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Collaborating Courses through Problem-Based Blended Learning

Analysis of Students' Perspectives

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Abstract

This study explores students' perspectives on the integration of Problem-Based Learning (PBL) and Blended Learning (BL) in a collaborative course environment. By examining a cohort of undergraduate students across two interdisciplinary courses, the research aims to understand how these pedagogical approaches influence student collaboration, engagement, and perceived learning outcomes. Data were collected through surveys and one-to-one semi-structured interviews, revealing that students generally appreciated the flexibility and interactive nature of BL and active learning of PBL. However, few students faced challenges with team coordination, time management, and guidance intensity during the PBBL implementation. The study concludes with recommendations for educators to enhance collaborative learning through strategic course design.

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Introduction

The Survey of Adult Skills (OECD, 2021) showed that the essential competencies required in the workplace or industry include literacy, numeracy, and problem-solving skills in a technology-based environment. The study results show that the problem-solving skills of students and graduates still need to be improved. The results of the 2016 PaySclae survey revealed that 60% of company owners who were respondents stated that university graduates have low problem-solving skills (Klegeris, 2021). Further, (Burkholder et al., 2021) stated that only some undergraduate programs have successfully trained students to solve authentic problems. The problems that students solve in the classroom are substantively different from those in the workplace (Grant & Dickson, 2006; Jonassen et al., 2006). As a result, many graduates find it challenging to solve authentic problems in the workplace (Jonassen et al., 2006; Klegeris, 2021). This fact is exacerbated by the rapid sophistication of technology that demands problem-solving in a technology-based environment. The Survey of Adult Skills results show that only 1 in 3 workers can solve problems using technology (OECD, 2021).

The low problem-solving skills of students can be attributed to the on-campus learning approach, which differs from the real-world work environment (Klegeris, 2021; Valiente & Lee, 2020). On-campus learning aims to enhance students' knowledge and skills in specific subject areas (Klegeris, 2021), emphasizing established theories and concepts (Dalsgaard & Godsk, 2007). The problems students encounter during their studies often require solutions from a single discipline, unlike the unstructured, complex, and multidisciplinary nature of real-world work problems (Burkholder et al., 2021; Jonassen et al., 2006).

One recommended approach for improving problem-solving skills is Problem-based Blended Learning (PBBL) (Dalsgaard & Godsk, 2007; Donnelly, 2010; Rahmawati et al., 2021; Siregar et al., 2019). PBBL combines problem-based learning (PBL) with blended learning (BL), which incorporates both offline and online modes of learning (S. Amin et al., 2020; Dalsgaard & Godsk, 2007; Woltering et al., 2009). By combining both approaches, students are expected to benefit from the strengths of each type of learning, developing problem-solving and collaborative skills as the core characteristics of PBL (A. Amin et al., 2021; Houghton, 2023).

The ideas of PBBL align with constructivist learning theory (Dalsgaard & Godsk, 2007; Donnelly, 2010; Houghton, 2023). The idea behind constructivism is that through reflection and experience, students actively create their world knowledge and understanding (Harlow et al., 2007; Schunk, 2012; Woolfolk & Hoy, 2018). In PBL, students are given real-life, unstructured, complex problems, encouraging them to collaborate to identify the issue, obtain pertinent data, and suggest solutions (Donnelly, 2010). In this learning, thus, students learn to think critically, solve problems, and create new knowledge (Klegeris, 2021; Yew & Goh, 2016). The use of a BL environment supports PBL by providing diverse learning modalities. Students can actively engage with course materials and collaborate with peers through more flexible and individualized learning experiences in BL (Han & Ellis, 2021; Susiyawati et al., 2022). Problem-solving processes in PBL can be enhanced using online resources, collaborative tools, and data analysis software, which are enabled in BL (S. Amin et al., 2020; Donnelly, 2010; Houghton, 2023). These tools facilitate deeper engagement and allow students to construct their understanding through a combination of independent exploration and guided instruction. Moreover, BL promotes self-directed learning (Cremers et al., 2014; Geng et al., 2019; Sriarunrasmee et al., 2015), a key element of constructivism. Students can control the pace and timing of their learning, choosing when to engage with online content and when to seek clarification through face-to-face interaction. Thus, it is evident that PBBL is in line with constructive principles.

PBBL also provides opportunities for students to participate in interdisciplinary learning (Crichton et al., 2022; Johnson & Griffin, 2023; MacLeod & van der Veen, 2020). Interdisciplinary learning focuses on the integration and interaction between different fields of study. Therefore, students merge knowledge from various disciplines to develop new perspectives on a specific problem (Borrego & Newswander, 2010; Stentoft, 2017). Previous research has identified five categories of learning outcomes associated explicitly with interdisciplinary learning, including integrating disciplines, teamwork for interdisciplinary learning, communication, and critical awareness (Borrego & Newswander, 2010; Cowden & Santiago, 2016; Routhe et al., 2021).

The interdisciplinary PBL among students is generally seen as beneficial, but some challenges exist. Challenges include student engagement, varying motivation, and group maturity (Agyeman et al., 2019; Crichton et al., 2022; Johnson & Griffin, 2023). Soares et al. (2013) highlighted the need for more student support than their lecturers had anticipated. Issues such as 'social loafing' (Aggarwal & O'Brien, 2008) and consequent lack of trust have been identified (Borrego & Newswander, 2010; Crichton et al., 2022), leading to some students not being enthusiastic about group PBL. Practical issues like scheduling across different disciplines are also potentially causing students to

struggle to find meeting time (Crichton et al., 2022; Gombrich, 2018). Students' time management skills may also be insufficiently developed (Johnson & Griffin, 2023), exacerbating the difficulties of meeting together.

Therefore, assessing student perspectives is crucial in evaluating the efficacy of PBBL. Some studies suggest that students generally view PBBL positively (Crichton et al., 2022; Dalsgaard & Godsk, 2007; Donnelly, 2010; Ismail & Edi, 2022; Sattarova et al., 2021; Shimizu et al., 2019). However, opinions on its effectiveness vary based on how well it promotes engagement and interaction. The main strength of PBBL lies in its capacity to create adaptable learning environments, and students value the mix of independent learning and structured group work (Houghton, 2023), resulting in an increase in motivation and self-efficacy (Ismail & Edi, 2022; Shimizu et al., 2019). Many mentioned that online platforms effectively supported their learning, enabling seamless collaboration even in virtual settings (Houghton, 2023). Despite the benefits, some students highlighted difficulties with online collaboration, particularly regarding engagement (Crichton et al., 2022; Lomer & Palmer, 2023). Many still favored in-person sessions for the richer, more dynamic discussions that typically take place (Cronje, 2022; Lomer & Palmer, 2023; Susiyawati et al., 2022), as they considered as 'actual learning' (Lomer & Palmer, 2023). Students also feel that implementing PBBL did not provide educational services that matched the tuition fees they paid (Lomer & Palmer, 2023). More expenses are required for internet accessibility (Ismail & Edi, 2022).

Overall, PBBL is considered a viable and practical approach, with students expressing satisfaction with its ability to enhance learning outcomes and flexibility. However, there are concerns about optimizing engagement in digital formats. The inconsistent results indicate that the benefits of PBBL are not conclusive. Exploration of students' perception of PBBL implementation in more complex collaborative courses is essential since previous studies focused on PBBL in a single subject (Stentoft, 2017). Previous studies on students' attitudes toward PBBL in multidisciplinary contexts are limited to engineering problems (Crichton et al., 2022; Johnson & Griffin, 2023; MacLeod & van der Veen, 2020). This study explores students' perspectives on the effectiveness of collaborative courses in PBBL, focusing on a more general problem about the environment integrating two science courses. Specifically, it seeks to understand how this approach impacts student collaboration, engagement, perceived learning outcomes, and challenges during the implementation of PBBL.

Method

Research Context

This current study investigated the implementation of PBBL in a four-year undergraduate program of Science Education at the Universitas Negeri Surabaya, a state university in Surabaya, Indonesia. The PBBL was applied by collaborating with two interdisciplinary courses, "Ecology" and "Anatomy and Physiology of Living Things". Both were 15-week undergraduate lecturer-based courses run once a week in the Odd Semester in 2023. At the beginning of the semester, the lecturers discussed a potential authentic problem relevant to the collaborative courses' learning outcomes. Namely, students are able to (1) master the substantive concepts of plant anatomy and physiology of living things and their application to solve problems in daily life (Anatomy and Physiology of Living Things course) and (2) design scientific investigations to explain and solve problems related to Ecology (Ecology course). To achieve those outcomes, students in groups of five were required to identify environmental problems around them that affected the anatomy of plants and animals and propose solutions for the identified problem. The four-week PBBL blended face-to-face meetings and online learning using a SIDIA LMS to facilitate asynchronous and synchronous activities. All learning resources for both courses are also available in the SIDIA. Students' PBBL activities and results were recorded as a report and presented to the lecturers at the end of the PBBL. The assessment of the PBBL was conducted using a rubric focused on the quality of the report and presentation.

Research Design

This study employed a mixed-methods approach combining quantitative survey and qualitative interview data. Focusing on an explanatory sequential design (Creswell, 2015), this study collected quantitative data followed by qualitative information to elaborate on the quantitative results. This selected design allowed for a comprehensive analysis of student perspectives on implementing PBBL in collaborative courses.

Participants

The study involved undergraduate students from all (five) available classes who enrolled in the two courses: "Ecology" and "Anatomy and Physiology of Living Things", at a Science Education Study Program at a state university in Surabaya, Indonesia. A total of 120 of 136 students completed the survey, and 12 of them were invited to one-to-one semi-structured interview sessions. The interviewees were selected through purposive sampling based on their responses to the

survey questions and class representation. This strategy gave more profound insights into their experiences during the implementation of PBBL in collaborative courses.

Data Collection Methods

This study used a 20-item survey of two identity elements, 12 five-point Likert-scale questions, and eight essay-format queries to collect quantitative data. The survey assessed students' perceptions of engagement, collaboration, and learning outcomes. The questionnaire was developed by the authors by referring to the four levels of training program evaluation, including reaction, learning, behavior, and results (Kirkpatrick & Kirkpatrick, 2006) in combination with the framework of collaborative PBBL: authentic problem, cooperation, self-regulated learning, and collaboration (Ibrahim et al., 2015). Examples of questionnaire questions are available in Figure 1. The questionnaire was administered to the participants at the end of the collaborative project using Google Forms. Additionally, 12 one-to-one semi-structured interview sessions were conducted for 30 minutes using an interview protocol to triangulate the collected survey data.

Please respond to the following questions based on your perceptions and experiences to determine the effectiveness of the Ecology, Anatomy, and Physiology of Living Organisms Collaboration Project.

Instruction: Please choose the appropriate response after each question!

1	How were the project objectives explained to you?	Very Unclear	1	2	3	4	5	Very Clear
2	How relevant was this project to the courses you took?	Not Relevant	1	2	3	4	5	Highly Relevant
3	How well was the collaboration between the integrated courses in this project?	Very Poor	1	2	3	4	5	Very Good
4	How effective was this project-based learning compared to traditional teaching methods?	Very Ineffective	1	2	3	4	5	Very Effective
5	How would you rate the level of difficulty of this project?	Very Easy	1	2	3	4	5	Very Difficult
6	What suggestions do you have to improve the collaboration between courses in future project-based learning?							

Figure 1. Examples of questionnaire questions on the Ecology and Anatomy and Physiology of Living Organisms collaboration project.

Data Analysis

The surveys provided quantitative data, which was analyzed using descriptive statistics, including frequencies and percentages. On the other hand, qualitative data from the interviews was analyzed using thematic analysis to identify key

themes related to collaboration, engagement, effectiveness, and challenges. Both types of data were used to triangulate the research findings.

Results

A total of 136 students, distributed in five classes, participated in the PBBL-collaborating Ecology and Anatomy and Physiology of Living Things courses during the 2023-2024 Odd Semester. Students' satisfaction toward the PBBL implementation, collected from 120 participants, is shown in Figure 2.

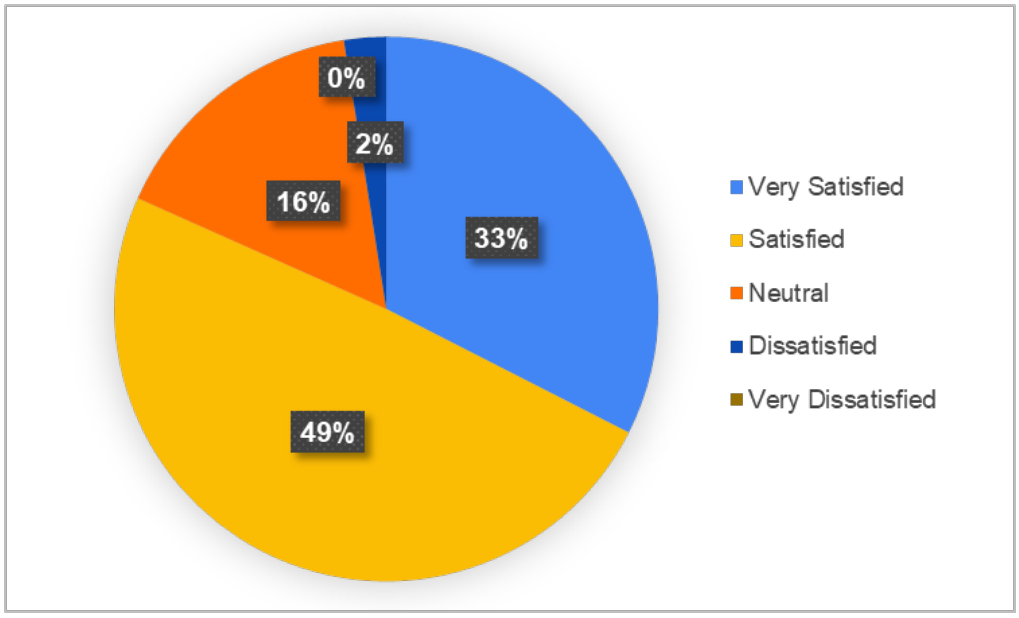

Figure 2. Percentages of students' satisfaction toward the PBBL implementation.

Figure 2 shows that most participants were satisfied (49%) and very satisfied (33%) with the PBBL implementation, which brought together two courses. Some students highlighted the benefits of this learning, including gaining a better understanding of scientific concepts and developing collaboration as well as problem-solving skills, as a student stated:

> (1) "Through observation and experiments, increase understanding of scientific concepts applied in authentic contexts, develop collaboration skills as well as problem-solving."

The students' satisfaction was influenced by various aspects of the PBL implementation in the collaborating courses, including collaboration, engagement, learning outcomes, and challenges. Each of these aspects will be further discussed in the following paragraphs.

Findings on Collaboration

The collaboration aspect during the PBBL implementation was assessed using the survey, which focused on questions about the quality of collaborative courses, group communication, and collaboration skills. The survey results for the three indicators are presented in Figure 3.

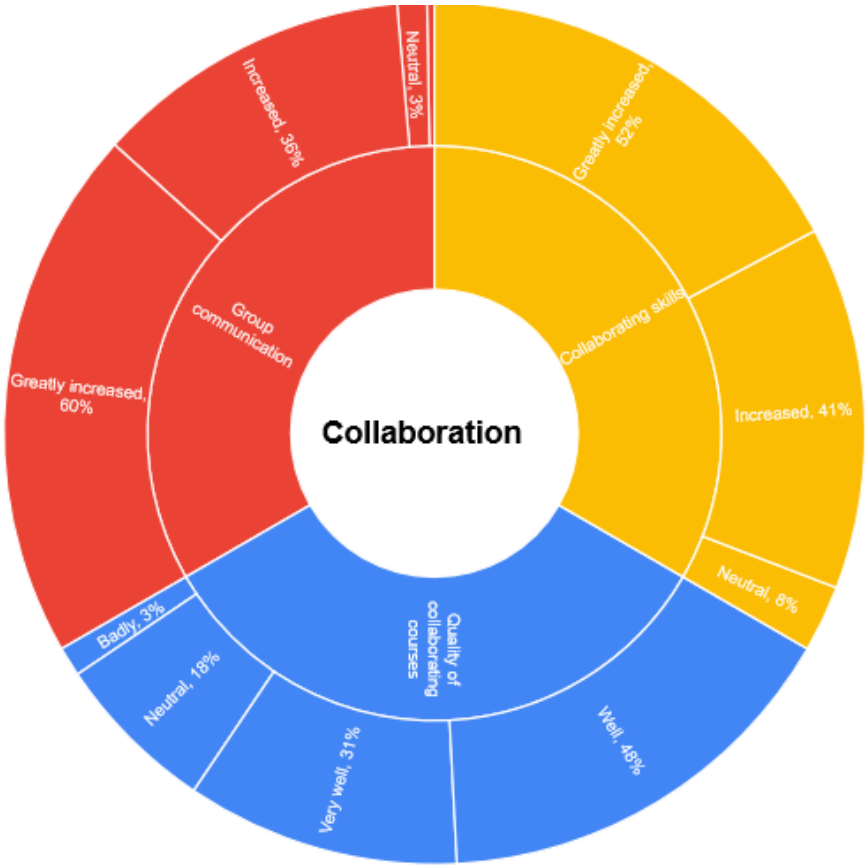

Figure 3. Percentages of students' survey responses on the quality of collaborating courses, group communication, and collaboration skills during the PBL implementation.

The data in Figure 3 reveal a significant trend: the majority of students participating in the PBBL activity viewed the collaboration between the Ecology and Anatomy and Physiology of Living Things courses in a positive light. They reported that the two courses collaborated well (48%) and even very well (31%) during the PBBL implementation. This positive feedback from students underscores the success of the collaborating courses. As one student put it,

> (2) "By studying living things in an ecosystem with certain conditions, it is possible to observe directly and indirectly how body structure and physiological functions are related to adaptation to their environment."

Another student added,

> (3) "Students can understand the concept of the environment and the anatomy of living things in it."

However, it is essential to note that 3% of the participants identified areas for improvement in the course collaboration. One student suggested,

> (4) "It is better to hold a learning session with the two subjects, where lecturers from both courses teach collaboratively, providing a broader perspective to students."

This feedback underscores the potential for a more integrated approach. Another student highlighted the issue of inconsistent lecturer explanations, stating,

> (5) "The explanations given by the lecturers on the anatomy and physiology of living things and ecology were slightly different, so we need to revise the activity several times."

This feedback underscores the need for consistent teacher guidance for a successful PBBL (MacLeod & van der Veen, 2020; Stentoft, 2017).

In terms of group communication, more than half of the participants indicated that the PBBL activity greatly increased (60%) and increased (36%) students' communication within a group (see Figure 3). This finding is due to the project's learning environment, the group selection method, and the nature of the PBBL, as explained in the following interview responses.

> (6) "The project provided group learning experiences with a more interesting and fun learning atmosphere, so each group member was actively communicated and involved in working on the project."

> *(7)* "Since the selection of group members is determined by the students, the collaboration becomes very interactive. Communication is carried out offline and online, even at night, because this project requires intensive discussions."

Thus, it is unsurprising that most students (52% and 41%) acknowledged enhancing their collaboration skills due to the PBBL activity.

Findings on Engagement

Students' engagement in PBBL activity was analyzed based on their responses to survey items focusing on goal clarity, course relevancy, guidance quality, and learning resource availability. Figure 4 exhibits the students' responses to the four indicators in the survey.

Figure 4. Percentages of students' survey responses on goal clarity, course relevancy, guidance quality, and learning resource availability during the PBL implementation.

When discussing goal clarity, most students indicated that the goals of the PBBL activity were conveyed to them very clearly (31%) or clearly (50%), encouraging their participation. An interviewee elaborated on this finding:

> (8) "I became more aware of the biotic and abiotic components in the project, the interaction between the two in improving or vice versa, even damaging the environment and ecosystem. In addition, it also improves my literacy, helps me understand how the ecosystem works, and helps me find solutions to the problems obtained from literacy."

In contrast, 4% of students struggled to understand the purpose of the PBBL that collaborating the two courses, as an interviewee explained:

> (9) "…clear instructions or directions are needed on what the purpose of this project is so that students are not confused in its implementation."

It implies the critical role of assistance during the PBBL.

The relevance of the PBBL activity to the courses being enrolled also encouraged students' engagement. As shown in Figure 2, most students suggested that the PBBL activity was highly relevant (53%) or relevant (41%) to the collaborating courses. The following interview responses elaborate on this finding:

> (10) "The project is relevant to the real world and connects the material in both courses with real situations and problems faced by the community so that we can determine the unsolved problems in certain areas."

> (11) "The best aspect of the collaborative project of the two courses is the cross-disciplinary integration that allows students to apply concepts in the anatomy and physiology of living things to solve real problems in ecology so that students feel more motivated because they see the direct relevance between what they are learning and its practical application."

Another factor in students' engagement with the PBBL activity was the quality of the lecturers' guidance. Figure 4 shows that most students agreed that lecturers provided very sufficient or sufficient assistance during the PBBL work. Related to this fact, a student mentioned

> (12) "The guidance provided was quite satisfactory. Panel discussions involving lecturers and students from both courses to discuss the project have been carried out online, followed by offline guidance and monitoring or forums in LMS so that the project can run smoothly. However, the intensity of guidance in both courses is not equal, so it needs to be improved."

The insufficiency of lecturers' assistance led to their difficulty in accomplishing the PBBL task, as shown in Responses (4) and (9).

In addition, the availability of learning resources affected students' engagement in the PBBL activity. According to most students, the learning resources provided during the PBBL were sufficient (44%) or very sufficient (23%) to support them to accomplish the task well. The provided learning resources included relevant textbooks, PowerPoint slides, a PBBL activity and assessment guideline, and a worksheet. Nevertheless, a few students mentioned that they needed more relevant resources to help them complete the PBBL activity, as a student stated:

> (13) "The self-study provided is still lacking; it is necessary to provide sample reports as a reference so that the project is more directed."

In contrast, another student argued:

(14) "The learning resources provided are quite helpful to complete the project. Because the problems identified by each group are different, it is the group's responsibility to find other relevant references."

Those contrary opinions suggest that students must develop self-directed learning for successful PBBL (Ghani et al., 2021; Yew & Goh, 2016).

Findings on Effectiveness

The effectiveness of the PBBL in this study was assessed using four indicators based on survey responses: comparison to the conventional approach, difficulty level, impact on understanding, and problem-solving skills. The survey results for those indicators are shown in Figure 5.

Figure 5. Percentages of students' survey responses in comparison of PBBL to the conventional approach, difficulty level, impact on understanding, and problem-solving skills during the PBL implementation.

Compared to the conventional approach, most students perceived the PBBL was more effective (53%) or highly effective (29%) in teaching collaborative courses. This effectiveness of PBBL is supported by students' responses on the survey item about the impact of PBBL on their conceptual understanding. As shown in Figure 5, most students perceived that their conceptual understanding of both courses was increased (61%) or greatly increased (28%) at the end of the PBBL activity, as a student mentioned:

> (15) "The best aspects of the project were comprehension of learning materials…"

Detailed information on how students gain benefits of PBBL on conceptual understanding is elaborated in Responses (2), (3), and (8).

Additionally, the effectiveness of the PBBL on problem-solving skills was also perceived by students. Due to the nature of the PBBL, students found that identifying problems and finding solutions during the PBBL improved (49%) or greatly improved (43%) their problem-solving skills. A student's response supported the finding:

> (16) "From this project, we can learn to be more independent by looking for ideas, innovations, and solutions to solve problems in the environment in real life, and become more confident in making all decisions together with the team."

This sense of independence and confidence is crucial to PBBL's empowerment.

However, most students perceived the PBBL task as difficult (43%) or very difficult (15%). A student argued:

> (17) "The most challenging aspect of this learning was identifying environments with problems that can affect the environmental ecosystem."

These findings indicated that the PBBL task in this current study met the nature of this approach, which involves an intricate problem that lacks clear structure, has conflicting objectives, has multiple solutions, and has criteria for evaluating solutions (Jonassen et al., 2006).

Findings on Challenges

Despite the positive perceptions, some challenges were experienced by students during the PBBL implementations. While most students perceived collaboration positively, few participants conveyed their obstacles when working together. A student stated:

(18) "The most challenging aspect of this project was coordinating the team well and collaborating with members with various mindsets and opinions so that they could have the same mindset and teamwork could run in harmony without any obstacles detrimental to team members."

The nature of authentic problems leads to multiple perspectives and solutions (Jonassen et al., 2006). However, these differences caused frustration for some students when working in a team.

Contrary to the data in Figure 4, few students were less engaged during the PPBL. A student conveyed:

(19) "Ensuring that all team members were actively involved and contributed to the project equally was a challenge, especially if there were those who tended to be passive or non-contributing."

This phenomenon is known as 'social loafing' when someone in a group does not contribute their fair share (Aggarwal & O'Brien, 2008). According to Crichton et al. (2022), the problem often stems from the clash between students' perceived priorities and ineffective time management. A student response supports this argument, as she mentioned

(20) "The challenging aspect is conditioning the time of each group member to work on this project better and more efficiently because we all have different free time and other interests besides this project that are equally important."

Furthermore, while most students expressed the PBBL's effectiveness, a few complained about the lack of preparation and inadequate guidance. A student said:

(21) "Lack of preparation from both lecturers and students so that students were overwhelmed at the beginning of working on the project."

Another student added:

(22) "Lecturers need to provide constructive and regular feedback throughout the project to help students identify what has been done well and what needs to be improved."

These findings suggested that careful preparation and lecturer facilitation are critical for successful PBBL implementation (MacLeod & van der Veen, 2020).

Discussions

The findings of this study indicate that students generally had positive perceptions of PBBL in collaborative courses, as also reported in other studies (Crichton et al., 2022; Ismail & Edi, 2022; Johnson & Griffin, 2023; MacLeod & van der Veen, 2020; Shimizu et al., 2019; Woltering et al., 2009). Most participants of this study revealed an increase in collaboration, engagement, and learning outcomes when the PBBL was implemented.

The effectiveness of PBBL in fostering collaboration aligns with the findings in previous research (Crichton et al., 2022; Rahmawati et al., 2021; Woltering et al., 2009). The nature of problem-based learning, which exposes students to authentic problems, necessitates interdisciplinary discussions (Stentoft, 2017; Yew & Goh, 2016). Integrating relevant courses into a problem-based learning approach encourages students to collaborate, exchange ideas, and share responsibility in solving real, complex, and ill-structured problems (Crichton et al., 2022; MacLeod & van der Veen, 2020). Collaboration is a functional skill crucial for a successful PBBL (Ghani et al., 2021), and its development is facilitated in the PBBL through technology, which enables intensive and flexible interactions and communication (Donnelly, 2010). However, the challenge of ensuring consistency in lecturer explanations suggests that a more structured and integrated approach to instruction could further enhance the experience. Implementing co-teaching strategies where both lecturers collaboratively guide students may mitigate inconsistencies (Perera et al., 2020; Zach & Avugos, 2024).

Students' increased engagement in PBBL was also reported in relevant studies (Agyeman et al., 2019; Houghton, 2023; Wagino et al., 2024; Zhao et al., 2023). Several factors drive students' engagement in PBBL, including the clarity of goals, the relevance of the project, and the quality of guidance. Providing more explicit guidelines and structured orientations at the project's outset could improve engagement and reduce uncertainty (Crichton et al., 2022). The authenticity of problems in PBBL promotes students to actively engage in the activity because they see the applicability of the theories being learned (Houghton, 2023). The use of technology in this learning approach also increases the creativity of content delivery (Morton et al., 2016), accessibility of learning resources (Houghton, 2023), and maintains teacher-student and student-student interactions (Öncü & Bıchelmeyer, 2021; Susiyawati et al., 2024).

The effectiveness of PBBL compared to conventional approaches, as reported in this current research, has been recognized in similar studies (Dalsgaard & Godsk, 2007; Dawilai et al., 2021; Rahmawati et al., 2021). Previous

investigations have also demonstrated that this learning approach has positive effects on learning outcomes (S. Amin et al., 2020; Nurkhin et al., 2020), conceptual understanding (Herliana et al., 2020; Johnson & Griffin, 2023; Nurkhin et al., 2020), and aids in the development of students' problem-solving skills (Crichton et al., 2022; Johnson & Griffin, 2023). Dawilai et al. (2021) contended that the effectiveness of PBBL is driven by the flexible learning environments that support students in solving authentic problems. The online platform in the PBBL also facilitates students' active learning to develop investigation, conduct inquiry processes, and analyze problem-solving strategies (Anderson et al., 2008; Klegeris, 2021; Stewart et al., 2007).

However, some challenges were noted, such as difficulties in team coordination, time management, and varying levels of lecturer guidance. These findings align with previous research on PBBL (Crichton et al., 2022; Johnson & Griffin, 2023; Rahmawati et al., 2021; Woltering et al., 2009). Strategies such as assigning specific roles to team members, incorporating peer assessments, and promoting accountability through progress-tracking tools could enhance group coordination and productivity (Crichton et al., 2022; Gombrich, 2018; Johnson & Griffin, 2023). The findings also suggest the need for consistent and intensive teacher guidance (MacLeod & van der Veen, 2020; Stentoft, 2017) and self-directed learning capability (Ghani et al., 2021; Yew & Goh, 2016) for successful PBBL.

A critical limitation of this study is the reliance on self-reported data from surveys and interviews, which may be subject to response bias. Future studies should incorporate objective student performance and engagement measures to validate these findings. Additionally, while the study was conducted in the context of two interdisciplinary science courses, its generalizability to other disciplines remains uncertain. Comparative studies involving different subject areas could provide a more comprehensive understanding of PBBL's effectiveness across educational contexts.

Implication for Educational Practice

The results suggest several implications for the implementation of PBBL in higher education, particularly in collaborative courses. First, educators should consider structured interventions to address team coordination and time management challenges. Strategies such as assigning defined roles within groups, incorporating peer evaluation mechanisms, and providing structured timelines could enhance group work efficiency. Second, lecturer involvement is crucial for student success in PBBL environments. The study findings indicate that inconsistent lecturer guidance led to confusion among students. To mitigate this, institutions should encourage collaborative teaching approaches where faculty members from different disciplines co-teach sessions, ensuring

consistency in explanations and expectations. Additionally, providing regular formative feedback throughout the PBBL process can help students stay on track and refine their problem-solving approaches.

Conclusions and recommendations

The study emphasizes the potential of PBBL in improving collaboration, engagement, and learning outcomes in interdisciplinary courses. Overall, students positively perceived the integrated approach, although they did note challenges with group dynamics and technical aspects. Combining PBL and BL in collaborative courses shows promise for higher education, providing students with a more interactive and adaptable learning experience. However, it is essential to consider course design, careful preparations, and intensive guidance and support mechanisms to address the noted challenges. Educators and institutions should consider implementing and improving the PBBL approach in collaborative courses to better equip students for real-life challenges. Ongoing research and student feedback will be crucial in optimizing these educational practices.

While this study offers valuable insights, further research is needed to refine PBBL methodologies and expand their applicability. Future research should explore the long-term impact of PBBL on students' problem-solving and professional skills through longitudinal studies. Additionally, investigating the effectiveness of PBBL in different academic disciplines beyond science education could provide a more comprehensive understanding of its applicability. With the rapid advancement of educational technology, studies should also assess the integration of emerging tools, such as artificial intelligence-driven learning assistants, to support and enhance PBBL experiences. Furthermore, faculty training models should be developed and examined to improve lecturers' facilitation skills and ensure consistency in implementing PBBL. Addressing these research gaps will contribute to refining PBBL methodologies and strengthening its role as a practical pedagogical approach in higher education.

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