders, namely customers, sponsor or team members, represented by other students, instructors, or even chatter bots. However, this communication is usually focused on disseminating information during the project execution, but not elaborating a project communication plan.

In summary, we can observe that the existing IUs for teaching PM tools do not completely cover all PM knowledge areas in conformance with the PMBOK. Moreover, analysing the tools adopted by these studies, it has been evident that so far the employment of some instructional feedback technique demands the adoption of an educational PM tool. However, such tools have demonstrated to be focused on specific parts of the PM process, limiting the contribution of the instructional feedback in relation to other parts of the PM process, as demanded by a professional use of PM tools. Thus, in order to optimize learning in a more comprehensive and relevant way, it may be advantageous to employ some instructional feedback technique in a professional PM tool covering all PM knowledge areas in compliance with PMBOK.

4. Research Design

This study aims at the development and evaluation of an instructional feedback technique integrated in an IU for teaching a PM tool. Therefore, we conducted an exploratory case study (Yin, 2014) (Fig. 3) in order to understand the students’ perceptions about the contribution of the instructional feedback during the IU.

The case study is performed according to the procedure proposed by Yin (2014) and Wohlin *et al.* (2012):

- **Study definition.** The study is defined, including the establishment of its goal, and defining how the goal is going to be evaluated in terms of analysis questions and metrics, following the Goal/Question/Metric (GQM) approach (Basili *et al.*, 1994). Based on the measurement plan, data collection instruments are developed.
- **Study execution.** The study execution follows the ADDIE approach (Branch, 2009), addressing the design, development and application of the instructional feedback technique in an IU. This includes the customization of an IU for teaching a PM tool, in which the instructional feedback technique is employed. Here, we enhance PiMENTO (Gonçalves and Wangenheim, 2016a), an IU focused on the teaching of a PM tool aligned with PMBOK processes, adopting the open-source PM tool dotProject+, which is evolved to include the instructional feedback technique. The IU is applied in practice in PM courses collecting data as defined by the measurement plan.
- **Analysis and Interpretation.** The study is analysed through descriptive statistics methods, evaluating the collected data regarding student perception about the quality of the instructional feedback technique.

This study was approved by the ethics committee CEPESH/UFSC – under the nº. 47734215.9.0000.0121.

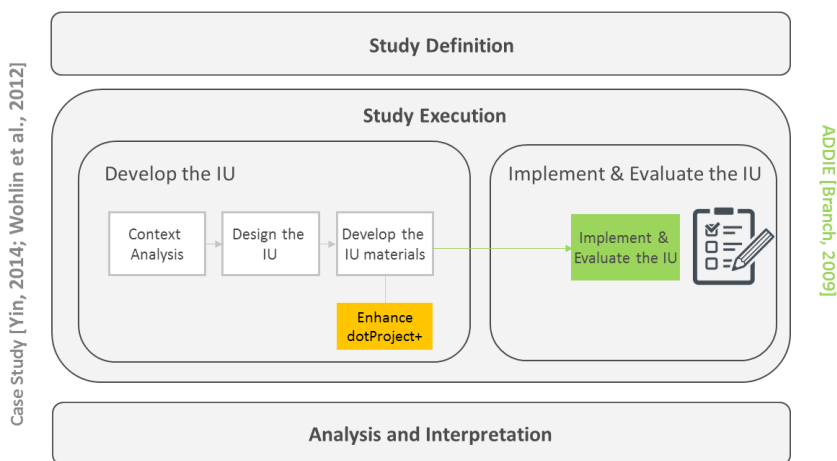


Fig. 3. Overview on research methodology.

5. Study Definition

The objective of this study is to analyse the quality of the instructional feedback technique employed in PiMENTO IU with respect to content, strategy, learning, materials, and user experience from the point of view of the students in the context of higher education computing courses. In order to achieve this objective, we carried out an exploratory case study, applying the IU in higher education computing courses, analysing the students' perception about the instructional feedback technique.

Following The GQM approach, analysis questions were defined with respect to each quality aspect: content (the topics addressed), strategy (the moment the messages are delivered to students and how they were approached by the messages), learning (students' perception of learning through the feedback messages), materials (quality of the feedback technique implemented into dotProject+), and user experience (how students ap-

Table 3
GQM plan

Metric	Questioner Item
Goal: Analyse the instructional feedback technique in the PiMENTO IU, aiming at evaluating its quality in relation to content, strategy, learning, material and user experience, under students' point of view, in the context of higher education computer courses.	
<i>AQ01: How appropriate is the content presented by the instructional feedback technique?</i>	
M1. Median of students' perception regarding the content coverage.	The feedback messages delivered by dotProject+ provide information for all knowledge areas (coverage).
M2. Median of students' perception regarding the content depth.	The feedback messages delivered by dotProject+ expose the content clearly and with enough information for my understanding (depth).
<i>AQ02: What is the quality of the instructional strategy?</i>	
M3. Median of students' perception regarding the time for feedback delivery.	I consider the moment that the feedback messages are delivered to be appropriate.
M4. Median of students' perception regarding how feedback messages approach them.	I consider the format of the messages and the employed terminology is appropriate.
<i>AQ03: What is the contribution of the instructional feedback technique for student learning?</i>	
M5. Median of students' perception regarding the instructional feedback technique contribution in their learning.	The explanations presented by the feedback messages assisted in the improvement of my learning.
<i>AQ04: What is the quality of the instructional feedback add-on module implemented in dotProject+?</i>	
M6. Median of students' perception regarding the quality of feedback technique as an instructional material.	I consider the feedback messages delivered during the usage of dotProject+ as a useful instrument for my learning.
<i>AQ05: What is the user experience promoted by the instructional feedback technique?</i>	
M7. Median of the recommendation level of the instructional feedback technique by students.	I would recommend the usage of the instructional feedback technique to other students that need to learn PM tools.
M8. Median of students' perception of motivation during the IU activities owing to the instructional feedback mechanism.	The feedback messages delivered by dotProject+ have increased my motivation to improve the project charter and the project plan.

preciated to interact with this technique and its effects on students' motivation). A complete list of analysis questions and metrics is presented in Table 3.

Data is collected through a questionnaire composed of items as presented in Table 3. The questionnaire items are defined as affirmations with responses on a 5-point *Likert* scale (Wohlin *et al.*, 2012), ranging from -2 (totally disagree) to 2 (totally agree). The questionnaire also contains open questions asking students to indicate strengths, improvement opportunities and other comments regarding the instructional feedback technique. Additional data has been collected by analysing the students' works as well as through log files of their usage of the tool dotProject+. This data is used in order to analyse to which degree the students were able use a PM tool to develop the project charter and the project plan, as well as, to which degree the instructional feedback technique has been utilized by students. Data collection has been carried out just after the application of all IU lectures.

6. PiMENTO IU

The PiMENTO (Project ManagemEnt TOols) IU aims at teaching a PM tool during project initiation and planning in conformance with the PMBOK, covering all PM knowledge areas.

6.1. Context Analysis

The IU is designed to be used as part of PM or SE courses. In this context, the target audience is typically composed of students between 18 and 30 years, who do not have prior experience with PM tools but who are often studying or already have studied some SE course.

The teaching of PM tools is usually done as part of a SE course or in PM specific courses. These courses, besides teaching the usage of PM tools, also cover the teaching of PM concepts, including knowledge, skills, and techniques to carry out the PM process. In this context, PM tools are introduced as an important instrument to assist the PM process execution.

These higher education classes are typically conducted in classrooms and/or computer labs with Internet access.

6.2. Design of the Instructional Unit

Based on the ACM/IEEE curriculum guidelines (ACM and IEEE, 2013), the learning objectives of the PiMENTO IU are defined focusing on teaching the usage of a PM tool during project initiating and planning:

- a) After the students completed the IU, they should know how to use a PM tool to elaborate a project charter for a software project.

- b) After the students completed the IU, they should know how to use a PM tool to elaborate a software project plan, addressing all PM knowledge areas in conformance with PMBOK.

The IU content is designed to address the PM tool's functionalities to support the initiating and planning process groups as well as theoretical knowledge with respect to these processes.

The instructional strategies adopted include expositive classes and experiential learning (Branch, 2009; Dick and Carey, 2006). The unit is sequenced by alternating the presentation of theoretical knowledge through expositive lectures, and practical classes, in which students use a PM tool to carry out the respective part of the PM process presented the previous theoretical lecture. The practical classes begin with an expositive presentation, in which the instructor explains how to use the PM tool functionalities to support the respective part of the PM process, and then, students use the PM tool in order to elaborate their own project charters and project plans. In total, the IU is composed of 13 lectures with duration of 1:40h each. The planned content, instructional activities and materials designed for each lecture are presented in the IU syllabus (Table 4).

Table 4
IU syllabus

Class	Content	Instructional method	Resources and materials
1T	<ul style="list-style-type: none"> Project initiation 	Expositive lecture. Exercises: related to project initiation.	<ul style="list-style-type: none"> Projector/Notebook Slides
1P	<ul style="list-style-type: none"> Project initiation dotProject+: for project initiation 	Expositive lecture: explanation about tool functionalities. Experiential learning: dotProject+ usage by students.	<ul style="list-style-type: none"> Computers with internet Projector dotProject+ Usage guide slides
2T	<ul style="list-style-type: none"> Scope planning 	Expositive lecture. Exercise: related to scope planning.	<ul style="list-style-type: none"> Projector/Notebook Slides
2P	<ul style="list-style-type: none"> Scope planning 	Expositive lecture: explanation about tool functionalities. Experiential learning: dotProject+ usage by students.	<ul style="list-style-type: none"> Computers with internet Projector dotProject+ Usage guide slides
3T	<ul style="list-style-type: none"> Time planning 	Expositive lecture. Exercises: related to time planning.	<ul style="list-style-type: none"> Projector/Notebook Slides
3P	<ul style="list-style-type: none"> Time planning 	Expositive lecture. Experiential learning: dotProject+ usage by students.	<ul style="list-style-type: none"> Computers with internet Projector dotProject+ Usage guide slides
4T	<ul style="list-style-type: none"> Cost planning 	Expositive lecture. Exercises: related to cost planning.	<ul style="list-style-type: none"> Projector/Notebook Slides.
4P	<ul style="list-style-type: none"> Cost planning 	Expositive lecture: explanation about tool functionalities. Experiential learning: dotProject+ usage by students.	<ul style="list-style-type: none"> Computers with internet Projector dotProject+ Usage guide slides

Class	Content	Instructional method	Resources and materials
5T	<ul style="list-style-type: none"> • HR planning. • Communication planning • Quality planning. • Procurement planning. 	Expositive lecture. Exercises: related to HR, communication, quality, and procurement planning.	<ul style="list-style-type: none"> • Projector/Notebook • Slides
5P	<ul style="list-style-type: none"> • HR planning. • Communication planning • Quality planning. • Acquisition planning. 	Expositive lecture: explanation about tool functionalities. Experiential learning: dotProject+ usage by students.	<ul style="list-style-type: none"> • Computers with internet • Projector • dotProject+ • Usage guide slides
6T	<ul style="list-style-type: none"> • Risk planning • Stakeholders planning. 	Expositive lecture. Exercises: related to stakeholders planning.	<ul style="list-style-type: none"> • Projector/Notebook • Slides
6P	<ul style="list-style-type: none"> • Risk planning • Stakeholders planning. • Project plan exportation. 	Expositive lecture: explanation about tool functionalities. Experiential learning: dotProject+ usage by students.	<ul style="list-style-type: none"> • Computers with internet • Projector • dotProject+ • Usage guide slides
–	–	Project charter and plan deliver.	• Computer with internet
7	<ul style="list-style-type: none"> • Project charter • Project plan 	Presentation: students present their work to other class members.	<ul style="list-style-type: none"> • Projector/Notebook • Slides
–	–	Project charter and plan correction.	• Computer with internet

The main activity that the students carry out is the elaboration of a project charter and project plan using dotProject+. The theme for this project is a capstone project, which every student must develop when concluding their undergraduate computing program. During the elaboration of the project charter and the project plan, students are organized in groups composed of up to 4 members each. Its grouping enables them to discuss, for example, effort estimations to carry out project activities and possible risks.

The students’ learning is assessed by evaluating the students’ project charters and plans (written and oral presentation) using a rubric and exam questions. During the oral presentation of the project charter and plan, students also receive feedback from the instructor, indicating strengths and weaknesses. They can use these suggestions to improve the orally presented project charter and plan before submitting a final written version, which is used for grading.

6.3. Development of the Instructional Material

Based on the design of the PiMENTO IU, instructional materials have been developed, including the enhancement of a PM tool and a usage guide presenting the use of its functionalities. In the context of this IU, the PM tool – dotProject+ was enhanced, including the set of functionalities to fulfil the IU demands.

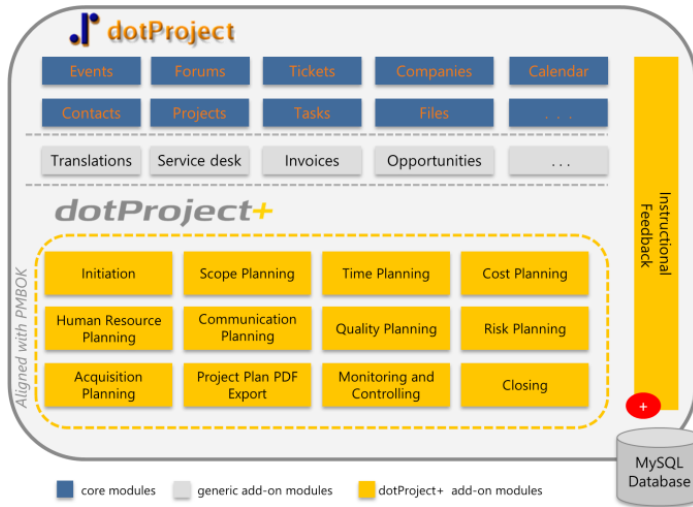


Fig. 4. Overview on dotProject+.

6.3.1. dotProject+

As one of the most popular open-source web-based PM tools, we have adopted dotProject for teaching. Here, we are specifically using an extension, dotProject+ (Gonçalves and Wangenheim, 2016a) that provides support to an extensive part of the PM process in alignment with PMBOK (Fig. 4). In relation with the initiation and planning process dotProject+ provides support for all PM knowledge areas.

Its main functionalities support the elaboration of the project charter and the elaboration of project plans in alignment with PMBOK. Moreover, dotProject+ generates the project plan, being composed by the plans produced for each knowledge area, as a single and structured plan. It is also supports the generation of a PDF document of these artefacts.

6.3.2. Usage Guide

The usage guide is composed of a set of slides that may be adopted by instructors in expositive lectures as well as the students as a reference material during the instructional activities. This usage guide is structured through the PM process represented using the BPMN notation (Weske, 2012) (Fig. 5).

The usage guide presents the usage of the tool step by step demonstrating for each activity screens and explaining how to use dotProject+ functionalities to support that process activity.

6.3.3. Instructional Feedback Technique

Aiming at improving the teaching of PM tools, we propose a new instructional feedback technique based on instructional feedback guidelines (Thurlings *et al.*, 2013), experiences reported by related studies (Gonçalves and Wangenheim, 2016b), as well as our teaching experiences observing typical students' errors made during the learning process.

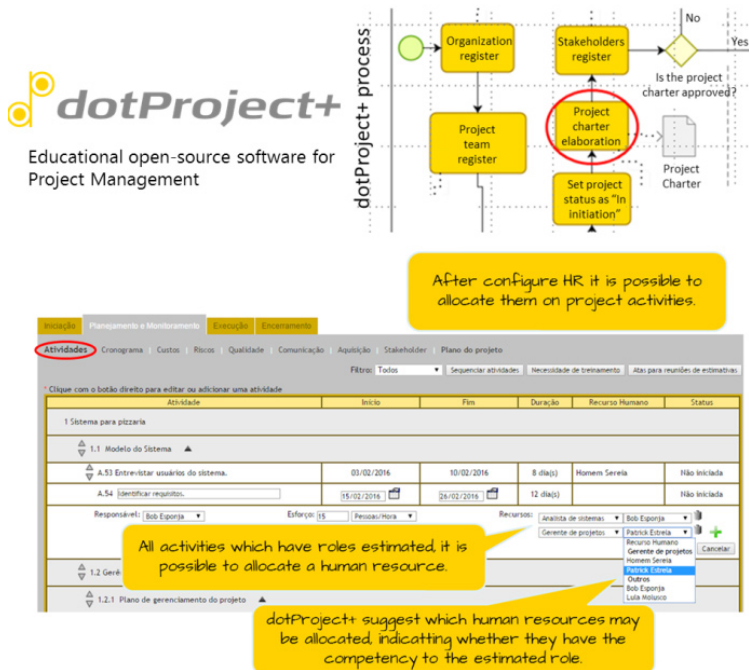


Fig. 5. dotProject+ usage guide.

In order to integrate the instructional feedback into the IU and aiming at an optimization of the learning process, we decided to design an instructional feedback technique that would provide instructions to students based on the project charter and project plan being developed with the PM tool.

The feedback messages are presented immediately to students, while interacting with the PM tool, indicating possible omissions and suggestions on what is necessary to complete the project plan. However, in order to keep interruptions minimal intrusive, the messages can be read by them when they want. Taking into consideration students' learning preferences, it is also possible to turn off the instructional feedback functionality, as maybe experienced students do not want to receive feedback during the tool usage.

We adopt an elaboration approach, focusing on the constructive evaluation of student actions. Analysing the project charters and project plans being developed, typical issues are identified, e.g. project activities with duration estimated before estimating their effort; project costs baselines not including a contingency reserve for project risks; risks mitigation and contingency actions not matching planned management strategies; etc.

The feedback messages are categorized according to the respective PM knowledge area, as this information may indicate to which knowledge area the issue that needs to be corrected is related. The feedback messages are delivered in two formats (Thurlings *et al.*, 2013; Fund, 2010): first a short message (presented as a question) is visualized in a feedback panel to instigate the student's curiosity, and the second is presented when requested by the student providing a detailed feedback message.

The instructional feedback technique follows the workflow as presented in Fig. 6, beginning with the students' interaction with the PM tool, until receiving of the complete feedback message.

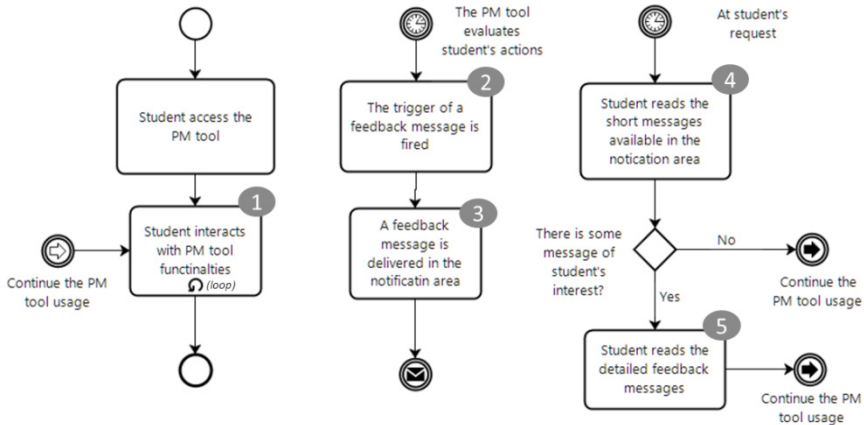


Fig. 6. Instructional feedback workflow.

Table 5
Examples of general instructional feedback

PM know- ledge area	Trigger	Feedback short message (question)	Feedback complete messages
Integration	When student complete the project charter elaboration, but it still not authorized.	Did you remember to obtain the project charter approval?	You have concluded the project charter. However, it still needs to be authorized by the project sponsor to ensure the estimated resources will be authorized. You may inform the project charter approval using the workflow actions available in the project charter form.
Scope	When student initiates the activities estimates (effort, duration, and resources) but still not estimate the work packages size/complexity.	Did you already estimate the size/ complexity for all work packages?	Observe that still exist work packages which size/complexity was not estimated. It is necessary before carry out the time and cost estimates.
Time	When identified that student create circular dependencies among project activities (when two activities depend on the conclusion of each other to start).	Do you know that there are circular dependencies in your project?	Attention to not create circular dependencies. It is when two activities depend on the conclusion of each to start. You may divide some of these activities for enabling the linear sequencing of these activities.
Cost	After the cost baseline creation, and when there are risks registered for the project, but any risk set in the contingency reserve.	Do you know that the financial impact of project risks may be included in the contingency reserve?	During the cost planning is important to analyse the contingency reserve. You may verity among the project risks, which ones have to be included in the contingency reserve, and flag them checking the option "Include in the contingency reserve".
Risk	When a prevention plan has been registered for an "Eliminated" risk.	There are prevention plans for eliminated risks?	Remember that eliminated risks do not exist anymore and consequentially do not demand to be prevented.

Considering that it is necessary to give general feedback (about the PM process) as well as specific feedback (about the content of what is being elaborated for the specific project), the feedback messages are also categorized in terms of their character (generic or specific). The generic messages may be applied on any software project, as they are related to the PM process in general, evaluating deviations in the student usage of the PM tool and the steps defined for such process. Some examples of general feedback are presented in Table 5, indicating the respective knowledge area, the trigger for delivering this feedback, and the short and detailed messages.

On the other hand, specific messages are provided for projects on the specific IU project theme, a capstone project. These messages typically regard the content of what is being elaborated, providing suggestions and examples of content. Examples of these messages are presented in Table 6.

The feedback messages are delivered to students when their trigger is fired. The status of the triggers are computed based on the evaluation of the content of the stu-

Table 6
Examples of specific instructional feedback

PM knowledge area	Trigger	Feedback short message (question)	Feedback complete messages
Communication	After student have registered two communication frequencies in the project plan, and there is no “monthly” or “weekly” frequency.	There is some periodical meeting with your advisor?	During the capstone project it is necessary periodical meetings with the advisor. You may register these meetings in the communication plan and its periodicity.
Quality	When student initiated the elaboration of the quality plan, but the field “Norms, policies, and quality guidelines” has less than 150 characters.	Have you identified the rules and norms to produce a capstone project yet?	A capstone project may follow certain technical restrictions, as formatting rules, structure, and even about its deadline. These guidelines are normally defined by the educational institution. You may register such information in the “Norms, policies, and quality guidelines” field.
HR	After registering 3 roles in the organizational diagram, and there is no role for advisor, student, or board member.	Were the roles of a capstone project defined?	A capstone project must include roles for advisor, student, and board members. Such roles may be included in the organizational diagram.
Procurement	If the student has less than 3 items in the procurement plan when concluding the project plan.	There are just few planned acquisitions. Do you already have registered the main acquisitions for your capstone project?	Remember that capstone projects may include acquisition such as books, specific software or hardware, printing supplies, beyond other items to for carrying out experiments or case studies.
Stakeholder	If the student has registered less than 3 stakeholders when concluding the project plan.	Have you already identified the stakeholders for the capstone project?	Typically capstone projects include at least the following stakeholders: student, advisor, and board members. Other stakeholders may vary according to the project application area.

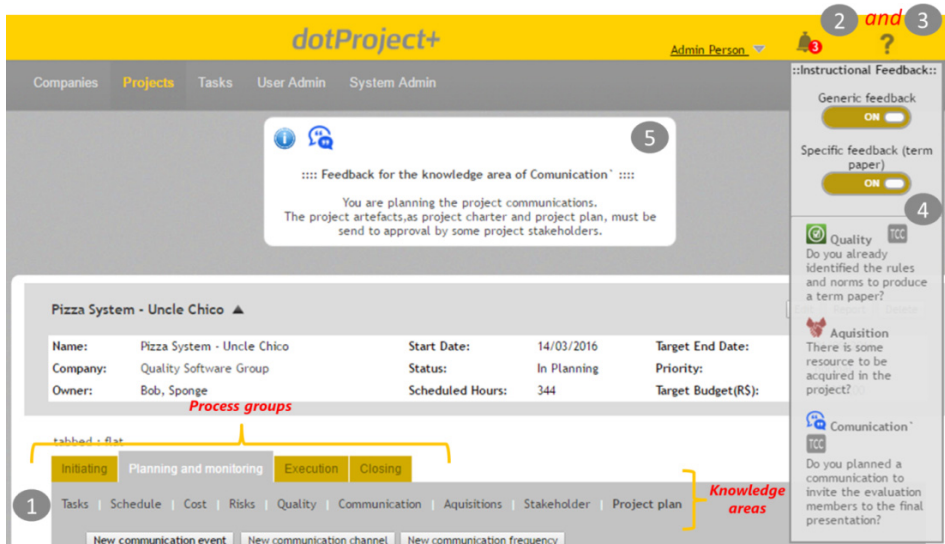


Fig. 7. Instructional feedback in dotProject+.

dent's project charter and project plan. For instance, when a student starts to register risks, feedback messages with suggestions of risks examples for capstone projects are delivered.

Implementation of the feedback technique into dotProject+

The instructional feedback technique was implemented as a new add-on module for dotProject+. In Fig. 7 the steps designed for the instructional feedback workflow (Fig. 6) are highlighted, being represented by their respective numbers.

Fig. 7 demonstrates the functionalities of this add-on module. First, the students interact with dotProject+ functionalities (step 1) and the tool evaluates these actions (step 2) firing the triggers. When feedback is delivered, a notification is shown in the bell icon (step 3), indicating that there are feedback messages (as well as how many messages are given). Once the students click to check the messages, the short messages (questions) for the feedback messages are displayed (step 4). In case the student clicks on a short message the complete message is displayed in the feedback message area (step 5).

This add-on module is published as part of dotProject+, under the license GPL v3, and is freely available for download in dotmods (<https://sourceforge.net/projects/dotmods/>) the official repository for dotProject add-on modules.

7. Application of the IU

The created instructional feedback technique has been applied in a series of case studies executed during the first and second semester in 2016. It has been applied in 4 different classes from 3 educational institutions, including a total of 64 students (Table 7).

Table 7
IU applications using the instructional feedback technique

Semester	Educational institution	Program	Course	Instructor*	n° of students	Collected answers
2016-1	UFSC	Computer Science	Planning and management of software projects	Instructor A	14	10
2016-2	UFSC	Computer Science	Planning and management of software projects	Instructor A	34	29
2016-2	UFMS	Computer Science	Project management	Instructor B	6	5
2016-2	UFPB	Computer Science	Software project management	Instructor C	10	7

Legend:

UFSC – Federal University of Santa Catarina

UFMS – Federal University of Mato Grosso do Sul

UFPB – Federal University of Paraiba

* Due to privacy reasons instructor names have been omitted.

Data collected in the case studies were pooled in a single sample, and used cumulatively in order to evaluate the instructional feedback technique. The pooling of data was possible due to the similarity of the courses and the adoption of the same data collection instruments. Despite the case studies being carried out in different courses, they are compatible, demanding the same prerequisites (e.g. SE course) and containing related syllabus, both including the teaching of PM tools aligned with PMBOK. The similarity and standardization in terms of definitions, methods, and measurements are essential aspects for the pooling of data (Kish, 1994). In this respect, the studies are similar in terms of definition (with the objective to evaluate the instructional feedback technique), research design (case studies), and context (higher education computer courses). In addition, the case studies are standardized in terms of measures (quality factors), data collection method (Table 3), and response format (5-point Likert scale).

During the practical classes, student reaction was observed when interacting with the functionalities of the instructional feedback add-on module. These functionalities have been explained to students in the beginning of the practical lectures, preceding the presentation of dotProject+ support to the initiating and planning process groups. However, it was observed that in the initial classes, the instructional feedback was not much used by the student, as they did not perceive its existence. At this point, the instructors stressed again the advantage of the feedback and a wider usage has been observed based on dotProject+ log files and students' feedback.

After the IU lectures, the students answered the evaluation questionnaire. From a total of 64 students, 51 answered the questionnaire, representing a participation rate of 80%. As their participation was non-mandatory and anonymous, the main reason for students not answering the questionnaire was their absence in the respective class.

8. Evaluation of the IU

The quality of the instructional feedback technique is analysed and discussed based on the defined analysis questions.

AQ1. How appropriate is the content presented by the instructional feedback technique?

About 60% of the students considered the content depth adequately addressed, indicating that the messages are detailed enough for understanding. Yet, some students indicate they would prefer to receive more detailed explanations about some topics. However, since most students have agreed that the addressed depth is suitable for their learning, and at the same time do not overload them with an excess of information, a possible improvement could be providing some external references (e.g. IU slides or other online materials). Thus, satisfying also students that demand more information for their understanding.

On the other hand, in relation to the content coverage, 60% of the students indicate it was not satisfactory, as they did not perceive messages with respect to all PM knowledge areas. Analysing the descriptive answers, it is evident that this could be due to problems to visualize the messages as soon as they are available. As presented in Fig. 6, the notification of these messages is just a flag in the bell icon. Thus, even with feedback messages being delivered for all PM knowledge areas, students may not have noticed the existence of such messages. Consequently, several improvements were suggested by students in relation to the intrusiveness of the feedback messages, which are discussed when analysing the user experience dimension (AQ05).

AQ02: What is the quality of the instructional strategy?

The instructional strategy was analysed based on the moment that the instructional feedback messages are delivered, and how these messages reach the students. In relation to the moment of delivery, the proposed technique has adopted an immediate but not intrusive approach. In this regard, about 60% of the students consider it was appropriate for their learning. Nevertheless, the other 40% disagrees. When analysing the descriptive answers, it becomes evident that the problem may not be related to the moment of delivery, but again with the low intrusiveness of their notification. Specifically, some students indicated that they did not perceive the existence of new messages as soon as they became available due to the discreteness of the notification. Often they only noticed the messages later on, when they were working already on a different part of the PM process, which may have complicated for them to return to the issue pointed out in the message. Thus, an improvement suggestion is that the feedback message also contains a link to the screen to which it refers.

However, most students agree that the moment of delivery is satisfactory. Once they understood how to check for new messages, they were able to read them as soon as they became available. They also indicated that the immediate delivery approach was appreciated, as it assisted them in verifying if artefacts they were planning were complete or if they had forgotten to execute some step of the PM process.

The instructional feedback technique has also defined strategies related to how to approach the students. The designed approach has been positively evaluated by 66% of

students. They agreed that the messages questioning them about a certain topic, and later presenting detailed explanations and examples, assisted their learning.

Yet, regarding the instructional strategy, few students informed they would like to have more time for practical lectures, thus, obtaining more time to read the feedback messages. A possible reason for these comments is that many students may have started the usage of the instructional feedback technique in the last practical classes, consequently having a reduced time to completely explore the feedback messages. Additionally, due to time restrictions typically pertaining this kind of IU (Gonçalves and Wangenheim, 2016a), increasing the quantity of practical lectures may be unfeasible. As an alternative for students, who demand more time for reading the feedback messages, maybe to enable the access of dotProject+ externally to the educational institution, being able to continue their studying at home.

AQ03: What was the contribution of the instructional feedback technique for student learning?

About 65% of the students agreed that it is a useful instrument for their learning. Its main contribution is the assistance with the comprehension of concepts, providing contextualized explanations that reinforce the understanding of PM concepts. Another important feature for student learning are the examples provided by the feedback messages, explaining what is expected for each part of the project charter and project plan. In this regard, students appreciated receiving messages dedicated to their capstone project, the IU project theme. This specific feedback provides examples, for instance, demonstrating possible stakeholders, activities, risks, and acquisitions typically required for this kind of project. Hence, these examples instigate students to elaborate their project plan and also to discuss other alternatives in order to improve the completeness of the PM artefacts.

Yet, although about 30% of the students disagree that such technique contributes to their learning, a possible cause could be it not being identified. This may be due to the different learning preferences, and/or related to the discreteness of the feedback messages.

AQ04: What is the quality of the instructional feedback add-on module implemented in dotProject+?

When asked about the quality of the instructional feedback add-on module as a didactic material, 75% of the students considered it an important instrument for their learning. Some students indicated that, when they understood how to check the notification of new feedback messages, they appreciated the constant update with new messages as they interacted with dotProject+. They also emphasized the completeness of dotProject+ in relation to the set of functionalities provided, enabling them to develop the complete project plan with only one tool. However, as the constant updates with feedback messages takes a certain time, some students expressed the need to have more time to check the feedback messages properly.

AQ05: What was the user experience promoted by the instructional feedback technique?

The user experience was analysed based on the recommendation the students would make to other students with similar educational needs. Nearly 80% of the students agreed

that they would recommend it to their peers, as they considered it a positive experience. They indicated that it assisted to detect errors and remembered them to include important information that might be missing.

Nevertheless, when specifically asked about the motivation promoted by the instructional feedback technique, almost half of students indicated that they did not the technique did not contribute to their motivation. This may have happened due to the differences in student learning preferences, since the other half agreed that this technique has contributed to their motivation. Another reason may be lack of usage again due to the discreteness of the notifications, as these students also indicated that they would prefer to receive more intrusive feedback messages, ensuring they are going to read it in the appropriate moment in order to consequently take advantage of this technique. In this context, some students also suggested the use of some sound alert, informing when a new feedback message is delivered. Another improvement suggestion is to provide some functionality that could redirect to the screen to where the feedback suggestion may be applied. This is expected to assist the student to find where the correction may be done, even when the message is read long after its delivery. So, based on the collected information, we may infer that when students make proper use of this technique, it has a good chance to increase student motivation.

9. Discussion

Based on the perceptions of the students, it leads us to conclude that the instructional feedback technique is an important instrument to improve the learning of PM tools, and it may also increase their motivation during this process.

The instructional feedback technique was designed to address content for each PM knowledge area, criticizing mistakes students typically make during the elaboration of the project charter and the project plan. The feedback messages have a satisfactory coverage of the addressed part of the PM process. Yet, it still can be improved performing further analysis of the project charters and project plans delivered by students, and identifying recurrent mistakes, which would be avoided or minimize the delivery of new feedback messages.

In relation to the instructional strategy, the immediate and non-intrusive delivery of the feedback has shown to be appropriated for the teaching of PM tools. However, we also identified several improvement opportunities. This includes a more obvious notification when new messages are delivered as well as the flexibilization of the delivery strategy addressing these differences in the learning preference of the target audience. For instance, offering the possibility to configure either a less intrusive approach, accumulating the feedback messages in the notification area, or a more intrusive approach, just displaying the feedback messages as soon as its trigger is fired.

Through the implementation of the instructional feedback with respect to all PM knowledge areas in dotProject+, a professional web-based open-source PM tool can be used for teaching the usage of PM tools more effectively. As the feedback functionality is configurable, it can be turned on during the learning process and turned off during the professional usage of this tool.

And, although many students criticized some aspects of this technique, including the lack of depth or content coverage, almost 70% of the students agreed that this technique has positively contributed to their learning. So, the instructional feedback technique demonstrated that it may attend its purpose, while important improvement opportunities may be explored, aiming at addressing differences in learning preferences.

9.1. *Threats to Validity*

As any research, there are some threats to validity (Wohlin *et al.*, 2012). Threats to conclusion validity may occur due to inconsistencies in the collected data. In this research the individuals may lack some knowledge related to PM, even while being taught about it during the course. It may lead to wrong interpretations of questionnaire items and as a consequence lead to incorrect answers. To reduce this threat, the questionnaire was designed carefully analysing the wording, bringing it as near as possible to the students' language. Another threat is related to the fact that the students answered the questionnaire during the course and may have been afraid to criticize some aspects of the proposed instructional feedback technique. This was mitigated by anonymising the answers and applying the questionnaire only after all student grading had been concluded.

Threats to construction validity are related to the data collection instrument, which may not contain the necessary questions to reach the evaluation goal. To minimize this threat, we employed the GQM approach to design the evaluation, systematically decomposing the evaluation goal into analysis questions and metrics, which were then represented by questionnaire items.

Threats to external validity may occur by not obtaining a significant sample. We mitigated that applying the IU in 4 classes, collecting data from a total of 51 students, from 3 different educational institutions. However, it is still important to conduct further studies, with the aim at generalizing the obtained results.

10. Conclusion

This article presents the design and evaluation of an instructional feedback technique, enhancing the teaching of PM tools aligned with PMBOK in higher computing education. It provides immediate and automatic feedback messages to students as they interact with the functionalities of a PM tool. Such messages include examples and suggestions about how to improve the project charter and the project plan developed using the PM tool. Its evaluation demonstrates the instructional feedback technique was welcomed by the students, providing a first indication that it can be a useful educational technique, being able to improve their learning and motivation during the instructional activities. Future studies could address several improvements suggested, such as different levels of feedback message intrusiveness and configuration of explanation depth, according to student learning preferences and performance.

Acknowledgements

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