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Exploring the synergistic effects of combining design thinking and project-based learning in a blended course

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Abstract

This article presents an account of our experience in designing and implementing a course titled "Integration Project 3", in which we combined design thinking and project-based learning approaches. The course, conducted between March and June 2023, involved twelve undergraduate students from the Department of Technology in Educational Design at the Federal University of São Paulo situated in São Paulo, Brazil. Our research objective aimed to elucidate the synergistic effect of combining both approaches. Employing a mixed-method research design, we collected data from the students' project website, from focus group activities and from a questionnaire. We conducted a systemic analysis utilizing causal loop diagrams. The findings of our study are as follows: 1) The implementation of design thinking methodology in addressing challenges faced by community partners not only motivated the students to learn but also facilitated the development of their problem-solving skills. 2) The integration of project-based learning and design thinking methodologies engendered the development of students' project management skills and facilitated the application of acquired knowledge across various academic disciplines, thereby promoting interdisciplinary learning. 3) The students' determination to work on real-life project tasks was influenced positively by their motivation to learn and negatively by the stress due to real-life project constraints.

Introduction

The Department of Technology in Educational Design at the Federal University of São Paulo, known as TEDE, offers a two-and-a-half-year undergraduate course that focuses on developing instructional designers. Throughout the course, there are four capstone courses, one for each semester, called "Integration Projects". These courses aim to bridge the knowledge gained from supportive courses taken by students during each semester.

In "Integration Project 1", the objective is to encourage students to work on projects related to networked open learning experiences, such as designing and evaluating Massive Open Online Courses (MOOCs). In "Integration Project 2", students undertake projects that involve non-formal education, in collaboration with NGOs and public institutions.

The primary goal of "Integration Project 3" is to provide students with a practical opportunity to apply conceptual frameworks in designing educational experiences within the formal education context. This includes projects with schools at fundamental and high school levels. Lastly, "Integration Project 4" challenges students to collaborate with corporations in designing educational courses. These capstone disciplines serve as a way for students to integrate their learning across different areas and apply their knowledge and skills in practical settings, aligning with the overall objective of the instructional design program at TEDE.

In this article, we analyze "Integration project 3", developed in the first semester of 2023 and delivered to twelve students. The students were presented with a challenge: to develop educational products or initiatives, including courses, games, and more, specifically designed for Early Childhood Education Center Paulistinha, a public K-8 educational institution, our institutional partner (hereafter referred to as Paulistinha). To encourage collaboration and promote a harmonious working environment, the students were divided into teams of four. Each team was given the freedom to choose a single project from a carefully curated list (Table 1) provided by the principal of Paulistinha.

The course spanned a duration of 15 weeks and was implemented using a blended learning methodology, combining both online and face-to-face components. The students engaged in only three physical meetings with the professors throughout the course, with the majority of the activities conducted online. However, the students were granted autonomy to arrange additional in-person meetings with the institutional partner as necessary, facilitating the resolution of queries or enabling the testing of the prototypes developed by the students.

The course preparation

The Integration Project was led by two professors who assumed the responsibility of guiding the course. A month prior to its commencement, these professors proactively initiated contact with the principal of the school, articulating the overarching objectives of "Integration Project 3" and inquiring about any specific educational requirements the institution may have had. Subsequently, the principal promptly established communication channels with the school's teachers, proposing four distinct project themes aligned with the creation of educational products and initiatives (as summarized in Table 1).

Table 1. The project's themes.

Project theme	Description
Paulistinha's portal project	The task assigned to the students involved the creation of a comprehensive online portal that would serve as an informational hub for the school, encompassing detailed insights into the school's infrastructure, facilities, as well as highlighting the diverse range of activities undertaken by its students.
Paulistinha's memory project	The students were tasked with the mission of creating a dynamic online portal that would present the rich history of the school, spanning its inception in the year 1950 to the present day. This portal would serve as a captivating platform, incorporating a compelling blend of archival photographs, descriptive narratives, and engaging videos, all meticulously curated to capture and present the enduring legacy and evolution of the institution over the years.
Paulistinha's web radio project	The students have been entrusted with the task of developing a captivating web radio platform, which would serve as an innovative and dynamic medium for disseminating news and hosting podcasts meticulously curated by the school's teachers. This project would provide a unique opportunity for the school's students to harness their creative talents.
Paulistinha´s diversity Project	The students have been assigned the responsibility of creating a comprehensive digital repository of multimedia resources, encompassing diverse materials related to issues of diversity. This repository, consisting of texts, videos, and audios, is intended to be utilized by the teachers at school in their respective courses.

The professors informed the principal that the projects would be developed over a span of 12 weeks. Throughout the project's duration, students would engage with the school principal and teachers, seeking clarification about the products and initiatives to be developed. The professors underscored the significance of the school administrators providing prompt responses to the students' queries, to ensure that the progress of their projects is not impeded. The school representatives were requested to respond to the students' inquiries, ensuring that their responses were provided by the end of the week in which the questions were posed.

The professors leading the Integration Project proceeded to design a course that integrated project-based learning and design thinking approaches. The students would work in teams, with each team focusing on one of the project's themes. Subsequently, the professors shared their course concepts with their colleagues within the department, encouraging collaboration and seeking input for further improvement. The professors actively engaged in a constructive dialogue, asking probing questions and providing valuable suggestions to enhance the course design. Upon receiving the departmental approval, the two professors established a virtual learning environment using Moodle.

The course schedule was thoughtfully structured to enable students to follow MIT Teaching System Lab's (MITx, 2019) six-stage framework (Discover, Focus, Imagine, Prototype, Try, Reflect and Share) while working on their projects.

To document their progress, each team of students was mandated to develop a project website, furnishing a weekly report of their undertakings. Consequently, four student websites were established (one for Paulistinha's portal project, one for Paulistinha's memory project, one for Paulistinha's web radio project, and one for Paulistinha's diversity project). Additionally, they were encouraged to reflect upon their learning experiences on their project's website, documenting any challenges encountered and the solutions they employed to overcome them.

The course delivery

The course delivery was structured into clear and sequential phases, starting with the Discover and Focus phases, which spanned the initial month. During this period, student teams conducted visits to schools and engaged in meetings with principals, teachers, and students. Through interviews and collaborative activities, these interactions provided valuable insights into the context and challenges they would encounter. Furthermore, questionnaires were distributed to the teachers, facilitating the establishment of project boundaries to ensure minimal overlap between projects.

At the conclusion of the Discover and Focus phases, the students participated in a face-to-face meeting with the professors, where they presented their insights gained during this phase. Subsequently, the course transitioned into the Imagine and Prototype phases, which lasted for one month. Within this phase, student teams engaged in intensive brainstorming sessions, fostering the generation of diverse solutions to the identified problems. These efforts culminated in the development of prototypes.

Following the Imagine and Prototype phases, the course progressed into the Try, Reflect, and Share phases, which extended over a duration of two months. During these phases, the students actively tested their prototypes with the involvement of students and teachers of Paulistinha. Based on the feedback received, the students refined their prototypes, leading to the finalization of the products that were eventually delivered to the teachers at school.

Theoretical review

Design thinking is a systematic problem-solving approach that incorporates empathy, collaboration, and iteration as essential elements (Brown, 2008). It can be developed by following a method with defined stages. However, there is no consensus among researchers regarding the precise number or naming of stages within the design thinking process (Arantes do Amaral et al., 2023). Scholars propose different frameworks, including five-stage (Plattner et al., 2010), six-stage (Lewrick et al., 2018), and even eight-stage processes (Mueller-Roterberg, 2018). They are all very similar; they all begin with one stage that aims to understand and define the problem and the people who have this problem. Then, it progresses to figure out different solutions to that problem, followed by the development and testing of prototypes that could be used to solve the problem. These prototypes may evolve into a final product or service that solves the problem.

Although these approaches share similarities, we chose to adopt the MIT Teaching System Lab's (MITx, 2019) six-stage framework for design thinking in our course. This framework consists of the following stages: discovery, focus, imagine, prototype, try, and reflect and share (Figure 1).

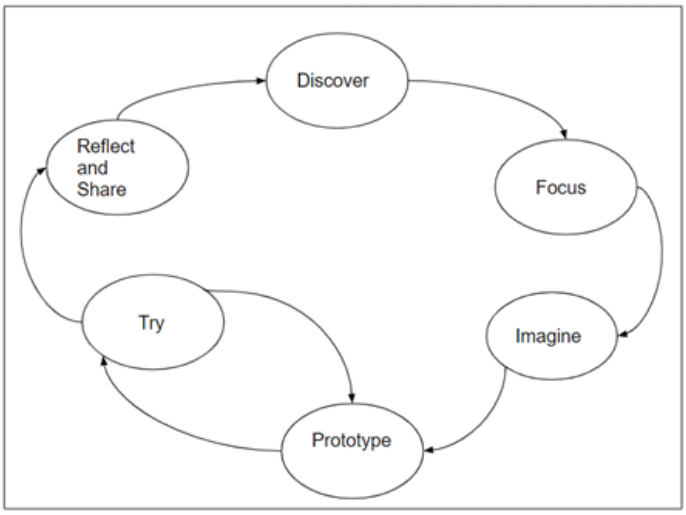

Figure 1. MIT Teaching System Lab's six-stage framework (based on MITx, 2019).

We determined that this particular framework would be more accessible and comprehensible for our students, enabling them to effectively understand and follow the design thinking process. The objective of the discovery stage is to develop an understanding of the problem and the individuals affected by it, commonly referred to as users. Designers employ various methods such as interviews, focus group activities, questionnaires, and field observations to gain a clear understanding of the contextual nuances. They immerse themselves in the users' context to glean insights. The discovery stage is also known by other scholars as empathize stage (Wolniak, 2017) or understand stage (Lewrick et al., 2018) .

During the focus stage, designers define the problem statement and identify key challenges. Other researchers call this stage as "define stage" (Wolniak, 2017). In the imagine stage, designers explore multiple possibilities to solve the problem and select the most viable option. The imagine stage is also referred as "ideate stage" by other scholars (Sándorová, 2020). The prototype and try stages are closely connected. Designers create prototypes, which can take the form of sketches, models, storyboards, software, or any other device, and subsequently subject them to rigorous testing. These two phases are highly interactive and often involve active participation from the users. Prototypes can be refined or discarded based on feedback received during these processes. The prototype and try stages are also referred as "create stage" by other researchers (Luchs, 2015).

During the reflection and sharing process, designers contemplate the solution, and the process followed. If the prototype successfully addresses the problem, the design process concludes. However, if further refinement is required, designers may initiate additional six-stage cycles to iterate and improve their design solution.

Contemporary educational institutions, including K-12 schools (Li & Zhan, 2022), universities (Arantes do Amaral et. al, 2022), and graduate schools (Kurokawa, 2013), have increasingly embraced the integration of design challenges and interdisciplinary projects into their curricula across various grade levels. This pedagogical approach enables students to apply design thinking methodologies and cultivate their ability to generate innovative solutions for real-world problems. By engaging in hands-on activities and collaborative ideation, students are afforded opportunities to identify problems, develop prototypes, and rigorously test their ideas. These projects encompass a diverse array of themes and objectives. For instance, students may undertake endeavors focused on formulating sustainable solutions for issues within their school or community, such as the establishment of recycling initiatives or the implementation of energy-efficient practices (Dotson et al., 2020; Earle & Leyva-de la Hiz, 2021). Alternatively, they may participate in initiatives aiming to promote inclusivity (Ballenger & Sinclair, 2020), collaborate with community organizations (Ramos et al., 2016) or businesses (Glen et al., 2015), engage in STEAM (Science, Technology, Engineering, the Arts and Mathematics) projects (Ananda et al., 2023), redesign courses (Acharya et al., 2021), or partake in humanitarian design endeavors, among other possibilities.

Designing and delivering a course centered on design thinking presents several challenges. Firstly, it necessitates a paradigm shift from a traditional teacher-centered approach to a student-driven model, thereby requiring a corresponding transformation in the mindset of educators (Noh & Abdul Karim, 2021). Secondly, design thinking is inherently challenging due to its reliance on interdisciplinary collaboration and the need to foster cooperation among teachers from diverse disciplines and perspectives (Maciver et al., 2016). Thirdly, incorporating design thinking processes within the course timeline presents a notable challenge.

In order to overcome these challenges, researchers (Beneroso & Robinson, 2022; Parmar, 2014) are integrating design thinking and project-based learning approaches. Project-based learning is a student-centered educational approach that fosters hands-on activities, fostering collaboration (Larmer et al., 2015) and allowing the teacher to incorporate design thinking processes in the course timeline (Boss & Larmer, 2018).

Academic discourse has notably emphasized the significance of affording students the opportunity to engage in substantive real-world projects (Lamer et al., 2015), endeavors which not only stimulate the development of students' abilities but also culminate in the creation of products or services that yield tangible societal advantages (Jacoby, 2014). Scholarly investigation has extended to encompass academic undertakings uniting university students with institutional collaborators, including entities such as non-governmental organizations (Arantes do Amaral, 2019), corporations (Badir et al., 2023), and educational institutions (Catapano & Gray, 2015; Kaldi et al., 2011). Nevertheless, scholars (Arantes do Amaral & Matsusaki, 2017) have also underscored the intricate challenges inherent in establishing and nurturing such collaborative alliances. Notably, scholars (Markham et al., 2003) have articulated the imperative of harmonizing institutional agendas with the academic calendar, thereby ensuring seamless integration. Furthermore, researchers (Arantes do Amaral, 2020) have underscored the potential challenges encountered within these collaborative ventures, spanning from limited partner commitment and delayed responsiveness to student inquiries to the discernment of inadequately aligned project themes.

In the present exposition, we embark on a comprehensive examination of a specific pedagogical endeavor involving university students and a public school institution. Within this context, our discourse delves into the convergence of project-based learning paradigms with the design thinking approach. Scholarly literature has extolled the virtues of amalgamating these two pedagogical frameworks, manifesting benefits such as the nurturing of students' innovation skills (Collins & Chiaramonte, 2017), fostering creativity (Cummings & Yur-Austin, 2022) and promoting empathy (Hashim et al., 2019).

However, there is still a notable gap in understanding the synergistic effects that arise from combining these approaches. This article seeks to address this gap by providing a comprehensive examination of the combined use of design thinking and project-based learning in a course, thereby offering insights into the potential benefits and outcomes of this integration.

Method

This study employed a sequential mixed methods approach (Creswell, 2014). Initially, qualitative data were collected by scrutinizing the projects' websites and conducting three focus group sessions with all student teams (one at the commencement of the course, one in the middle, and one at the conclusion). This allowed for the identification of recurring themes. Subsequently, an analysis was conducted to explore the interconnections among these themes using a causal loop diagram. This analysis revealed the need for further inquiry to gain a deeper understanding of the dynamics within the course. As a result, a questionnaire was administered to all students, gathering both quantitative and qualitative data. The collected data were analyzed, and based on the findings, refinements were made to the causal loop diagram. Through this iterative process, a comprehensive understanding of the synergistic effects arising from the combination of design thinking and project-based learning within the course was achieved.

Participants

Twelve students, consisting of eight males and four females, ranging in age from 24 to 45 years, participated in the course.

Data collection procedures

As mentioned earlier, qualitative data were collected from two sources: the students' project websites and focus group activities. The project websites served as a platform for

the students to share their reflections on the completed activities, including their overall project experience and learning outcomes. Furthermore, the project websites provided insights into how the students applied the knowledge gained from other courses to their specific projects, illuminating their understanding of integrating and utilizing course content in their individual projects.

Quantitative and qualitative data were collected through the administration of a questionnaire (Appendix 1) at the end of the course. The questionnaire consisted of five distinct parts. Each part had closed-ended questions to be answered following a five-point Likert scale and one open-ended question.

Part 1 comprised four closed-ended questions that assessed the sources of stress experienced by students during the project, along with one closed-ended question related to the causal relationship between stress and willingness to perform project tasks. Part 2 included four closed-ended questions designed to gauge the students' perceptions of the application of design thinking methods in their projects, along with one closed-ended question related to the causal relationship between design thinking and motivation to learn. Part 3 consisted of an additional set of four closed-ended questions aimed at eliciting the students' perceptions and reflections on their utilization of project management tools, along with one closed-ended question related to the causal relationship between the development of project management skills and willingness to learn. Finally, Part 4 encompassed five closed-ended questions regarding the students' evaluation of the overall course structure. Part 5 consisted of five questions that explored the causal relationships between different factors. These included the relationship between stress and motivation to perform project tasks, the connection between the use of design thinking and motivation to learn, the correlation between the use of design thinking and the development of problem-solving skills, as well as the association between the development of project management skills and motivation to learn. Additionally, each part included an open-ended question prompting the students to provide any additional feedback or thoughts that were not addressed by the closed-ended questions.

Data analysis procedure

The qualitative data were analyzed following Yin's (2015) qualitative analysis method. First, we collected sentences from the project websites and notes from the focus group, creating a dataset. Then, we separated sentences with similar meanings into groups. After that, we created recurrent themes that summarized the main ideas.

Next, we created a causal loop diagram connecting variables representing the recurrent themes and performed a systemic analysis (Arantes do Amaral et al., 2023). Through this process, we realized that there were some causal relationships that needed further understanding and confirmation. Therefore, we administered the aforementioned questionnaire to the students to gather additional data. As mentioned previously, this questionnaire included both closed-ended and open-ended questions. The closed-ended questions provided us with quantitative data, while the open-ended questions provided qualitative data. To analyze the quantitative data, we developed an R program. For the qualitative data, we followed Yin's (2015) method again. Subsequently, we improved our causal loop diagram and analyzed the synergistic effects of combining design thinking and project-based learning in our course.

Results

Results from qualitative data

Recurrent Theme 1 (RT1): Delayed responses from school representatives

The students conveyed their challenges in establishing effective communication channels with the designated representatives of the educational institution. Furthermore, they expressed difficulties in obtaining timely feedback essential for the progression of their projects. Notably, one particular group of students highlighted the occurrence of delays in receiving feedback. These delays were attributed to the absence of their primary contact within the school, who had taken a holiday leave. As a result, a substitute teacher had to assume the responsibilities, impeding the timely dissemination of valuable feedback.

Recurrent Theme 2 (RT2): Lack of computational resources and internet connection at the school

During an on-site visit to the school, the students discovered a concerning inadequacy in computer availability, with only three units dispersed throughout the entire school. Additionally, the internet connection was characterized by frequent disruptions and sluggish performance. These circumstances posed a significant obstacle, considering that the majority of their projects focused on developing web-based products intended for use by students within the school.

Recurrent Theme 3 (RT3): Changes in project scope during the projects

The majority of project groups revealed that their initial project scopes underwent various modifications during the course of their work. These alterations ranged from minor adjustments to more substantial transformations. For instance, one group reported a radical shift in scope: their original project aimed to create a web-radio platform, but after two weeks, they significantly revised the scope to develop a virtual learning environment. This revised project aimed to facilitate content sharing among the school's students, encompassing textual, visual, and audio materials. The students expressed the perception that school representatives occasionally lacked a clear understanding of their own requirements and how the proposed projects could effectively address them.

Recurrent Theme 4 (RT4): The iterative process of prototype testing with the users helped to clarify the project scope

According to feedback from our students, the process of testing the prototypes has proven beneficial for both the students themselves and the teachers of the school. It has contributed to a more comprehensive understanding of the projects' scope. During the testing phase, students were able to identify limitations inherent in the prototypes, discern challenges experienced by the intended users (i.e., the children attending the school), and identify ambiguities in the product specifications. This testing phase has not only deepened our students' understanding of the final product to be created but has also empowered our school's teachers by illuminating numerous possibilities for integrating the product into their classroom activities.

Recurrent Theme 5 (RT5): The projects integrated the content of other courses, making them interdisciplinary

On their project websites, the students consistently documented their reflections on the interrelationships between the current course and their concurrent academic endeavors. They specifically articulated the application of various conceptual frameworks taught in other courses (such as universal design, project management, and innovation) This integration of diverse knowledge domains resulted in the interdisciplinary nature of their projects.

Recurrent Theme 6 (RT6): The combination of the design thinking method and the project-based learning approach enabled students to develop creative problem-solving skills, project management skills, collaboration, and empathy

As the course followed a project-based learning approach, the students were tasked with delivering specific artifacts, such as project charters, requirement analyses, and design documents, following the course's master schedule. The examination of the project websites revealed that the students diligently adhered to the six-step framework of design thinking. Notably, the students exhibited the application of empathy during their interactions with the school's teachers by adopting a perspective congruent with the educators' standpoint, engaging in active listening, extending support to develop information technology tools favorable for the enhancement of classroom activities, and sharing their experiential insights. In addition to that, the students employed project management tools to meticulously plan their projects and generated multiple innovative solutions during the imaginative phase of the design thinking process.

Results from quantitative data

In this section, we provide a summary of the findings regarding the distribution of students' responses to the closed-ended questions. Each question offered students the opportunity to select one of five options, according to the five-point Likert scale: "Totally disagree," "Disagree," "Neither agree nor disagree," "Agree," and "Totally agree." We analyze the data using four stacked charts, where each chart represents the percentage distribution of students' responses. The color scheme employed in the charts is as follows: dark brown denotes "Totally disagree," light brown corresponds to "Disagree," grey signifies "Neither agree nor disagree," light green represents "Agree," and dark green indicates "Totally agree."

Figure 2 illustrates the students' responses to four questions regarding the sources of stress experienced by students during the project (see Appendix 1). The stacked chart (Figure 2) shows that 64% of the students agreed or totally agreed that the delays in receiving feedback from Paulistinha were stressful. Only 18% of the students agreed that the changes in the project's schedule were stressful, and similarly, only 18% of the students agreed that the lack of Paulistinha's computational resources was stressful. Additionally, 18% of the students agreed or totally agreed that changes in the project's scope were stressful. Therefore, this leads to quantitative finding number 1 (QF1):

> The primary source of stress for students was found to be the delay in receiving responses to their inquiries.

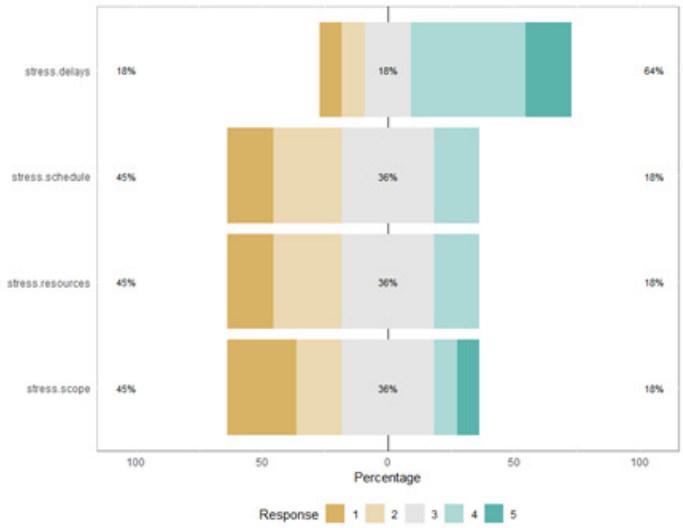

Figure 2. The students' answers related to stress.

Figure 3 presents the students' responses to four questions concerning their perceptions of the activities conducted during the design thinking stages (see Appendix 1). The stacked chart in Figure 3 reveals that a significant majority of 91% of the students agreed or completely agreed that they were able to comprehend the context of the community partner and define the requirements of the product during the 'discover' and 'focus' stages. Similarly, the same percentage of students agreed that they generated multiple solutions to the problem during the 'imagine' stage. Furthermore, all students unanimously agreed that they successfully created prototypes and conducted testing during the 'prototype' and 'try' stages. Additionally, 91% of the students agreed that they were able to engage in reflection on the processes undertaken and share insights during the reflect and share stages. Hence, these findings support quantitative finding number 2 (QF2):

The students effectively implemented the activities advocated by design thinking methodology.

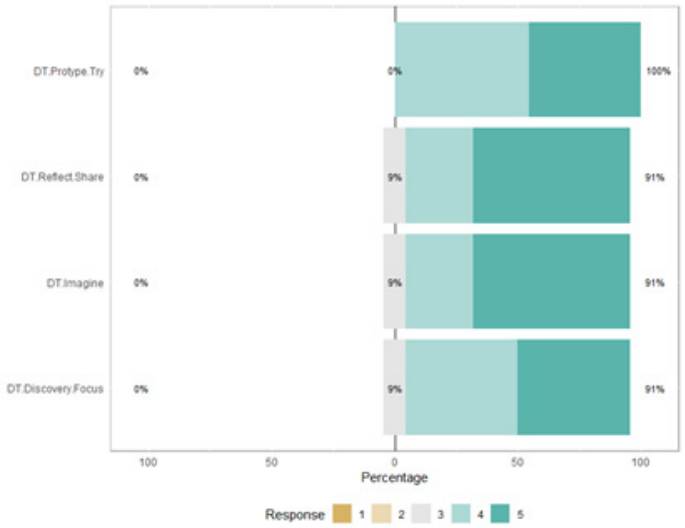

Figure 3. The students' answers related to the design thinking methodology.

Figure 4 presents the students' responses to four questions regarding their perceptions of the development of their project management skills (see Appendix 1). The stacked chart in Figure 4 reveals that all students agreed or totally agreed that they have developed project planning, project controlling, and project communication skills. Furthermore, a significant majority of students (91%) agreed or completely agreed that they were able to enhance their collaboration skills. These findings substantiate quantitative finding number 3 (QF3):

> The projects have facilitated the development of project management skills among the students.

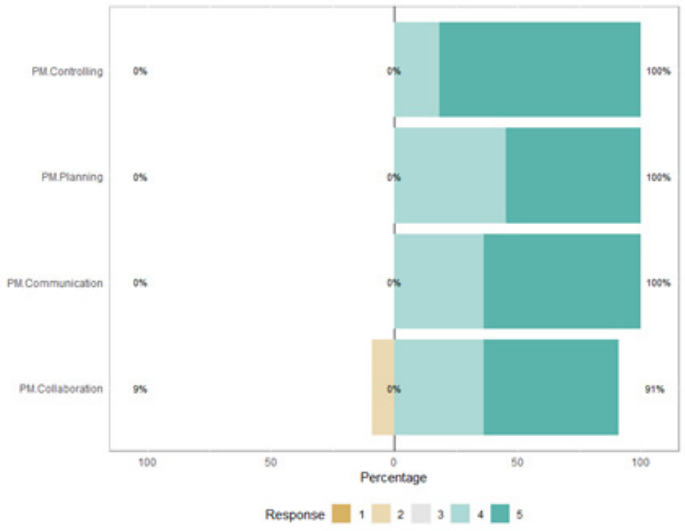

Figure 4. The students' answers related to the development of project management skills.

Figure 5 presents the students' responses to five questions pertaining to their perceptions of the course, including the teaching and learning strategy (the combination of project-based learning and design thinking), course management, and available resources (see Appendix 1). The stacked chart depicted in Figure 5 illuminates that all students agreed or totally agreed with the helpfulness of the professors' feedback, the well-organized Moodle learning environment, and the adequacy of the teaching and learning approach. Moreover, a significant majority of students (91%) agreed or completely agreed that the course met their expectations. Furthermore, a considerable 73% of the students agreed or completely agreed that working with a real-world community partner was a motivating experience. These findings substantiate quantitative finding number 4 (QF4):

> The teaching and learning strategies (the combination of project-based learning and design thinking), as well as the course management, have demonstrated effectiveness.

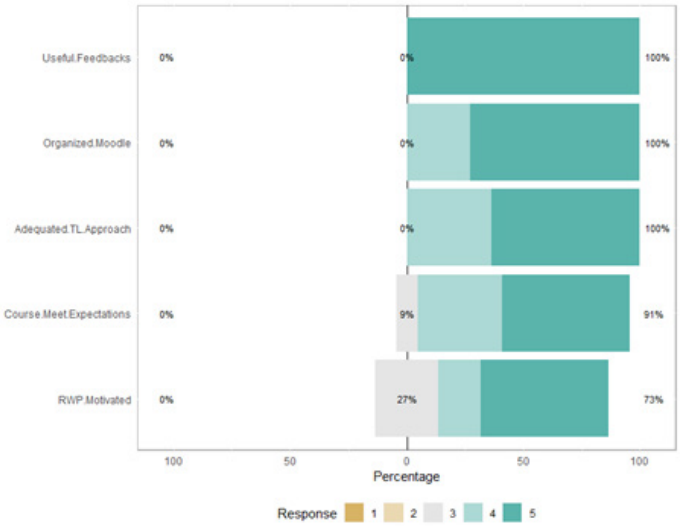

Figure 5. The students' answers related to the course.

Figure 6 illustrates the students' responses to five questions pertaining to their perception of causal relationships (refer to Appendix 1). The stacked chart depicted in Figure 6 reveals that a notable majority of 91% of the students agreed or totally agreed that there exists a positive causal relationship between the development of their project management skills and their motivation to learn. Similarly, the same percentage of students agreed or totally agreed that there is a positive causal relationship between the use of design thinking and their problem-solving skills. Additionally, 82% of the students agreed or totally agreed that a positive relationship exists between the use of design thinking and their motivation to learn. Moreover, 73% of the students concurred that there is a positive relationship between the accomplishment of project tasks and the development of project management skills. Furthermore, 45% of the students agreed or totally agreed that stress had a negative impact on their motivation to work on project tasks. These findings substantiate QF5 to QF8:

QF5: The development of project management skills and the use of design thinking positively impacted their motivation to learn.

QF6: The combination of design thinking and project-based learning positively influenced the development of problem-

solving skills.

QF7: Stress had a negative impact on the motivation to work on projects for nearly half of the students.

QF8: The accomplishment of project tasks positively affected the development of project management skills.

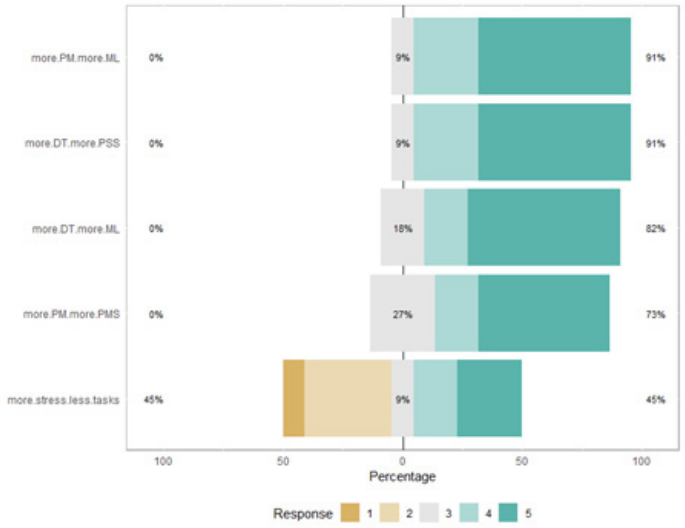

Figure 6. The students' perceptions about the causal relationships.

Discussion

The data (RT4, QF2, RT6, QF3) revealed that through the iterative processes of design thinking, the students improved their problem-solving skills. The data also revealed (RT6 and QF6) that as the students continued to refine their problem-solving skills, their motivation to learn intensified, as illustrated by the positive feedback loop labeled "Developing Problem-Solving Skills" in Figure 7. Hence, this leads us to our first finding:

> The implementation of the design thinking methodology in addressing challenges faced by community partners not only motivated the students to learn but also facilitated the development of their problem-solving skills.

This finding aligns with the research conducted by Guaman-Quintanilla et al. (2023), in which they observed that integrating design thinking in higher education settings enhances students' problem-solving abilities. This finding is also in line with the research conducted by Hashim et al. (2019), wherein they observed that the utilization of design thinking cultivates empathic relationships, thereby promoting students' motivation to learn.

The data (QF2, QF4, QF6, and QF8) revealed that the combination of project-based learning and design thinking approaches facilitated the engagement of students in authentic project-based tasks that required the sharing of ideas and collaborative efforts for project planning and execution (RT6 and QF3). Moreover, the students applied what they had learned in other courses they were taking at the same time that they were developing the project, notably the Project Management course (RT5). Based on the quantitative results (QF5), we may affirm that the development of project management skills had a positive influence on their motivation to learn, as indicated by the positive feedback loop labeled "Developing Project Management Skills" in Figure 7. This led us to our second finding:

> The integration of project-based learning and design thinking methodologies engendered the development of students' project management skills and facilitated the application of acquired knowledge across various academic disciplines, thereby promoting interdisciplinary learning.

This finding is aligned with the findings of other researchers (Ewin et al., 2017; Dijksterhuis & Silvius, 2017), who pointed out the connection between the development of project management skills and the use of design thinking methodology. It also aligns with the findings of Ge and Wang (2021), who pointed out that the combination of both approaches can promote interdisciplinary learning.

However, engaging with the school introduced various challenges for the students. Notably, they encountered issues concerning the responsiveness of school representatives in addressing their inquiries promptly (RT1). Furthermore, a significant number of projects experienced alterations to the project scope initiated by the school representatives after project initiation (RT3). Additionally, resource limitations, such as insufficient access to computers for prototype testing, were encountered by the students (RT2). Moreover, the students faced time constraints imposed by the course schedule. Collectively, these challenges heightened student stress levels, thereby exerting a detrimental impact on their determination to work on project tasks (QF7), creating a negative feedback loop (see Figure 7, loop labeled "Impacts of Real-life Project Constraints"). On the other hand, this negative feedback loop was overcome by the dynamics that led to an increase in motivation to learn (see Figure 7, the positive feedback loop "Development of Skills Motivates to Learn"). This leads us to our third finding:

> The students' determination to work on real-life project tasks was positively influenced by their motivation to learn and negatively by the stress due to real-life project constraints.

This finding is consistent with the research conducted by Lake and Whipps (2016), which highlights that involvement with community partners can be characterized by complexities and unpredictability. This finding is also in alignment with the research conducted by Arantes do Amaral (2019), which suggests that community-based learning creates learning benefits but may also induce stress among students.

Conclusion

Our empirical investigation has provided valuable insights into the synergistic effects of integrating design thinking and project-based learning in the course, resulting in a mutually reinforcing and enriched learning experience. By

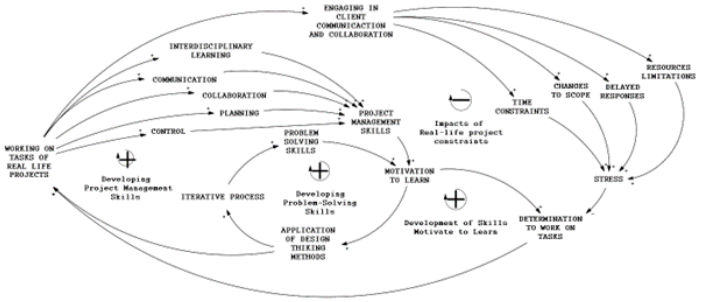

Figure 7. The causal loop diagram that represents the course's dynamics.

immersing students in real-life challenges and guiding them through the iterative design process, design thinking fosters their ability to comprehend complex problems and generate innovative solutions. This approach encourages students to think creatively, consider multiple perspectives, and embrace a human-centered approach to problem-solving.

Furthermore, the incorporation of project-based learning as a scaffold in the course has facilitated collaborative knowledge sharing among students and the development of their project management skills. Working on authentic projects with community partners has enabled students to apply their knowledge and skills in a practical context, leading to a deeper understanding of the subject matter and fostering interdisciplinary connections. The combination of design thinking and project-based learning has not only expanded students' academic horizons but also nurtured their ability to work collaboratively, communicate effectively, and manage projects successfully. Moreover, we can confidently state that this educational approach has significantly contributed to the competences and skills of our students, who are prospective educational designers.

Our findings emphasize the importance of effective communication channels with community partners, proactive management of project scope, and adequate allocation of resources to create a supportive learning environment. We understand that projects involving university students and schools can be challenging. It's a learning process; it takes time for school administrators to understand the importance of providing timely feedback to the students. Hopefully, in future projects, as the school administrators become accustomed to the communication processes and project schedules, the issues we faced in these projects will be minimized.

Additionally, strategies to manage and alleviate student stress should be considered, such as providing additional support and flexibility within the course schedule. By addressing these challenges, educators and institutions can further enhance the effectiveness of the synergistic integration of design thinking and project-based learning.

In conclusion, our study provides compelling evidence for the synergistic effects of integrating design thinking and project-based learning in promoting students' problem-solving skills, interdisciplinary learning, and motivation to learn. By embracing these approaches, educators can empower students to become innovative thinkers, adaptable problem solvers, and collaborative contributors in various professional settings. This research contributes to the growing body of knowledge on innovative teaching and learning methodologies and offers valuable insights for educators and institutions striving to enhance student learning experiences.

Limitations

One might argue that the case study involved only 12 students, potentially resulting in a small sample size for drawing robust conclusions. However, it is worth highlighting that this case study facilitated an in-depth exploration of the course dynamics, enabling a detailed examination of interactions among university students, administrators, and teachers. Speculatively, these dynamics could conceivably extend to analogous academic contexts featuring larger student cohorts. Moreover, one could contemplate the inclusion of multiple schools for comparative purposes. Nevertheless, introducing more schools might not inherently lead to a more comprehensive study. The act of comparing and contrasting across multiple institutions could introduce confounding variables, including varying school cultures, demographics, and administrative structures. These factors could potentially complicate the analysis and interpretation of the findings.

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Appendix

Appendix A: The questionnaire.

Questionnaire - Closed-ended Questions
For each statement, students had five choices (Totally Disagree, Disagree, Neither Agree nor Disagree, Agree, Totally Agree).

Part 1: Questions about stress:

1. The changes in the project scope caused me stress.
2. The delayed response from the institutional partner to our questions/requests regarding the project caused me stress.
3. The limited computational resources in the school for conducting tests stressed me out.
4. The short deadline for project tasks stressed me out.

Part 2: Questions about design thinking:

1. The DISCOVER and FOCUS processes helped me understand the context of our community partner and define the product requirements.
2. The IMAGINE process made me think of various solutions to the proposed problem.
3. The PROTOTYPING and TRY processes helped me develop a prototype to solve the proposed problem.
4. The REFLECT AND SHARE process made me reflect on the prototype development process and the project itself.

Part 3: Questions about project management:

1. The need to communicate with my colleagues and institutional partners helped me develop communication skills.
2. The need to work in a team helped me develop collaboration skills.
3. The need for planning helped me develop planning skills.
4. The need to record project tasks on the website helped me develop my task management skills.

Part 4: Questions about course structure:

1. The pedagogical proposal and methodology of the integrative project were adequate.
2. Working on a real project for a real institutional partner (Paulistinha) has been motivating.
3. The Moodle classroom is organized clearly, allowing easy access to materials.
4. The weekly feedback (in videos) has been useful.
5. Overall, the course met my expectations.

Part 5: Questions about causal relationships:

1. The more stressed I become, the less motivated I am to perform project tasks.
2. The use of Design Thinking has motivated me to learn more.
3. The integrative project has helped me develop managerial skills.
4. The application of DESIGN THINKING processes has improved my ability to solve real problems.
5. The development of my managerial skills has increased my motivation to learn.

Questionnaire: Open-ended Questions

1. Please tell me if you have experienced any stressful situations during the project.
2. Do you have anything else to say about your experience with the use of design thinking in the project?
3. Is there anything you would like to add regarding your experience in managing your project?
4. Do you have anything else to add about your experience in the integrative project?