How Can Collaborative Work Shape the Evolution of a Project Management Teaching Tool?

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*Abstract. **Research Context**: Project Management (PM) is essential in Software Engineering (SE) education, requiring technical and collaborative skills. Effective tools must incorporate modern PM methodologies to address evolving educational needs. **Practical Problem**: Existing tools lack features such as real-time collaboration, integration of updated PM principles, and adaptability, limiting their ability to develop comprehensive PM skills among students. **Proposed Solution**: This study enhances a collaborative web-based IS for PM education, integrating the 6th and 7th editions of the PMBOK®. New features, including a real-time collaborative editor and hybrid project management approaches, were implemented to improve learning outcomes. **Related IS Theory**: Using the 3C model (Communication, Coordination, Cooperation), the tool was designed to facilitate effective collaboration and align with established collaborative frameworks in IS research. **Research Method**: We employed an user-centered development, with surveys and iterative testing guiding enhancements. Modern technologies, such as React and Yjs, enabled real-time functionalities. The tool's usability and functionality were evaluated through user feedback. **Summary of Results**: The enhanced tool supports real-time collaboration, advanced document editing, and hybrid PM practices, addressing previous limitations. It serves as a practical example of applying IS frameworks to PM education. **Contributions and Impact to IS Area**: This study demonstrates how IS can transform PM education through collaborative systems and agile methodologies, aligning tools with both academic and industry needs. Future work includes case studies to further validate the tool's impact.*

1. Introduction

Project Management (PM) is the structured application of knowledge, skills, tools, and techniques to achieve project objectives within time, cost, quality, and resource constraints [PMI 2021]. In Information Systems (IS) research, PM is not only relevant for ensuring efficiency in software development but also for shaping sociotechnical environments that integrate people, processes, and technology [Laudon and Laudon 2019]. Thus, educating project managers requires a balanced development of technical knowledge, collaborative competencies, and behavioral skills such as communication, teamwork, and leadership [Farooq et al. 2022].

Additionally, according to Faroq et al. [2022], PM training focuses on educating managers about the knowledge areas and their relevance throughout a project's lifecycle. In the absence of clear guidance, however, there may be confusion regarding the practical application of these concepts, potentially leading to increased challenges, whether due to lack of experience, difficulties in project management, or other obstacles [Badewi 2016].

While the PMBOK® Guide [PMI 2017, PMI 2021] has long been a reference for PM education, the transition from its 6th edition (knowledge areas) to the 7th edition (principles and domains) reflects a paradigm shift toward agile, adaptive, and hybrid approaches. These changes challenge educators to adapt teaching practices and tools, ensuring that students are not only familiar with formal methodologies but also capable of applying them in collaborative, dynamic contexts [Thomas and Mengel 2008].

In this scenario, Collaborative Information Systems (CIS) [Bafoutsou and Mentzas 2002] play a strategic role in bridging the gap between academic instruction and industry practices. By supporting communication, coordination, and cooperation [Pimentel and Fuks 2011], they can transform project management education into a more interactive and practice-oriented experience. However, widely used platforms (*e.g.*, Trello, Asana, Jira) are primarily business-oriented and do not explicitly align with pedagogical frameworks or the PMBOK®. This evidences the need for tailored solutions that combine academic usability with professional standards.

This study addresses this gap by presenting the evolution of a collaborative web-based IS designed to support PM education. More than a support tool, the system qualifies as an IS because it integrates information from multiple stakeholders, processes project data into decision-making artifacts (*e.g.*, Gantt charts, Kanban boards), and fosters real-time collaboration [Laudon and Laudon 2019]. Its design is guided by the 3C model [Pimentel and Fuks 2011], ensuring that each functionality directly contributes to enhancing communication, coordination, and cooperation among students and instructors.

The main contributions of this work are twofold: (i) **Practical**: by delivering a collaborative IS that supports both the 6th and 7th editions of PMBOK®, thus serving as a pedagogical bridge between traditional and agile practices; and (ii) **Theoretical**: by demonstrating how IS frameworks (*e.g.*, the 3C model) can be operationalized to enhance PM education, offering insights into the intersection of IS theory and educational practice.

2. Background

2.1. Project Management

Project Management (PM) is the application of knowledge, skills, tools, and techniques to meet project requirements, with the planning phase considered critical for risk management, as it can impact subsequent stages such as execution, control, monitoring, and closure [Oliveira et al. 2021]. In the context of Software Engineering (SE), PM is a crucial area for the success of software development ventures [Farooq et al. 2022]. However, it is essential to consider various factors that directly influence outcomes. In this regard, the PMBOK® Guide emerges as an extremely valuable tool.

The PMBOK® Guide is a widely recognized reference that provides guidelines and best practices for project management. In the current context, the PMBOK® can be adapted by incorporating agile methodologies to address the specific needs of the appli-

cation domain [PMI 2021]. Agile approaches to project management, particularly in software development, have been the focus of studies, with research indicating that risk management in agile software projects can lead to improved outcomes. Furthermore, the complexity of Software Engineering projects, especially in multi-project environments, highlights the importance of identifying and assessing complex projects [Faria et al. 2021].

2.2. PMBOK®

The PMBOK® Guide (Project Management Body of Knowledge) is a widely recognized and utilized resource for guiding project management practices. It presents methodologies, tools, and techniques applicable to various projects, regardless of sector or area of expertise [PMI 2021]. Additionally, the guide provides a comprehensive framework covering critical knowledge areas, such as scope, time, cost, quality, resources, communications, risks, and procurement, supporting project management activities [PMI 2017].

The PMBOK® Guide has evolved over the years, making it essential to understand the differences between its various editions. The latest edition, the 7th, further integrates agile, adaptive, and hybrid approaches to project management, reflecting the growing trend toward agile practices in software development and other domains involving complex tasks [PMI 2021].

2.3. Collaborative Systems

To classify current collaborative systems (*CSCW - Computer Supported Cooperative Work*), the 3C Model was utilized [Pimentel and Fuks 2011]. This model defines collaboration as encompassing three key dimensions:

- **Communication**: Exchange of messages and notifications;
- **Coordination**: Management of stakeholders, activities, and resources;
- **Cooperation**: Operations within a shared, simultaneous (real-time) space for task execution.

Based on this model, we identified four essential characteristics for PM:

- **Access to Information (Communication)**: Refers to providing various pieces of information in a simplified manner, for instance, about the activities to be carried out by the development team. This includes the various planning documents from the knowledge areas outlined in the PMBOK®;
- **Assistance for Project Managers (Cooperation)**: Involves facilitating project management by offering mechanisms for controlling and monitoring stakeholder engagement and tracking the performance of the work carried out by the development team;
- **Collaboration Between Managers and Development Team (Communication and Cooperation)**: Involves allowing the development team to actively participate in the proposed solution's development, for example, enabling activities to be performed within a defined timeframe but with flexible schedules, focusing on the achieved results and delivery quality;
- **Management, Control, and Monitoring of Activities (Coordination)**: Aims to allow managers to control and monitor the progress of activities planned for the development team.

It is expected that by combining these characteristics, the proposed web-based IS can enhance the performance of project managers in planning software development projects, optimizing their communication with development teams as well as their cooperation to achieve the project's objectives.

3. Related Work and Tools

Several tools have been developed for project management support, ranging from commercial platforms such as Asana, Trello, Jira, and ClickUp to academic solutions that integrate PM education with collaborative learning. Commercial tools emphasize productivity and workflow automation but lack alignment with the PMBOK® framework and pedagogical usability [Kerzner 2017].

Academic research has highlighted the benefits of collaborative approaches in PM education. [Santoro et al. 2005] demonstrated that structured planning of collaborative processes enhances knowledge transfer and teamwork. [Song et al. 2011] combined project-based and collaborative learning to improve software engineering education, while [Al-Fedaghi and Alsumait 2017] showed that collaborative project-based learning environments simulate real-world scenarios, improving student preparedness. Similarly, [Tan and Huet 2021] proposed an active learning strategy integrating collaboration and research-based learning, fostering critical thinking and engagement.

Despite these advances, existing initiatives do not fully integrate the latest PMBOK® principles, hybrid methodologies, and real-time collaboration features. Moreover, comparative studies of commercial platforms (Table 1) reveal their limitations in educational contexts, particularly regarding the absence of explicit pedagogical orientation and integration of PM standards. Unlike commercial platforms that emphasize task flow and productivity, the proposed tool embeds pedagogical scaffolding, guiding students through PMBOK-aligned artifacts and lifecycle reasoning rather than mere task manipulation.

Therefore, the proposed tool distinguishes itself by combining: (i) Explicit support for both PMBOK® 6th and 7th editions; (ii) Real-time collaborative editing through modern frameworks (Yjs, TipTap), and; (iii) Educational usability tailored to Software Engineering curricula. This alignment of professional standards, IS frameworks, and educational needs represents a unique contribution to the IS and PM education domains.

4. Research Methodology

This study adopted a User-Centered Design (UCD) approach [Gulliksen et al. 2003], emphasizing continuous involvement of end-users (students and instructors) throughout the development lifecycle. The methodological steps are summarized as follows:

(1) **Requirements Engineering**: Functional and non-functional requirements were elicited from prior tool versions and mapped to PMBOK® principles and the 3C model [Bernardino et al. 2022];

(2) **Survey and Focus Groups**: Two rounds of data collection (2023–2024) gathered feedback on usability gaps, collaborative needs, and alignment with course objectives [Neves et al. 2023, Araújo et al. 2024];

(3) **Iterative Prototyping and Testing**: Agile sprints produced successive tool versions, which were validated through formative usability tests;

Table 1. Comparative Overview of Our Web-based IS, ClickUp, Asana, and Jira.

Criterion / Tool	*Our Web-based IS*	ClickUp	Asana	Jira
Primary Objective	PMBOK®-based education	Task and productivity management	Collaborative project tracking	Agile project management
Educational Orientation	Yes (academic use)	No	No	No
Support for PMBOK 6th & 7th editions	Yes (hybrid support)	No	No	No
Real-Time Collaboration	Yes (Yjs + Web-Socket)	Yes	Yes	Yes (via Confluence)
Integrated Document Editing	Yes (custom RichEditor)	Limited	Basic	No (via Confluence)
Process Automation	In development	Advanced automations	Rule-based automations	Advanced workflows
Third-Party Integrations	Limited	Extensive (Slack, Google, etc.)	Extensive (Zoom, MS Teams)	Extensive (GitHub, Jenkins, etc.)
UI Usability	Moderate	High	High	Moderate
Target Audience	Students, educators	Business teams	General teams	Dev teams

(4) **Preliminary Evaluation**: Feedback indicated improvements in usability and demand for real-time collaboration;

(5) **Planned Case Study**: Following guidelines by [Runeson and Höst 2009], a case study is scheduled with undergraduate students to provide empirical evidence of learning outcomes, usability, and collaboration effectiveness.

Although this paper primarily reports on the design and development process, the future case study will enable a systematic evaluation of the tool's impact, bridging the current limitation identified by reviewers regarding the absence of empirical validation.

The empirical evaluation followed the case study guidelines proposed by [Runeson and Höst 2009], including context definition, data collection planning, and triangulation of qualitative and quantitative instruments. The study was structured around four phases of the course project—Initiation, Planning, Execution & Monitoring, and Closing—allowing longitudinal observation of tool usage and perception.

5. The Proposed Web-Based IS

We developed the proposed web-Based IS to be used in the Problem Solving VI (RP VI) course, with the objective of aligning with PM best practices as outlined in the PMBOK® Guide [PMI 2017]. In the second semester of 2019, the tool was implemented for use by students in the RP VI course within the Software Engineering program and also served as a test environment in other courses, including: (i) Verification and Validation, part of the Software Engineering graduate program; (ii) Problem Solving II, an undergraduate Software Engineering course focusing on Software Testing.

In the second semester of 2020, one year after its conception, the proposed web-based IS was integrated into Project Management education alongside the EasyPMDOC spreadsheet, establishing itself as the primary solution in the RP VI curriculum for learning best practices in software project management. This decision was supported by an

evaluation indicating that the solution's functionalities adequately met the curriculum's needs. In 2021, the web-based IS received updates to enhance interaction between instructors and students, introducing features that allow instructors to evaluate documents and provide feedback to students [Bernardino et al. 2022].

However, despite the tool being utilized for its intended purpose, there remain critical issues with its design and functionality. To address these challenges, two surveys were conducted to evaluate the current version of the tool and identify its primary shortcomings, which include the following [Araújo et al. 2024, Neves et al. 2023]:

(i) **External Tools**: The tool heavily relies on external tools, preventing integrated management within the platform.

(ii) **Relationships**: The lack of relationships between documents leads to data redundancy in the forms.

(iii) **Forms**: The tool is purely form-based, relying on simple text inputs.

(iv) **RichText**: The application lacks an advanced editor capable of handling more complex text formatting.

(v) **Collaborative Work**: The tool is unable to support collaborative and/or real-time work.

Building on this premise, in the first semester of 2023, an opportunity arose to form a team with the goal of refactoring and enhancing the proposed web-based IS. A team was assembled and divided into four roles with specific responsibilities. Currently, the project is being developed by a team of four (4) members, each performing distinct functions.

The development team for the tool has been structured into four distinct roles, each with specific responsibilities and contributions to the project:

1. **Requirements Engineering** (Yellow): Responsible for gathering, analyzing, and documenting the functional and non-functional requirements of the tool. This role ensures that the tool aligns with the users' needs and the project's objectives;

2. **Backend and Data Modeling** (Turquoise): Focused on designing and implementing the backend architecture and database models. This role handles the core logic, data storage, and integration with other components to ensure scalability and efficiency;

3. **Management and Quality** (Purple): Overseeing the project's progress, this role ensures that all tasks adhere to the timeline and quality standards. It involves monitoring deliverables, conducting quality assurance, and maintaining project documentation;

4. **Frontend and Usability** (Red): Tasked with designing and developing the User Interface (UI) and improving User eXperience (UX). This role prioritizes accessibility, responsiveness, and visual appeal to enhance the tool's usability.

Each team member collaborates closely with others, ensuring an integrated and seamless development process, while their specialized roles contribute to achieving the overall goals of the project.

It is important to highlight that the Silver Bullet [Neves et al. 2025] goes beyond the scope of a support software. According to [Laudon and Laudon 2019], an IS is defined as a set of interrelated components that collect, process, store, and distribute information to support decision-making, coordination, and control within organizations.
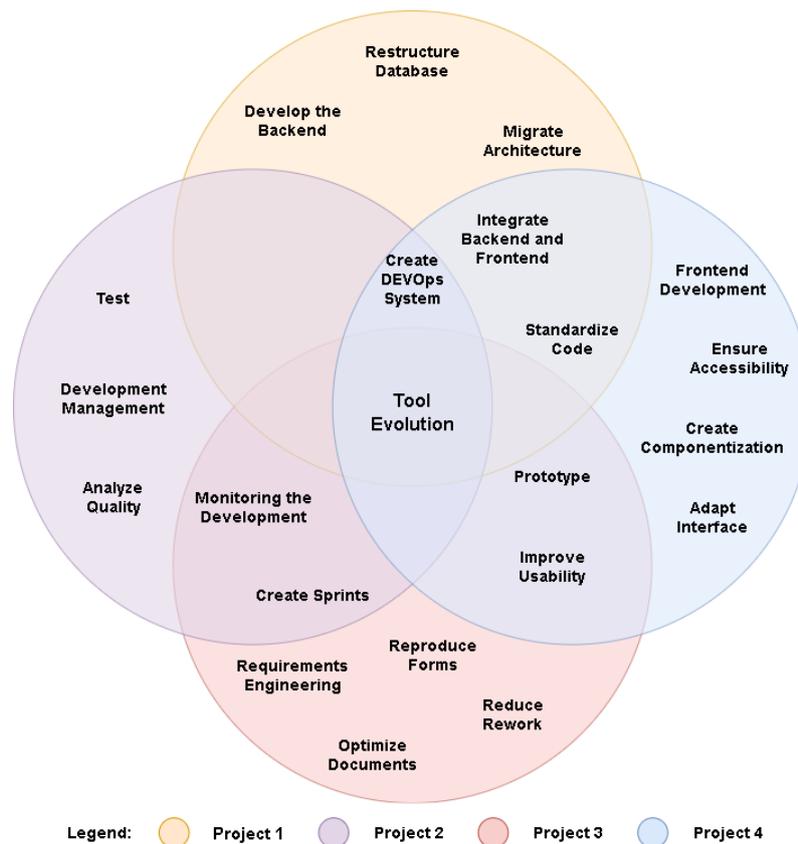
Figure 1. Team Roles, Responsibilities, and Their Projects

Following this perspective, our web-based IS qualifies as an IS because it:

(i) integrates information from multiple project documents and stakeholders;

(ii) provides mechanisms for processing and transforming data into meaningful insights through tools such as Kanban boards, Gantt charts, and automatic PBS generation;

(iii) supports managerial and operational decision-making by enabling monitoring and control of project progress, and;

(iv) fosters collaboration and coordination among managers, students, and instructors through real-time editing and evaluation functionalities.

Therefore, our proposed web-based IS is not merely a software tool but a management IS designed to support both academic and professional project management practices.

6. Collaborative Work in Project Management

The choice of the 3C model (Communication, Coordination, and Cooperation) proposed by [Pimentel and Fuks 2011] was motivated by its widespread use in analyzing collaborative systems within the IS field. Rather than being adopted arbitrarily, the model guided the identification of essential features for the tool. For example:

Communication: Implementation of notifications and comments to support student–professor interactions;

Coordination: Management of tasks and resources through Kanban and Gantt charts;

Cooperation: Real-time collaborative text editing using Yjs and TipTap.

This mapping demonstrates how each functionality directly stems from the 3C model dimensions.

6.1. Development Technologies

For the development of a software project, selecting appropriate tools is one of the crucial steps to ensure the efficiency, quality, and robustness of the final product. The selected tools play a vital role in various stages of the development lifecycle, from conception and planning to implementation, testing, and maintenance [Stolterman and Pierce 2012].

In this context, Table 2 presents the main technologies chosen for developing the new version of the proposed tool, including *frameworks* and libraries.

Table 2. List of main technologies chosen for development.

Biblioteca	Versão	Descrição
TypeScript	5.4.4	TypeScript is a strongly typed programming language based on JavaScript, providing more advanced tools at any scale.
React	18.2.0	A JavaScript library for developing reactive user interfaces. It also supports integration with TypeScript.
TailwindCSS	3.4.3	TailwindCSS is an open-source design framework that allows flexible customization of user interfaces using utility classes in CSS. It also facilitates the creation of responsive interfaces.
React Aria	3.32.0	React Aria is a library that provides accessible React hooks and components to facilitate the development of user interfaces compliant with web accessibility guidelines.
Framer Motion	10.18.0	Framer Motion is an animation library for React that simplifies the creation of animations in user interface components in a declarative and responsive way.
NextUI	2.4.2	NextUI is a complete user interface library for React, built on TailwindCSS, Framer Motion, and React Aria.
I18next	23.11.5	I18next is a JavaScript library for internationalization that allows translating content in a web application into multiple languages in a simple and efficient way.

Although internationalization and accessibility are already supported at the architectural level (*e.g.*, I18next and React Aria), future work will focus on completing language translations and validating accessibility compliance according to WCAG guidelines through automated tools and user testing.

Additionally, Tables 3, 4 and 5 provide the complete list of software requirements specified in the format of user stories, encompassing 59 functional requirements. Furthermore, Table 6 summarizes the Non-Functional Requirements (NFRs), detailing a total of 14 items. Both lists provide a status field on the stage of development of each requirement.

6.2. RichEditor & Collaboration

One of the most significant complaints from users of the proposed tool is the lack of a more comprehensive text editor, which can cause inconvenience when writing longer texts. To address this potential discomfort, we developed a RichEditor - a WYSIWYG (What You See Is What You Get) editor.

To achieve this, a headless library was chosen, meaning all styling and customization of the editor is delegated to the developer. The library, called TipTap[1], is fully customizable and built on ProseMirror[2], another WYSIWYG editor. Although the editor is

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[1]TipTap: `https://tiptap.dev/`

[2]ProseMirror: `https://prosemirror.net/`

Table 3. User Stories specified so far [continuous...]

ID	Name	Rl.	User Story	Pr.	St.
US1	Authentication	👥	As a user, I want to authenticate in the tool so I can access my projects.	⬆	✅
US2	Manage Workspaces	🖥	As a professor, I want to manage workspaces to group different existing projects and invite students.	⬆	✅
US3	Manage Projects	👥	As a user, I want to manage projects and invite managers, developers, and professors so I can execute the project.	⬆	✅
US4	Access Documents	👥	As a user, I want to access project documents in a practical and intuitive way through a user-friendly interface so I can review their content.	⬆	✅
US5	Submit Report	👤	As a student acting as the project manager, I want to submit a weekly report of my work to be evaluated.	⬆	✅
US6	Evaluate Student	🖥	As a professor, I want to evaluate students' weekly activities upon receiving their weekly reports.	⬆	✅
US7	View History	👥	As a user, I want access to a history of recently modified project documents so I can stay informed about the latest updates.	➡	🛠
US8	Synchronous Editing	👤	As a manager, I want to track edits made by others in the same document to avoid overwriting data.	⬆	✅
US9	Field Selection	👤	As a manager, I want to select the required fields from optional ones in the documents to avoid unnecessary fields in the project.	➡	✅
US10	Field Description	👤	As a manager, I want tips in the document fields to help me fill out each section correctly.	⬆	🛠
US11	Project Charter	👤	As a manager, I want to fill in the Project Charter to formalize the start of activities.	⬆	✅
US12	Business Case	👤	As a manager, I want to complete the Business Case document to analyze the project context.	⬆	✅
US13	Project Benefits	👤	As a manager, I want to register and manage the expected project benefits to estimate expectations and verify if they were achieved in the end.	⬆	✅
US14	Assumptions	👤	As a manager, I want to register the project assumptions to establish a solid starting point and be prepared to deal with risks.	⬆	✅
US15	Stakeholder Register	👤	As a manager, I want to register the project stakeholders to maintain a record and integrate them properly.	⬆	✅
US16	Project Management Plan	👤	As a manager, I want to create and maintain the Project Management Plan to plan how I will manage each phase and implement an appropriate approach.	⬆	✅
US17	Requirements Management Plan	👤	As a manager, I want to plan how the requirements will be maintained to ensure a correct approach in eliciting, specifying, and validating the project requirements.	⬆	✅
US18	Requirements Documentation	👤	As a manager, I want to document the project requirements to track the progress made and identify what still needs to be done.	⬆	✅
US19	Activities	👤	As a manager, I want to manage the project activities to assign tasks, monitor the schedule, and track progress, identifying what has been done and what remains.	⬆	✅
US20	Physical Resources	👤	As a manager, I want to manage the resources needed for the project and assign them to activities to control expenses, ensure needs are met, and be prepared for emerging demands during execution.	⬆	✅
US21	Activity Costs	👤	As a manager, I want to manage activity costs to monitor spending for each activity group and keep the project within the established budget.	⬆	✅
US22	Resource Costs	👤	As a manager, I want to view and manage the resources used in activities to monitor expenses and perform effective financial management of the project.	⬆	✅
US23	Work Breakdown Structure (WBS)	👤	As a manager, I want the tool to automatically generate the Work Breakdown Structure (WBS) based on a simplified activity registry to keep the WBS always updated with project changes.	⬆	✅
US24	Kanban - Manager	👤	As a manager, I want a Kanban board for activities to make it easier to visualize and track the workflow, providing better organization and project activity management.	⬆	✅
US25	Kanban - Developer	🖥	As a developer, I want to access the Kanban board to view my assigned tasks and change their statuses in order to show progress and ensure better communication and transparency in activity management.	⬆	✅
US26	Gantt Chart	👤	As a manager, I want the tool to generate a Gantt chart to compare the plan with the actual progress of the project, identifying deviations and facilitating corrective actions.	⬆	✅
US27	Scope Statement	👤	As a manager, I want to create the Scope Statement to clearly define what will be delivered, ensuring alignment between the team and stakeholders.	⬆	✅

Legend: Rl. = Role — 👥 = All — 🖥 = Professor — 👤 = Manager — 🖥 = Developer —— Pr. = Priority — ⬆ = Very High — ⬆ = High — ➡ = Medium —— St. = Status — ✅ = Implemented — 🛠 = In Development — ⌁ = Designed — ⏳ = Pending.

Table 4. User Stories specified so far [continuous...]

ID	Name	Rl.	User Story	Pr.	St.
US28	Cost Management Plan	👤	As a manager, I want to create a Cost Management Plan to estimate, budget, and control project costs, ensuring completion within the approved budget.	⬆	✅
US29	Quality Management Plan	👤	As a manager, I want to create a Quality Management Plan to define applicable quality standards and how they will be achieved, ensuring satisfactory results.	⬆	✅
US30	Resource Management Plan	👤	As a manager, I want to define a Resource Management Plan to identify, acquire, and manage the physical and human resources needed for efficient project execution.	⬆	✅
US31	Communications	👤	As a manager, I want to plan and manage project communications to ensure that the right information reaches the right stakeholders at the right time.	⬆	✅
US32	Risk Management Plan	👤	As a manager, I want to develop the risk management plan to identify, assess, and plan responses to project risks, minimizing negative impacts and maximizing positive ones.	⬆	✅
US33	Risk Register	👤	As a manager, I want to record the risks identified throughout the project to continuously monitor them and take preventive or corrective actions.	➡	✅
US34	Risk Responses	👤	As a manager, I want to define and record appropriate responses for each identified risk in order to minimize threats or seize opportunities in the project.	➡	✅
US35	Risk Review	👤	As a manager, I want to evaluate how well I am prepared to deal with my project's risks, so I can uncover new risks and make more assertive decisions.	⬆	✅
US36	Procurement Management Plan	👤	As a manager, I want to develop a procurement management plan to define how external products and services will be acquired, ensuring appropriate quality, deadlines, and costs.	➡	✅
US37	Procurement Assumptions	👤	As a manager, I want to document the assumptions related to project acquisitions to justify purchasing decisions and consider relevant external factors.	➡	✅
US38	Procurement Specifications	👤	As a manager, I want to detail the technical and functional specifications of the items to be acquired to ensure that suppliers fully understand what must be delivered.	⬆	✅
US39	Stakeholder Engagement	👤	As a manager, I want to plan and monitor stakeholder engagement throughout the project to ensure their active participation and align expectations.	⬆	✅
US40	Issue Log	👤	As a manager, I want to log and track the issues that arise during the project to ensure they are properly resolved and do not compromise objectives.	⬆	✅
US41	Work Performance Report	👤	As a manager, I want to generate work performance reports to compare planned progress with actual progress, identify deviations, and support decision-making.	⬆	✅
US42	Project Report	👤	As a manager, I want to compile a consolidated project report to present the progress, performance, and achieved results to stakeholders.	⬆	✅
US43	Quality Review	👤	As a manager, I want to perform quality checks on project deliverables to ensure they meet the defined standards.	⬆	✅
US44	Quality Report	👤	As a manager, I want to generate quality reports based on the performed checks to document conformities, non-conformities, and adopted corrective actions.	⬆	✅
US45	Team Assignment Document	👤	As a manager, I want to formalize the composition of the project team through a team appointment term to clearly define roles, responsibilities, and commitments.	➡	✅
US46	Change Log	👤	As a manager, I want to record all requested and approved changes to the project to maintain traceability and control over modifications.	⬆	✅
US47	Project Closure Document	👤	As a manager, I want to issue a project closure term to formally conclude the project, document achieved results, and officially end the activities.	⬆	✅
US48	Stakeholder Compensation	👤	As a manager, I want to record and track stakeholder remuneration, when applicable, to ensure all financial obligations are documented and fulfilled.	➡	🔧
US49	Stakeholder Groups	👤	As a manager, I want to categorize stakeholders into groups with common characteristics or interests to facilitate engagement and communication with each group.	➡	🔧
US50	Human Resource Breakdown Structure	👤	As a manager, I want to view a work breakdown structure of the human resources involved in the project to understand the distribution and allocation of the team throughout the project.	➡	🔧
US51	Physical Resource Breakdown Structure	👤	As a manager, I want to view a breakdown structure of the project's physical resources to facilitate asset control and proper allocation of materials and equipment.	➡	🔧

Legend: Rl. = Role — 👥 = All — 🧑‍🏫 = Professor — 👤 = Manager — 💻 = Developer —— Pr. = Priority — ⬆ = Very High — ⬆ = High — ➡ = Medium —— St. = Status — ✅ = Implemented — 🔧 = In Development — 🔀 = Designed — ⏳ = Pending.

Table 5. User Stories specified so far.

ID	Name	Rl.	User Story	Pr.	St.
US52	Cost Dashboard	👤	As a manager, I want to access a visual dashboard of the project costs to monitor real-time spending, identify deviations, and support financial decision-making.	⬆	⚙
US53	Project Schedule Network Diagram	👤	As a manager, I want to view the project schedule network diagram to understand the logical sequence of activities and identify the project's critical paths.	➡	⚙
US54	Deliverable Acceptance Document	👤	As a manager, I want to issue a delivery acceptance term to formalize the approval of project deliverables by stakeholders, ensuring the closure of activities.	➡	⚙
US55	User Guide	👥	As a user, I want to access the tool's user guide to understand how to use its features, facilitating learning and navigation.	➡	⏳
US56	Change History - Manager	👤	As a manager, I want to view the history of changes made in the project to track modifications and maintain control over the evolution of documents and activities, being able to define a baseline version and compare it with the current one.	➡	⏳
US57	Change History - Professor	👤	As a professor, I want to view the change history of the projects I supervise to track the evolution of deliverables and assess the team's progress.	➡	⏳
US58	Feedback Center - Manager	👤	As a project manager, I want to be able to see which of my project documents have received feedback recently so I can better understand what I need to improve.	⬆	⏳
US59	Feedback Center - Professor	👤	As a professor, I want to be able to see which documents need feedback in the projects I am working on so I can better guide the students who are managing the projects.	⬆	⏳

Legend: Rl. = Role — 👥 = All — 👤 = Professor — 👤 = Manager — 💻 = Developer —— Pr. = Priority — ⬆ = Very High — ⬆ = High — ➡ = Medium —— St. = Status — ✅ = Implemented — 🔧 = In Development — ⚙ = Designed — ⏳ = Pending.

Table 6. Non-functional requirements.

ID	Type	Description	Status
RNF01	🔵	The software must be accessible to people with disabilities.	🔧
RNF02	🔧	The software must have clear organization and good documentation, both in code and overall project documentation.	🔧
RNF03	🔵	The software must be responsive and able to adapt to different screen sizes.	🔧
RNF04	🔒	There must be an authentication system.	✅
RNF05	🔒	Passwords must be encrypted.	✅
RNF06	🔵	The software must support internationalization for multiple languages.	🔧
RNF07	🔵	The software must feature a user-friendly and intuitive interface.	🔧
RNF08	🔵	The software must assist users in understanding complex functionalities during their first use.	🔧
RNF09	🔒	The software must limit the number of user requests.	✅
RNF10	⏱	The software must not have response times longer than 5 seconds during graph generation.	🔧
RNF11	⏱	The software must feature an inactivity timer, disconnecting users after 4 hours of inactivity.	✅
RNF12	⏱	The software must respond to user requests in less than 250 milliseconds to ensure fast and smooth navigation.	🔧
RNF13	⏱	Pages must not take longer than 3 seconds to load.	🔧
RNF14	🔵	The system must offer support for two distinct interface themes - light or dark, allowing users to customize the visual appearance according to their preferences or to reduce eye strain during extended use.	✅

Legend: 🔵 = Usability — 🔧 = Maintainability — 🔒 = Security — ⏱ = Performance — ✅ = Implemented — 🔧 = In Development.

functional and comes with some pre-installed plugins, it is essentially a simple text box by default. Thus, the entire concept, styling, and state management logic for the editor are once again the responsibility of the developer.

Thus, to avoid creating something overly complex, the entire concept of the editor was based on existing editors, featuring a toolbar at the top and the text input field directly below. Figure 2 illustrates the structure of the component:

(**1**) label of the component linked to the input;
(**2**) tooltip providing additional relevant information on what needs to be done;
(**3**) toolbar for text manipulation;

(**4**) text input field;

(**5**) conversion of the current text into Overleaf format;

(**6**) option to hide the fixed toolbar;

(**7**) character count of the text;

(**8**) word count; and

(**9**) server connection status for collaboration.

Additionally, another identified issue is the absence of real-time collaboration within the documents. This collaboration refers to the ability of individuals or groups to work simultaneously on the same project, viewing and editing content instantaneously [Pimentel and Fuks 2011].
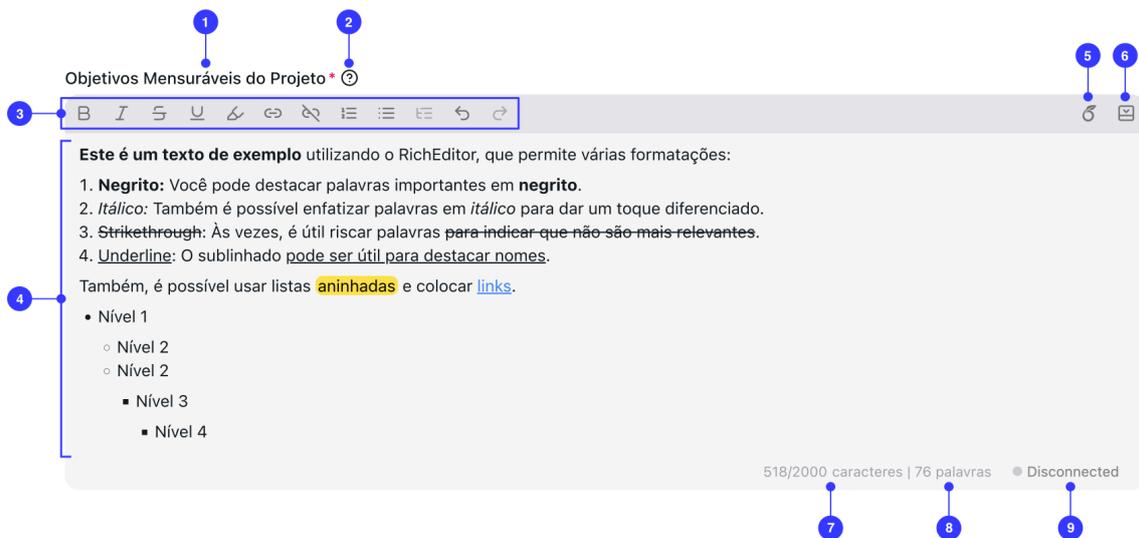
Figure 2. Component RichEditor

To address this issue and enhance collaboration efficiency among team members, a service was implemented to enable real-time user collaboration. The service utilizes a websocket server designed to handle documents in the editor's specific format. This service is based on Yjs[3], a framework that efficiently shares data types without conflicts, automatically distributing changes to other users. Additionally, the connection logic between a client and a websocket address is established using a combination of the current `id_Projeto` and `id_Documento`.

However, there are two connection scenarios, as follows:

(i) In document creation **new** pages automatic connection to the server is disabled. This is to prevent situations where multiple users creating new documents could inadvertently connect to the same session, as the document does not yet have an associated `id`. Consequently, users would enter a "queue", waiting for others to finish creating their documents. In this case, users can manually choose to connect or disconnect from the server.

(ii) In document editing (**edit**) pages: the connection is established automatically, as the document already has a unique identifier, avoiding conflicts with other documents. In this scenario, server disconnection is not allowed to prevent potential

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[3]Yjs: `https://docs.yjs.dev/`

data inconsistencies, even though a mechanism exists to merge versions when necessary.

To provide a visual representation, Figure 3 illustrates the result of this implementation, where four (4) users are connected to a document within the application, and each user can see the changes made by others in real-time.
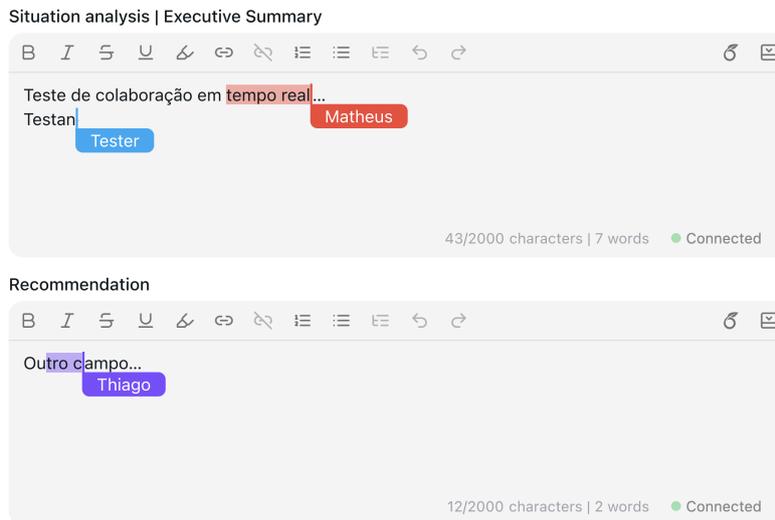

Figure 3. Example of Simultaneous Collaborative Editing

6.3. Functionality Limitations and Optimizations

Although the proposed tool meets the initial expectations, some limitations remain. The primary limitation is that, for now, the tool supports collaborative mode only in the textual fields of the **RichEditor** component, without enabling real-time tracking of changes in other fields. Additionally, there is a distinction between the creation pages (where a document does not yet have a unique identifier) and the editing pages (where the document is already saved in the database). This differentiation is crucial because, without it, if a user wanted to collaborate with others on the creation page of a document, it would affect all users attempting the same task, as there is currently no mechanism to differentiate user groups (resulting in everyone being placed in the same session). To address this, a modal was added, allowing users to generate or input an existing password for that specific field so other users can connect (Figure 4).
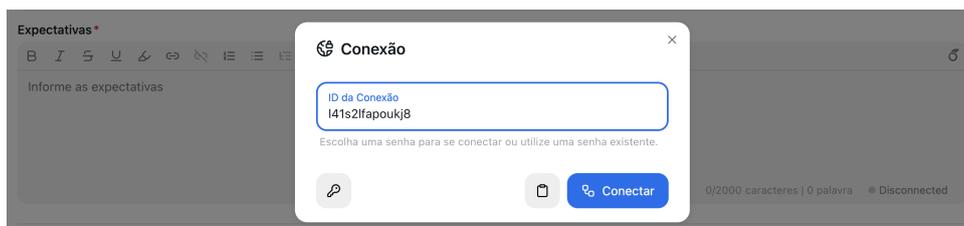

Figure 4. Connection Password Generation Modal for Collaboration

On the editing pages, there is a minor limitation related to the start of the collaboration session, where the data is initially loaded directly from the collaboration server and

appears empty. This behavior can create the impression of "lost" initial data. To address this, a "reset" button was added, allowing users to populate the field with data retrieved directly from the database. Once the field is populated, this issue no longer occurs.

Finally, as mentioned earlier, the proposed solution focuses exclusively on implementing collaboration within the **RichEditor** component, without extending to other equally critical components of the application, such as the tagging (`tag`) component, which is widely used in the proposed tool. Planned extensions include enabling real-time collaboration in additional artifacts, such as the Kanban board and visual project structures (*e.g.*, WBS), which currently present concurrency limitations.

7. Case Study

We conducted a case study [Runeson and Höst 2009] to evaluate overall usability, with particular attention to the effectiveness of the collaborative features implemented in the tool. We presented the protocol and results of this evaluation in the following sections.

7.1. Objectives and Research Questions

The empirical evaluation of the tool was guided by a case study protocol, with the main objective of analyzing the effectiveness of the new version in the context of teaching and practicing software project management. The investigation was based on three Research Questions (RQs), which are instrumental to this analysis from the perspective of the 3C model.

> **RQ1:** What are the strengths, weaknesses, and aspects for improvement in the new version of the tool?
>
> **RQ2:** Has the new version shown improvements in terms of efficiency and effectiveness for project management and its teaching?
>
> **RQ3:** Does the new version have an adequate level of usability, satisfy users, and encourage its continued use?

7.2. Context and Methodology

The study was conducted with 17 undergraduate students from a Software Engineering program during the second semester of 2024. The program adopts a Problem-Based Learning (PBL) methodology [Dolmans et al. 2005], in which students work in teams to manage a software project while simultaneously acting as developers for another team.

The sample comprised all students who voluntarily agreed to participate (17 out of 23 enrolled). As this research follows a case study strategy rather than a controlled experiment, the emphasis is placed on in-depth analysis of perceptions and behaviors within a real educational setting, in line with empirical software engineering guidelines [Runeson and Höst 2009]. All participants signed an Informed Consent Form (ICF), and participation was explicitly stated as unrelated to course grading, aiming to mitigate potential coercion or instructor bias.

Data collection was structured according to the four phases of the course project (Initiation, Planning, Execution & Monitoring, and Closing) and employed three complementary instruments. A Profile Assessment (PA) questionnaire was applied at the beginning of the study to characterize participants' background and prior experience. At the

end of each phase, a Feature Evaluation (FE) questionnaire was used to capture satisfaction and affect, following the circumplex model of affect [Russell 1980]. Finally, at the end of the course, a Usability Evaluation (UE) questionnaire based on the Technology Acceptance Model (TAM) [Davis et al. 1989] was administered to assess Perceived Ease of Use (PEoU), Perceived Usefulness (PU), and Intention to Use (IU).

Detailed descriptions of all instruments are publicly available in the Zenodo repository (Section Data Availability).

7.3. Results and Analysis from the 3C Model Perspective

The analysis of the data answered the research questions, and its results are presented and analyzed here in integration with the dimensions of the 3C model. The quantitative data collected through the Usability Evaluation (UE) questionnaire, which measures the dimensions of the TAM model, are summarized in Figure 5.
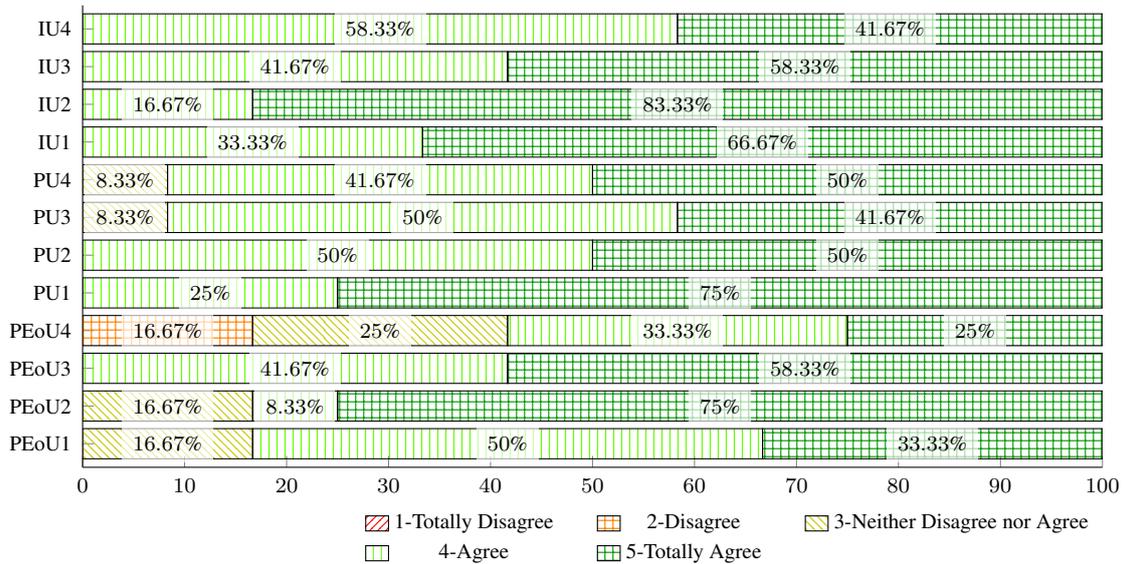

Figure 5. Results of the Usability Evaluation (UE) questionnaire based on the TAM model, detailing the responses for Perceived Ease of Use (PEoU), Perceived Usefulness (PU) and Intention to Use (IU).

7.3.1. Communication

The Communication dimension, which refers to the exchange of information, was positively evaluated. In response to **RQ1**, participants highlighted the interface design and the tooltips with examples as strengths that facilitated access to information. However, they also pointed to the absence of a centralized area for *feedback* as a limitation, indicating an opportunity for improvement in asynchronous communication between students and instructors. This limitation directly motivated the prioritization of a centralized feedback mechanism (US58/US59), which will consolidate asynchronous comments and provide instructors with an overview of evaluated and pending documents.

7.3.2. Coordination

Coordination, which encompasses the management of activities and resources, was considered effective. The high Perceived Usefulness (PU) revealed that users see the tool as a valuable aid for project management. Nevertheless, the results for **RQ1** show that there is still room for improvement: suggestions for the creation of a general *dashboard* and greater process automation reflect the need to optimize the control and monitoring mechanisms for planned activities.

7.3.3. Cooperation

The Cooperation dimension, focused on simultaneous work in a shared space, was where the tool demonstrated the most significant advancement. The implementation of the real-time collaborative editor directly addressed **RQ2** regarding efficiency: 70% of participants strongly agreed that the tool increased productivity, a significant leap from the 26% in the previous version [Bernardino et al. 2022]. This success in cooperation also impacted **RQ3**, with the Intention to Use (IU) being notably positive: 58% of users would strongly recommend the tool, compared to 41% in the previous version, reinforcing the positive perception of the new collaborative capability.

7.4. Discussion

The data analysis validates the tool's evolution, demonstrating that the integration of features guided by the 3C model positively impacted the user experience. The success of the real-time editing feature (**Cooperation**) was a decisive factor in increasing the perception of productivity and the intention for future use of the tool. Although Perceived Usefulness (PU) was high, indicating that the tool is seen as effective for project **Coordination**, the suggestions for improvement (such as the centralized *dashboard*) point to the need to further refine the control and monitoring mechanisms.

Finally, the results related to PEoU were more modest. The fact that the percentage of users who strongly agreed that the tool is easy to use (33.33%) remained similar to that of the previous version [Bernardino et al. 2022] suggests that, while powerful, the tool may have a steep learning curve. This becomes a point of focus for future work, aiming to ensure that the Communication, Coordination, and Cooperation functionalities are not only effective but also more intuitive and accessible.

To mitigate the identified learning curve, future iterations will focus on onboarding support, including an interactive guided tour on first access and richer contextual tooltips. These improvements extend the planned 'User Guide' functionality (US55) and aim to reduce initial cognitive load without sacrificing functional richness.

7.5. Threats to Validity

This study presents some limitations that should be considered when interpreting the results. Internal validity threats are related to the use of self-reported instruments (*e.g.*, TAM-based questionnaires and affect measures), which may be influenced by participants' subjective perceptions or social desirability bias. To mitigate this risk, data were collected at multiple moments throughout the project lifecycle and combined with qualitative feedback.

External validity is limited by the sample size and context. The study involved 17 undergraduate students from a single Software Engineering program, all engaged in a PBL course. As a case study, the goal was not statistical generalization but analytical generalization, providing in-depth insights into the use of the tool in a real educational setting. Replication in other courses, institutions, and industrial environments is required to broaden generalizability.

Construct validity may be affected by the exclusive reliance on questionnaires to assess usability and perceived usefulness. Although validated models such as TAM were employed, future studies should complement self-reported data with objective usage metrics (*e.g.*, interaction logs, task completion times) and observational techniques.

These limitations also inform future research directions, particularly regarding industrial validation, longitudinal studies, and mixed-method evaluation strategies. Despite these threats, the study provides credible and actionable insights into the design and evaluation of collaborative IS for project management education.

8. Key Contributions and Discussion of the Study

The contributions of this study can be articulated along two dimensions:

(i) **Theoretical Contributions (IS field)**: **(1)** Operationalization of the 3C model in the design of a collaborative educational IS, demonstrating how communication, coordination, and cooperation can guide functionality requirements; **(2)** Advancement of IS research in education by integrating PMBOK® standards with collaborative technologies, showing how IS frameworks can mediate pedagogical practices; **(3)** Contribution to the discourse on hybrid IS-supported methodologies, bridging predictive (PMBOK® 6th edition) and adaptive (PMBOK® 7th edition) approaches.

(ii) **Practical Contributions (Education and Industry)**: **(1)** Development of a collaborative web-based IS tailored for project management education, supporting real-time editing, structured PM documentation, and interactive feedback between students and instructors; **(2)** Provision of a pedagogical tool that aligns with professional standards (PMBOK® 6 and 7) while addressing academic usability requirements; **(3)** Creation of a roadmap for integrating collaborative IS into curricula, supporting the preparation of students for industry demands in agile and hybrid project management.

Together, these contributions reinforce the role of IS not only as a technological enabler but also as a transformative framework for project management education, with potential applicability to both academic and professional contexts.

Figure 6 presents our response, grounded in an analysis reflecting on the proposed study, highlighting its relevance to addressing the needs of academia and industry by enhancing communication, collaboration, and cooperation among individuals through IS technologies.

9. Final Remarks and Future Works

This study presented the evolution of a collaborative tool for teaching PM, aligning with the guidelines of the 7th edition of the PMBOK® and incorporating agile methodologies and collaborative mechanisms as proposed by the 3C Model

> **RQ** How can collaborative work shape the evolution of a PM teaching tool?
> **Response**: Collaborative work can significantly shape the evolution of a project management teaching tool by fostering real-time interaction, enabling iterative improvements, and integrating user feedback to address specific educational needs. The study demonstrates how the application of the 3C Model (Communication, Coordination, Cooperation) and the incorporation of technologies such as Yjs and TipTap for real-time collaboration enhance the functionality and usability of the tool. These features facilitate dynamic engagement among students and instructors, bridging theoretical knowledge with practical applications. Moreover, iterative testing and continuous updates, guided by user-centered design principles, ensure that the tool evolves to meet contemporary challenges in project management education, such as supporting both agile and hybrid methodologies. By leveraging collaborative work, the tool not only improves the learning experience but also serves as a scalable, adaptable solution that aligns with the evolving demands of the industry and academia.

Figure 6. Response to Research Question (Paper Title)

[Pimentel and Fuks 2011]. The proposal aims not only to enhance the learning experience for students but also to facilitate interaction between students (managers and development teams) and professors (sponsors), fostering a collaborative and efficient working environment. The analysis of user needs and the implementation of new functionalities, such as a more robust text editor and real-time collaboration capabilities, represent significant steps toward addressing the contemporary demands of SE education while making the solution more dynamic and flexible to meet the real-world needs of the job market.

An earlier version of the tool was presented to industry professionals in a focus group [Neves et al. 2023], where it generated strong practical interest. However, the current version, extended to support PMBOK® 7 and real-time collaboration, still requires validation in real industrial settings. Such validation is planned after incorporating the usability improvements identified in this primary academic study.

For the future, we plan to conduct a follow-up case study [Runeson and Höst 2009] with the new version of the tool in the second semester of 2026, involving undergraduate students enrolled in the course covering Software Project Management. This study aims to collect both quantitative and qualitative data on the tool's effectiveness, along with a usability evaluation to identify areas for improvement and ensure that the tool meets user expectations. We believe that the results of this study will not only contribute to the continuous enhancement of the tool but also provide valuable insights for the academic community on integrating collaborative technologies into project management education. Additionally, we intend to conduct interviews with experts in accessibility and user experience (UX) [Hassenzahl and Tractinsky 2006] to identify relevant aspects for further improving the tool in these areas.

Acknowledgments

Data Availability

We promote transparency and reproducibility by openly sharing the supporting data of our case study on Zenodo: `https://doi.org/10.5281/zenodo.17217594`. The questionnaires used in the evaluation are also provided in their original language (Portuguese), as they were administered to participants in that form.

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