Achieving Project Management Educational Web-Tool Evolution Using Service-based Software

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Abstract. *Project Management (PM) is vital in software development and the availability of educational tools enhances the learning experience of best practices. This study focuses on developing a web-tool for PM education and employed a service-based software approach to develop a web-tool. We conducted a survey using the LimeSurvey platform to identify PMBOK® aspects to define technical requirements, gather user input for the tool's new version, and formulate research questions to guide implementation. Survey results from 16 respondents revealed knowledge areas with insufficient PMBOK® coverage and areas needing non-functional improvements. The questionnaire design and administration adhered to best practices, offering valuable insights for tool development. This study emphasizes the significance of PM education and the need for effective tools. The developed web-tool aids students and professors in adhering to best practices and enhancing PM skills. Future research can focus on further enhancing the tool and evaluating its effectiveness in educational settings.*

1. Introduction

Project Management (PM) is vital during the software development and maintenance process [Radujković and Sjekavica 2017]. Various variables can lead to project failure, such as budget and schedule [Kerzner 2017]. The role of a project manager is to ensure that these obstacles are overcome and that a high-quality product is delivered. According to the study [Dominguez 2009], two-thirds of software projects fail, with many of the reasons related to the absence or inadequate practice of PM. PM can be defined as the planning, organizing, monitoring, and controlling of all aspects of a project, with the motivation of all stakeholders to achieve project requirements effectively, according to the imposed context such as cost, schedule, and constraints [PMI 2021]. Therefore, PM aims to bring together relevant aspects of software development, such as project planning, risk management, personnel, and scheduling [PMI 2021].

The importance of PM can be justified by studies conducted by the PMI, which revealed a 40 % increase in projects successfully meeting their objectives and fulfilling the initial business purpose. According to the PMI, organizations that prioritize the establishment of a PM culture report that 71% of their projects achieve their objectives and experience 13 times less financial loss. In contrast, companies that do not prioritize PM activities only achieve 52% of their objectives [PMI 2016]. The significance of effective PM for an organization extends beyond the successful execution of individual

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projects. When PM becomes ingrained in the organizational culture, it fosters an awareness that contemporary work life revolves around a sequence of self-directed endeavors [Kerzner 2017]. Consequently, the recognition of PM as a vital component of the computing curriculum has grown steadily. Considering that numerous students lack prior project experience, offering them practical exposure alongside PM principles becomes paramount [Hood and Hood 2006].

Our web-tool was created in 2018 to be used in the Problem Solving VI (PS6) course, with the aim of adhering to the best practices of PM through the Project Management Body of Knowledge (PMBOK®) guide authored by the Project Management Institute (PMI). In the second semester of 2019, the tool developed by [omitted for anonymous review] started being used by students in the PS6 course and was also tested in the following courses: (i) Software Validation and Verification (V&V) in the Postgraduate Program in Software Engineering; (ii) Problem Solving II (PS II) in the undergraduate program in Software Engineering at our campus.

In the second semester of 2020, one year after the tool was created, our web-tool began to be used in conjunction with the EasyPMDOC spreadsheet as a support tool for teaching PM, becoming the main tool used in the PS6 curriculum component. It was evaluated that the provided functionalities were already sufficient for its use. In 2021, the tool received new updates aimed at improving interaction between professors and students, introducing features for professors to provide feedback, evaluate documents, and exchange messages with students. Figure 1 summarize in a timeline the main milestones and achievements of this research project.

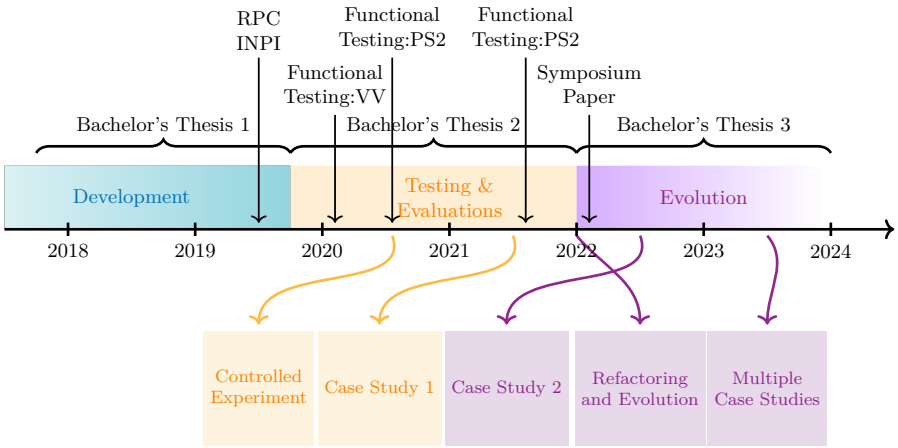

Figure 1. Project Timeline

However, software development is not straightforward, and for various reasons, restructuring the tool becomes necessary. Problems related to best practices, both in PM and programming, start to hinder the maintenance of the system, considering the size and knowledge of the teams that enter each year with the goal of fixing and improving the tool. Directed studies have also shown that the reformulation of some functionalities becomes necessary. The general objective is related to the refactoring of a PM system, taking into consideration the Software Requirements (SR) already elicited by our web-tool, and meeting the demand for functional and non-functional SRs obtained through the conducted survey. The specific objectives of this work include delivering proper docu-

mentation of the system for future repairs, as well as developing a microservices system, with at least authentication and PM services.

The main contributions of this study are related to the evolution of the database, ensuring performance, integrity, and proper use of the data persistence. It also includes the revision and update of the system documentation, the introduction of a multi-layered internal architecture to reduce coupling, and facilitate maintainability and readability. Furthermore, it is expected to deliver software with more aspects of interaction with other software, such as GitHub and Slack.

This study is organized as follows. Section 2 presents the survey protocol and discusses the threats to its validity. Section 3 discusses and analyzes the collected survey results. Section 4 outlines the software requirements and provides snapshots of the proposed solution. Section 5 compares our study with related work. Finally, Section 6 concludes with final considerations and ongoing work.

2. Survey

In this section, we present the survey methodology instrumented.

2.1. Survey Protocol

The main objective of the study is to understand the aspects in which the tool does not adequately meet the PMBOK® requirements. The questionnaire protocol was based on the methodology proposed [Kasunic 2005], consisting of seven (7) phases for its completion.

Identify the Research Objectives: The research objectives are as follows: 1. Identify aspects of our tool that do not conform to the technical requirements of the PMBOK®, based on user feedback' 2. Collect information from users through the questionnaire to gather insights and perspectives that will support the development of the new version of the tool; 3. Formulate research questions that will guide the implementation of these objectives.

RQ1. Which knowledge areas have fewer processes covered by the PMBOK®?
RQ2. What non-functional aspects require improvements?
RQ3. How can both functional and non-functional aspects be enhanced?

Identify & Characterize Target Audience: In the second stage of the survey, the aim is to properly define the profile of the research participants. Consequently, the target audience identified includes individuals who have already used the PM tool, including both professors and students. The respondent profiles for the questionnaire may vary in terms of their usage of the tool, but the main requirement for participation in the research is to have some prior experience with PM guidelines.

Design Sampling Plan: The development of the sampling plan is based on several questions:

(i) What is the size of the target population?
(ii) Can the target population be enumerated?
(iii) How can we ensure that the number of survey respondents is representative relative to the population size?

Based on the raised questions and to obtain a considerable sample size, three distinct strategies were adopted. The first strategy involved sending emails to all students who had taken the PS6 course and utilized our web-tool for their activities. The second strategy involved sending individual messages through the institutional chat platform. Lastly, individual messages were distributed through social media platforms. Therefore, the questionnaire was delivered through the following channels: Gmail, Google Chat, and WhatsApp, reaching a total of 54 individuals (target population).

Design & Write Questionnaire: After defining the initial phases, we established the questionnaire structure. the research adopted some best practices outlined in the studies by [Shull et al. 2007] and [Presser and Schuman 1980], which including:

(i) Including both open-ended and closed-ended questions;
(ii) Avoiding yes or no questions;
(iii) Avoiding jargon and colloquial language;
(iv) Each question focusing on one concept only;
(v) Including the name of the researcher and institution;
(vi) Not providing neutral response options in the questionnaire.

We chose the LimeSurvey[1], an open-source web solution, as our tool for creating and administering the questionnaire. Our aim is to gather data on the best ways to adopt knowledge areas in a PM tool, making our study an observational cross-sectional research. The questionnaire is self-administered, meaning that participants are responsible for reading and responding to the questions.

We started by presenting the Informed Consent Form (ICF), followed by identifying the respondents' profiles. Next, we asked questions regarding their experience in PM to group them accordingly for future analyses of the relationships among their answers [Cheung 2014]. Subsequently, we posed questions regarding compliance with the PMBOK® and the improvement of the tool. For the latter section, we chose a question based on the affect circumplex proposed by [Russell 1980]. This question enables participants to select the sentiment that accurately reflects their experience using the tool.

Pilot Test Questionnaire: Once the research instruments were developed, they needed to be validated to identify any errors and potential improvements in the survey instrument. Therefore, a pilot test should be conducted with a small sample similar to the target audience to validate the instruments before the actual survey administration. A pilot questionnaire was administered to 3 respondents who fit the target audience, and they were asked to provide feedback on the clarity of the questions and the overall survey experience, including any perceived fatigue from answering the questionnaire.

Distribute Questionnaire: The distribution of the questionnaire was based on the sampling plan and aimed to reach the entire target population, considering it was a small population. Following the initial distribution, the engagement of selected members was monitored on a weekly basis, and additional strategies were implemented to increase the response rate to the questionnaire.

2.2. Threats to Validity of Study

In this stage, the main threats to the validity of the presented study and the means to mitigate these threats were elicited according to [Wohlin et al. 2012]. **Construct Valid-**

[1]LimeSurvey: `https://www.limesurvey.org/`

ity: this aspect aims to understand the extent to which our operational measures truly represent what we have in mind and what we investigated according to our research questions. Therefore, to have a coherent questionnaire, we conducted a pilot survey. However, despite the adjustments we made, the questions may still be complex and incoherent [Sjøberg and Bergersen 2023]. **Internal Validity**: is related to verifying if there is any causal relationship between the treatment and the data we obtained. Furthermore, we interleaved open and closed-ended questions and defined the number of questions to prevent respondent fatigue. **External Validity**: this threats can cause significant problems for result analysis. To reduce threats related to sample size, questionnaire adherence, and obtaining a considerable number of respondents, we used different techniques to engage participants in the survey, including sending individual messages to the target audience through various social media platforms. **Conclusion Validity**: refers to the quality of our conclusions based on the relationship between the treatment and the results we obtained. To avoid any bias in our research, we sought a representative and randomly selected heterogeneous sample [Sjøberg and Bergersen 2023].

3. Result Analysis

The survey began in December 2022 and was concluded on January 20, 2023. The survey was distributed to 54 individuals. Nineteen of them responded to the questionnaire, and ultimately, 16 provided sufficient content for the analysis. Hence, the response rate of the survey was just over 35%, and the completion rate was nearly 85% (16/19). Considering the responses for analysis, we obtained a response rate of 29,6% (16/54). It is worth noting that there was not much participation from individuals who had used the tool two or more years ago, likely due to limited engagement with institutional networks.

3.1. Respondents' Profile

Figure 2 shows the distribution of respondents across the semesters of tool usage. In order to understand possible responses that pertain to the current version of the system and to functionalities and aspects that have undergone modifications in subsequent versions of our web-tool, it is important to observe when the respondents used the tool. The distribution of respondents, categorized by the year version of web-tool usage, is as follows: 2019 (1), 2020 (3), 2021 (7), and 2022 (5). These numbers reveal that the majority of respondents (43.75%) took the course in 2021, indicating a significant user base during that year. On the other hand, the smallest fraction (6.25%) consisted of users who utilized the web-tool in 2019, where the first version was employed by approximately eight students. Furthermore, the fraction of participants who took the course in 2020 accounted for 18.75%, and the respondents from 2022 constituted the remaining 31.25%.

Figure 3 presents data related to the participants' experience. The graph shows that the majority of respondents (68.75%) have a moderate level of experience in PM, four reported having little experience, and only one said they have a significant experience. Among the collected data, the majority of respondents reported knowing each area of the PMBOK® moderate or significant, with the following fractions for each area: scope with a positive result of 81.25%, followed by time and stakeholders with 75%, integration and risks with 62.5%, then quality, resources, and procurement with 56.25%, and lastly cost with 50%. The areas in which users reported knowing less were cost, with a negative result of 50%, and quality, resources, and procurement with a total of 43.75%.

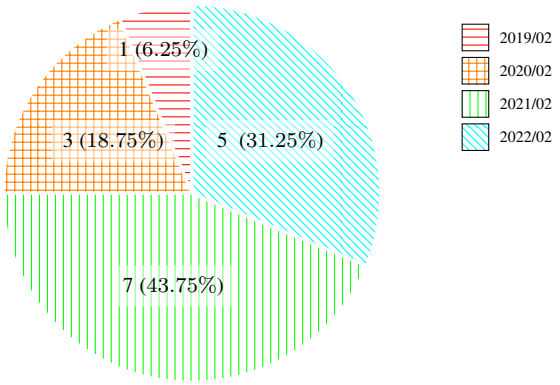

Figure 2. Distribution of Respondents by Semester.

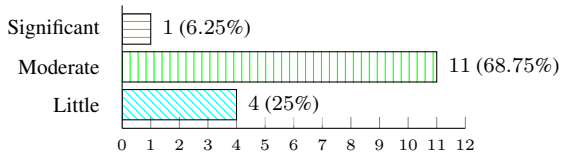

Figure 3. Respondent's Experience

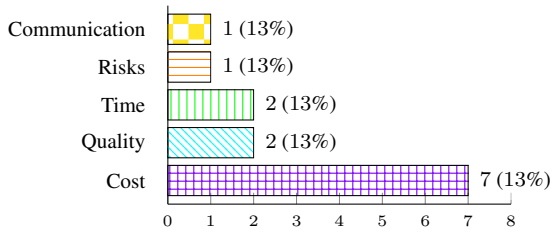

Figure 4. Knowledge Areas That Need Further Improvement

3.2. Compliance with the PMBOK®

Regarding the analyzed question groups, the questions related to the tool's fidelity in fulfilling the aspects of the PM Guide were the last group, which aimed to gather insights from participants on which areas of knowledge needed improvements and what could be enhanced. Figure 5 we observed that the area where users are most dissatisfied is cost, with 50% of respondents reporting being very or moderately dissatisfied, followed by time, with 37.5% reporting dissatisfaction. The areas where respondents are most satisfied are scope and communications. By observing Figure 4, it is also possible to identify the areas that participants consider most critical to be reworked, correlating with the observed satisfaction level. This allows us to answer RQ1, identifying cost as the primary area for refactoring, followed by time. Fernandes *et al.* [2022] conducted a survey of 793 practitioners from 75 different countries, revealing that the Knowledge Areas (KAs) of scope, time, risk, communication, and integration are highly relevant, each featuring at least three top PM practices. While our results align with the importance of time, cost did not emerge as a significant factor for the practitioners surveyed by Fernandes *et al.* [2022].

In analyzing the results obtained regarding the non-functional aspects of the tool, the following dissatisfaction order was observed: Interactivity (50%), Productivity (37.5%), and Ease of Use (31.5%). Jakob Nielsen [Nielsen 1993] highlights that key non-functional aspects, such as interactivity, productivity, and ease of use, are crucial for the overall user experience and effectiveness of software applications, which corroborates with our survey results. For instance, Salim *et al.* [2015] emphasizes the complex relationship between human-computer interaction (HCI) factors and the perceived ease of use in collaborative learning environments, underscoring the critical role of interactivity in technology adoption. Besides, the questionnaire also sought insights into function-

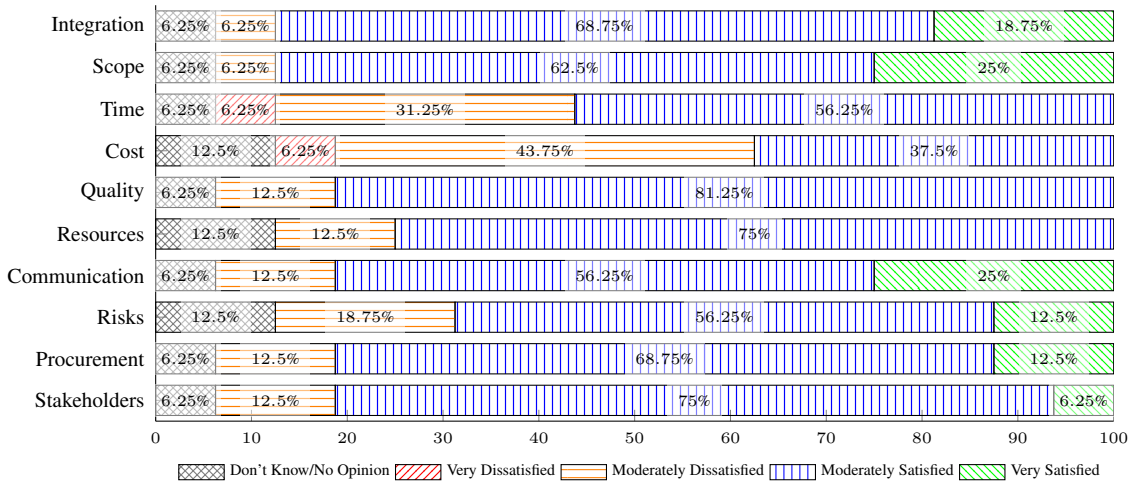

Figure 5. Satisfaction Level by Knowledge Area

alities that would enhance the user experience; however, the majority of the responses were related to non-functional requirements of the tool. Combining these responses with the disadvantages of our web-tool, valuable insights can be extracted to improve non-functional aspects. By grouping parts of the responses into different sets of terms related to non-functional aspects the following aspects were identified: Documentation, Process Relationships, Information Visibility, Use of External Tools, and Collaborative Editing.

Regarding documentation, respondents mentioned factors such as the lack of process mapping and interrelationships according to the PMBOK®, as well as inadequate descriptions of the purpose of each field in a process. These factors would improve the tool's ease of use. In terms of productivity, the term "use of external tools" was considered, with participants stating the need to use external means to manage their projects, specifically highlighting the inability to manage costs comprehensively. Integrating external tools can streamline workflows, eliminate data silos, and improve productivity by enabling disparate systems to communicate and exchange data seamlessly. This can significantly reduce manual data entry errors and save time by automating routine tasks [Chugh et al. 2023, Msafiri et al. 2023]. Furthermore, regarding productivity aspects, users reported a lack of process relationships, where fields in different processes are redundantly filled in, hindering productivity.

Finally, in terms of interactivity, highlighted by concepts such as "information visibility" and "collaborative editing", it becomes evident that participants perceive filling out forms and visualizing data through forms as occasionally inadequate. Another critical consideration is the tool's limitation in enabling real-time collaborative work, posing challenges for collective interaction among project members. These findings aligns with Dangelo *et al.* [2018], which examines how Real-Time Collaborative Editing (RTCE) features in collaborative software impact teamwork and productivity. Based on the gathered data, we conclude that for RQ2, the primary non-functional aspect is interactivity. To enhance interactivity (RQ3), exploring alternative methods for users to input and visualize project information will be necessary.

3.3. Emotion of the Experience

In our study, we expanded the assessment instruments by incorporating a new questions that utilizes a non-verbal method, called Emocards, for subjects to report their emotions. This addition builds upon the four existing assessment instruments. The Emocards method is based on Russell's Circumplex of Affection concept, which categorizes human emotions into different quadrants [Posner et al. 2005]. The Emocards method introduces graphical representations associated with octants in quadrants [Desmet et al. 2001]. These octants are based on Russell's Circumplex divisions, representing different states of mind such as happiness, relaxation, sadness, and irritability. Figure 6 displays the eight octants distributed among the four states of mind, along with the corresponding graphical representations. The Emocards method by introducing sixteen graphical representations of male/female pairs, each associated with one of the octants in the quadrants [Desmet et al. 2001]. These octants form the basis of the Russell's Circumplex divisions, where every two octants constitute a quadrant representing a specific state of mind. The first and second octants form a quadrant related to feelings of happiness, the third and fourth octants represent a quadrant associated with feelings of relaxation, the fifth and sixth octants represent a quadrant containing feelings of sadness, and the seventh and eighth octants define a quadrant encompassing feelings of irritability. To visualize the Emocards method, we present Figure 6, which displays the eight octants distributed among the four states of mind, accompanied by the sixteen graphical representations associated with each octant.

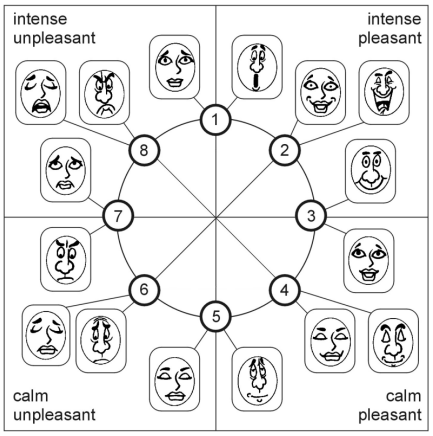

Figure 6. Emocards from Russell's Circumplex [Reijneveld et al. 2003].

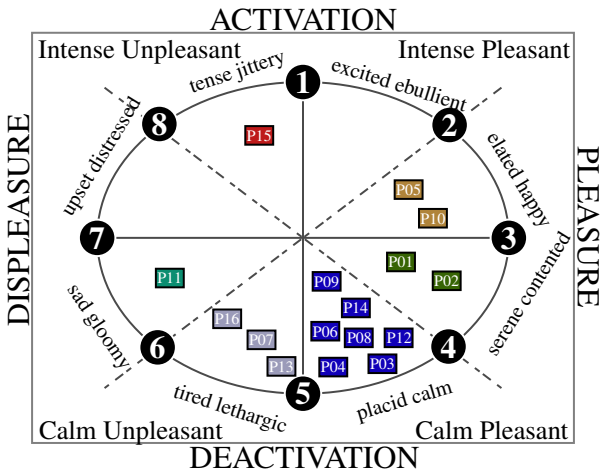

Figure 7. Russell's Affective Model [Russell 1980] of Respondents.

Moving forward, our objective was to assess the subjects' state of mind and emotions elicited. We organized the evaluation results within Russell's Circumplex. Notably, the responses exhibited a higher concentration in the quadrants associated with placid calm (Octant 5), totaling seven (7) responses. Additionally, one (1) subject expressed feelings related to tense jittery (Octant 1), and another one subject identified with the Emocards associated with the quadrant related to irritability (Octant 7). Figure 7 illustrates the distribution of subjects across the octants as predicted by the Emocards method, responding our survey. Hence, the majority of respondents (75%) classified the user experience of the web-tool as "tired lethargic, placid calm, and serene contented". Con-

sidering the statements related to non-functional aspects, it is possible to observe that a significant portion of the audience identifying with this sentiment is determined by aspects that make the tool challenging certain aspects of PM. Observing the users' emotions and the problems reported, it's inferable that the previous solution's forms were riddled with ambiguities, leading to user frustration and excessive workload.

4. The Proposal for the Web Tool Evolution

4.1. Software Requirements

Within the pillars of Software Engineering lies the documentation of an application. The user stories described in this section are associated with the essential functional requirements for the evolution of the application being described. We have added some new features in this version to make our website more user-friendly and efficient. Now, every PMBOK® process has it's own excel template to download, then the user can fill the fields in an excel file and import it in the website, after registering processes, the user will also be able to export the registers to an excel again. As a back-end as a service is being used, the security of authentication is now based on Json Web Token (JWT), controlling the users' session. As the survey results were available, process from the PMBOK® were redesigned considering the users' answers. Every form of PM was analyzed during weekly brainstorms to decide what features must be modified to meet users' exigency.

A huge problem seen by the survey results was how information were displayed on the screen, so in the Work Breakdown Structure (WBS), a graphic project tree of work packages will be generated as the tasks are registered in the project. The Earned Value Management (EVM) will display charts accordingly to indexes and activity costs throughout the project. Activity List, Resource Requirements and Duration Estimates will be redesigned to group activities by their packages to make easier to navigate through the items. Schedule Network Diagram (SND) will display a diagram of the sequential and logical relationship between tasks in a project. Stakeholder Calendars will display a calendar of availability of the team. Complementary, we highlight in Table 1 a list of educational software requirements to emphasize their contribution to Computer Education[2].

ID	User Story
US152.	*As a* professor, *I want to* evaluate, numerically (Likert Scale), the documents or processes created ;by the students, *so that* I can give feedback to my students.
US153.	*As a* student, *I want to* export the project data in an integrated way to Latex source-code (Overleaf), *so that* facilitate the process of submitting activity reports to the professors at each milestone.
US154.	*As a* professor, *I want to* comment on each of the components of the documents created by the students (similarly, the students can view the comments and respond to them), *so that* I can give feedback to my students about the fill of each component of project artifacts.
US155.	*As a* professor, *I want to* configure the formative assessments planned in the project, *so that* I can create a schedule for delivering assignments to students.
US156.	*As a* student, *I want to* periodically report their activities (Logbook), allowing the inclusion of external files as evidence, *so that* I can report my activities and evidence of performed tasks.
US157.	*As a* student, *I want to* earn points, badges, or other rewards and to compete or collaborate with peers in gamified challenges, *so that* I can motivate and track my progress in learning journey and enhance my social interaction and teamwork skills.

Table 1. Educational User Stories

[2]Due to space limitations, a complete list of user story requirements documentation was available in the Zenodo Repository: `https://doi.org/10.5281/zenodo.13323780`.

4.2. Our Tool for Project Management Teaching: Software Snapshot

To illustrate our tool, we present a visual depiction of our tool through two of its primary interfaces. The first screenshot, which can be seen in Figure 8 (left), presents the Menu grouped by Knowledge Areas based on PMBOK® 6th edition. The second screenshot Figure 8 (right) depicted a sample of forms a snippet of Project Charter process.

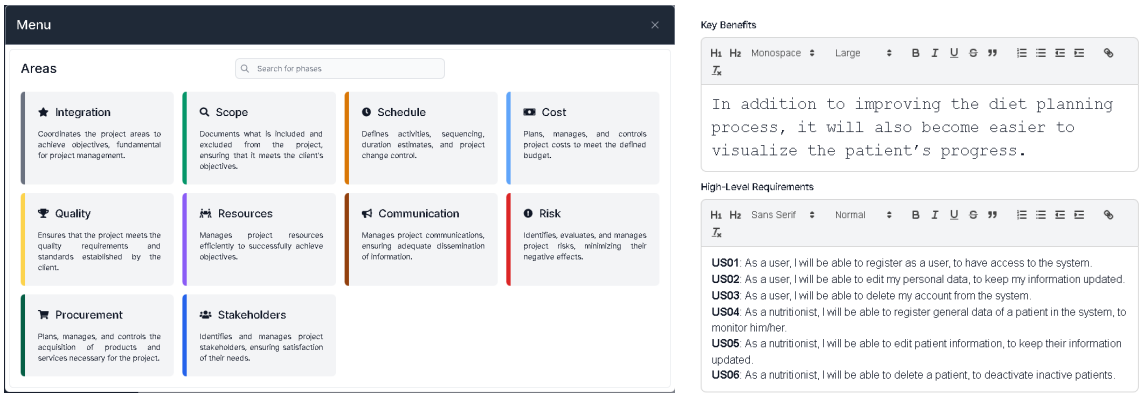

Figure 8. Screenshot of Our Tool for Project Management Teaching

5. Related Work

Hood and Hood [2006] adopted a novel approach by using simulated projects to teach PM to computing students. Their LEGO® bridge building project served as a practical illustration of PM principles, such as Earned Value Analysis (EVA). The simulation provided students with an opportunity to experience real-world challenges, particularly those related to scope changes. Engaging students in analyzing requirements, creating test plans, and assessing project progress through EVA graphs allowed them to grasp the significance of proper PM techniques.

Nakamura *et al.* [2011] introduced a mentor agent system that guided students in role-play training for PM. The system aimed to provide learners with a better training environment by adopting a scenario-driven architecture based on the learner's profile data. Results showed that the mentor agent system effectively helped students consider stakeholders' interests, fostering a sense of ownership and facilitating information sharing for informed decision-making.

In recently publications, Ralph [2018] detailed a postgraduate management course in SE, which was refined over several years to address challenges in teaching PM effectively. This course emphasized evidence-based readings, quizzes, slide-free lectures, in-class activities, and an ambitious project. By promoting research-led teaching and class-based research, the course demonstrated increased effectiveness compared to traditional methods with textbooks and superficial exams. Ralph proposed this approach as an alternative to the ACM/IEEE model curriculum, focusing on grounding in relevant SE and management theory.

Molleri *et al.* [2018] aimed to align software PM courses with effective learning outcomes by using a validated legacy game as a simulation tool. In this game, students planned and managed a software project under teacher guidance, motivating knowledge acquisition through problem-solving. The feedback from students and teachers reinforced

the game's potential to enhance learning, while also highlighting the need for pedagogical alignment and fair game measures.

Simulated projects have proven to be effective in teaching PM concepts to computing students. Whether through hands-on exercises like the LEGO® bridge building project, mentor agent systems, postgraduate courses with evidence-based readings, or legacy games, these approaches offer valuable insights for fostering theoretical and practical knowledge acquisition. By engaging students with real-world challenges, these simulations enable a deeper understanding of PM principles, preparing students for successful project handling in their future careers. Future research may focus on refining these approaches and expanding their integration into PM curricula for a more comprehensive learning experience.

6. Final Remarks

In conclusion, this study has provided valuable insights into the development and enhancement of educational tools for project management. The web-based tool created has served as a significant resource for both students and professors, facilitating the learning and application of best practices in project management.

Throughout this research, key issues and challenges in project management education were addressed, leading to the identification of areas for improvement in the web-tool. By conducting a thorough survey and analyzing the feedback received, we were able to pinpoint aspects that did not fully align with the technical requirements of the PMBOK®, paving the way for the development of a new version of the tool.

The significance of this study lies in its ability to not only highlight the importance of project management education but also to showcase the potential for innovative tools to support learning in this field. By refining the web-tool based on user feedback and survey results, we have demonstrated a commitment to continuous improvement and adaptation to meet the evolving needs of students and professors in project management education.

Looking ahead, this research opens up new avenues for thinking about project management education and the role of technology in enhancing learning experiences. By embracing the findings of this study and implementing the necessary enhancements to the web-tool, we aim to further elevate the quality of project management education and contribute to the advancement of teaching practices in this domain.

In essence, this study not only serves as a testament to the importance of effective tools in project management education but also sets the stage for future developments and innovations in educational technology. By leveraging the insights gained from this research, we can continue to refine and evolve educational tools to better support students and educators in their project management journey.

Additionally, our study presents a web-tool proposal for teaching project management in computing. To the best of our knowledge, no other educational tool supports professors and students in their teaching-learning processes. In the future, we plan to conduct multiple case studies in curricular components that teach project management across different undergraduate courses and universities.

Acknowledgments

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Data Availability

We are committed to promoting transparency and reproducibility in research. Following this commitment, we provide all the data supporting the findings of our study, which are openly available on Zenodo at `https://doi.org/10.5281/zenodo.13323780`.

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