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PAPER

Mobile App-Enhanced Project-Based Blended Learning to Develop Consistent Study Habits in Health Sciences Education

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ABSTRACT

This study investigates the impacts of project-based blended learning (PBBL) integrated with a mobile learning app on students' study habits in Japanese physical therapy education. The PBBL model emphasizes predominantly asynchronous learning via the mobile app supplemented strategically by synchronous sessions for interaction and motivation, and is designed to foster consistent study habits. The research employs a mixed-methods approach, analyzing quantitative data from learning logs and qualitative insights from student reflection sheets. Results demonstrate that PBBL significantly increased students' self-study time via the mobile app, with a positive correlation between consistent study habits and academic test scores. Qualitative analysis revealed that students participating in PBBL naturally gained insights into aspects of the universal behavior model through repeated practice and reflection while working on projects as a team. Integration of the mobile app provided real-time feedback through learning logs, thereby facilitating data-driven reflection and behavioral change. This PBBL model plays a crucial role, especially for first-year students, who are often prone to academic maladjustment, by fostering the skills necessary to establish a foundation for an enriched learning experience throughout their four-year undergraduate program.

KEYWORDS

project-based learning (PBL), blended learning, study habits, mobile learning app, first-year experience, physical therapy education

1 INTRODUCTION

A global movement in higher education is leveraging smart technologies to create effective personalized learning experiences [1], [2]. Specifically, the ongoing worldwide discussion addresses both the strategic integration of rapidly evolving artificial intelligence (AI) technologies into educational settings [3]–[8]

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and the factors influencing the adoption and use of AI applications to enhance students' academic performance [9]. In the field of health sciences education, the latest technologies are driving a shift from one-size-fits-all approaches to personalized learning tailored to the needs and pace of individual students [10], [11]. Nevertheless, empirical evidence on how these technologies can systematically cultivate self-regulated learning skills in pre-service health professionals remain unclear.

Physical therapy education is a continuum of learning throughout one's professional life. In the context of this study, the importance of lifelong learning is internationally recognized in the field of medicine, where knowledge and skills are continually developing [12]. To be a physical therapist who practices lifelong learning, it is essential to cultivate a habit of independent learning, maintain self-motivation, and effectively manage time outside of clinical duties. After graduation, physical therapists primarily learn asynchronously at their own pace, which is supplemented by synchronous learning opportunities such as conferences and workshops. However, in Japan, traditional, synchronous classroom lectures dominate undergraduate physical therapist education. This reliance on lecture-based instruction fails to adequately prepare students for the diverse learning methods and independent learning essential for success in their professional careers. Therefore, to foster physical therapists who are proactive, autonomous lifelong learners, it is crucial to bridge the gap between undergraduate education and the realities of professional practice by integrating postgraduate learning styles into the curriculum.

To address these limitations of traditional undergraduate physical therapy education in Japan, we introduced project-based blended learning (PBBL), which combines the elements of project-based learning (PBL) with a blended learning methodology [13]–[15]. Moreover, this research integrates a mobile learning app into this PBBL framework. This app collects learning logs and provides real-time feedback on learning status based on objective data to enhance individual students' awareness of their learning progress and further activate team-based reflection and discussion. As far as we know, no prior study has investigated the educational effects of integrating a mobile learning app into a PBBL framework. Therefore, the purpose of this study is to investigate the effectiveness of our PBBL model among physical therapy students. As a key outcome measure, this study focused on self-study time. This is because developing consistent self-study habits during undergraduate education is crucial in fostering lifelong learners, and self-study time is considered a key indicator of these habits.

While our PBBL model was designed for first- to third-year students to work in mixed-grade teams, the current study focuses particularly on first-year students for the following two reasons: (1) The recent rapid increase in higher education institutions accepting students with diverse academic abilities and study habits has created a need to enhance first-year education to develop basic academic skills and foster consistent study habits [16]. (2) It is expected that enhancing first-year education will improve academic performance and the advancement rate [17]. Accordingly, to maximize opportunities for higher education, which forms the foundation for acquiring the competencies to practice lifelong learning, it is necessary to introduce effective first-year education programs and evaluate their impact on student outcomes.

This study uses a mixed-methods approach. It combines quantitative analysis of learning logs from a learning app and qualitative analysis of descriptive content

from students' reflection sheets completed after the PBBL to examine the following research questions (RQs):

- RQ1: Does the PBBL influence students' self-study time via a mobile learning app?
- RQ2: Are consistent study habits using a mobile app related to academic test scores?
- RQ3: What key insights do students gain through the PBBL regarding developing consistent study habits?

2 LITERATURE REVIEW

2.1 Project-based blended learning

Project-based blended learning is a learning mode that integrates PBL into a blended learning environment. PBL is a student-driven learning, teacher-facilitated approach where learners pursue knowledge by investigating questions arising from their natural curiosity [18]. In the PBL framework, students engage in team-based activities to solve driving questions and create final products [14]. Throughout the project, they debate ideas, design plans, and analyze data. Here, technology is an essential component to enhance the learning experience of PBL by providing students with multiple ways to gather information, integrate ideas, and collaborate effectively [19]. It is expected that incorporating PBL will have a motivational effect that encourages students to learn proactively [14] and to focus on both the results and learning process [20].

Although the traditional PBL method has some drawbacks regarding group cooperation, such as a lack of communication between students and teachers, a blended learning environment facilitates cooperation through asynchronous communication platforms such as learning management systems. A systematic review of the literature revealed that blended learning offers students a personalized learning environment and thereby helps develop their self-directed learning skills [21]. These advantages of blended learning enable learners to engage in lifelong learning, not only during undergraduate education but also after graduation [22].

Previous research shows that PBBL positively impacts students' practical competence, self-learning skill, and teamwork abilities [23]. Our study builds on these findings by introducing a novel PBBL model that uniquely integrates a mobile learning environment. Our focus is not simply on the mere utilization of mobile learning tools. Rather, we conceptualize the PBBL as a pedagogical approach that fosters enhanced learning flexibility and enables both individual and group iterative reflection through frequent, data-driven feedback from learning logs to foster learner autonomy.

2.2 Mobile learning

Mobile learning refers to learning using mobile devices such as smartphones and tablets, typically excluding laptops, netbooks, and gaming consoles [24]. Mobile learning promotes independent learning experiences, as it enables students to easily access educational materials from anywhere at any time [25]. Well-designed mobile learning experiences help students develop autonomy over their learning content

through controlling the place, pace, and timing of their learning [26]. Compared to the traditional analog self-study method with paper and pencil, mobile learning offers a significant benefit of being free from temporal and spatial constraints. In this regard, UNESCO's policy guidelines [27] emphasize the need to model the effective use of mobile technology, share research findings, and establish a clear vision for its role in education.

The integration of mobile learning apps into educational contexts has fundamentally transformed how students learn. For instance, mobile learning enables students to utilize "dead moments" such as commuting or waiting times, to review class topics or prepare for upcoming classes. This practice consequently facilitates distributed learning and shifts study habits toward more frequent, shorter sessions that improve long-term retention over traditional cramming [28]. Mobile learning also offers this flexibility to working professionals, who reportedly use it for learning at home while multitasking with housework [29].

In our PBBL framework, the mobile learning environment is integrated as an asynchronous element, with a focus on both enhancing learning flexibility and leveraging objective data from learning logs to provide frequent feedback that facilitates students' self-regulated learning [30]. This helps improve the overall learning experience including synchronous activities.

3 METHODS AND MATERIALS

3.1 Participants

The participants were 108 students (37 females, 71 males, aged 20.3 ± 1.4 years) enrolled in a Japanese four-year physical therapy college. They included 36 first-year, 35 second-year, and 37 third-year students.

3.2 Ethical considerations

This study was conducted in accordance with the principles of the Declaration of Helsinki. The participants were fully informed—verbally and through explanatory documents—about the content of the study. Their consent was obtained through signed consent forms. The study was approved by the Research Ethics Committee of Tokyo Gakugei University (approval number: 895).

3.3 Project-based blended learning model design

The PBBL model implemented in this study integrates Monoxer (Monoxer Inc.), a mobile learning app designed to enhance long-term memory. The features and functions of this app are described in Section 3.4.

Figure 1 illustrates the PBBL model structure from the perspective of an individual student's learning process. It shows the transition from the learning environment "before PBBL" (April 2, 2024, to July 20, 2024) to the activities introduced "during PBBL" (August 26, 2024, to November 5, 2024). The arrow between these periods represents the flow of the timeline. As Figure 1 shows, learning "before PBBL" primarily involved individual mobile learning via Monoxer and

classroom-based learning. However, the "during PBBL" phase incorporated an additional, multi-layered collaborative PBL environment that featured chat communication and planned and unplanned synchronous learning activities. Structures designed to deliver frequent feedback based on learning logs further supported this environment.

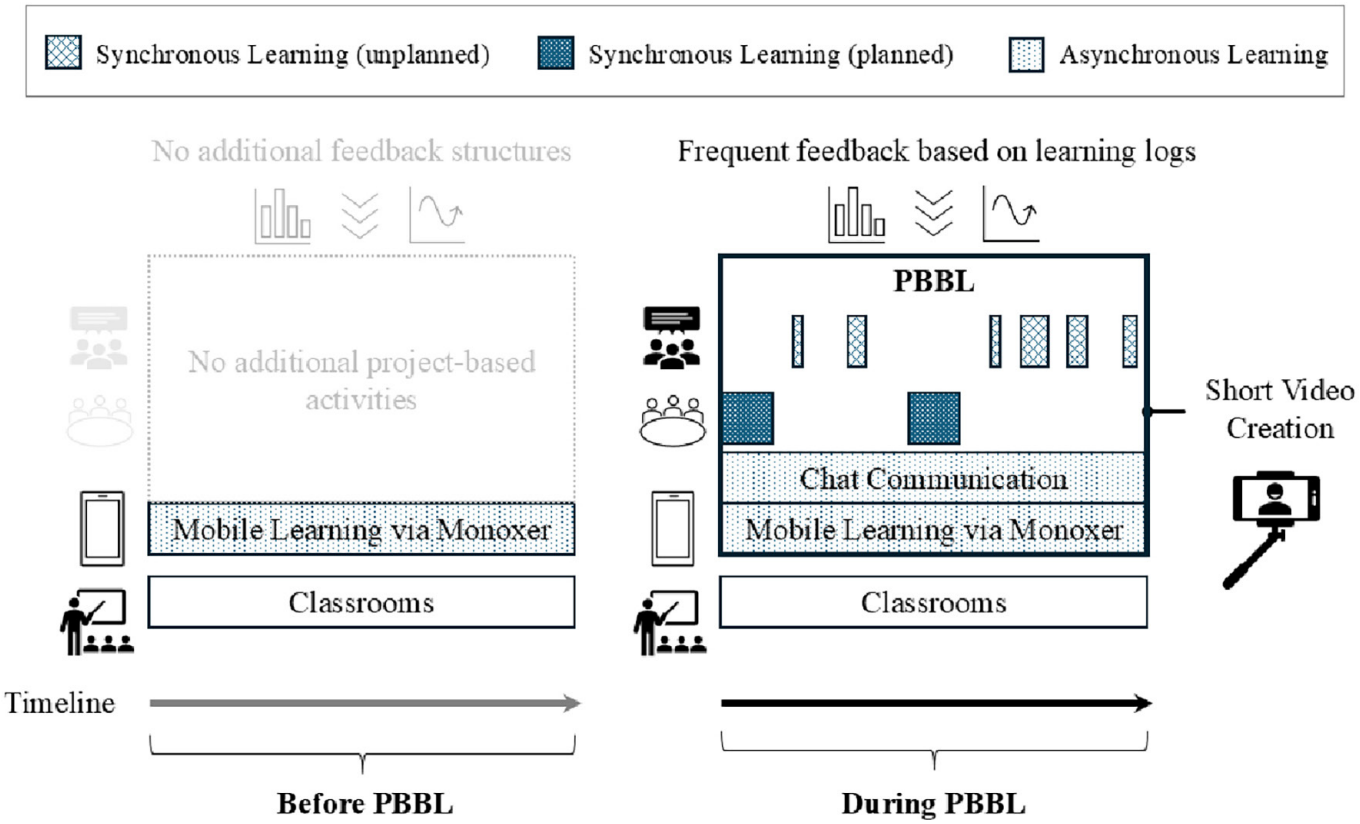

Fig. 1. PBBL model structure from the perspective of an individual student's learning process

In contrast, Figure 2 shifts the focus to the collaborative aspect, detailing the project cycle in PBBL from a team perspective through a flowchart of its collaborative activities and iterative reflection. In PBBL, students were divided into 20 mixed-grade teams and worked on a project for approximately a month, addressing the open-ended question: "How can we develop consistent study habits using Monoxer?" Team members were selected to ensure a mix of students with high and low app usage rates based on prior learning logs. One faculty member was assigned to each team as a facilitator. Students continued self-study using Monoxer asynchronously while sharing information and checking progress within their team through the chat tool in Microsoft Teams. Two synchronous communication opportunities were provided for students to meet face-to-face, once at the beginning of the project and then one month after the start, to discuss ideas, plans, and strategies. While these synchronous sessions were planned by faculty, students also engaged in unplanned synchronous interactions as needed for their group activities, for which they arranged their own schedules. In addition, to encourage reflection and discussion, each group's average completion rate of assignments (CRA) data—an indicator of consistent study habits—was posted on Microsoft Teams in two- to three-week intervals.

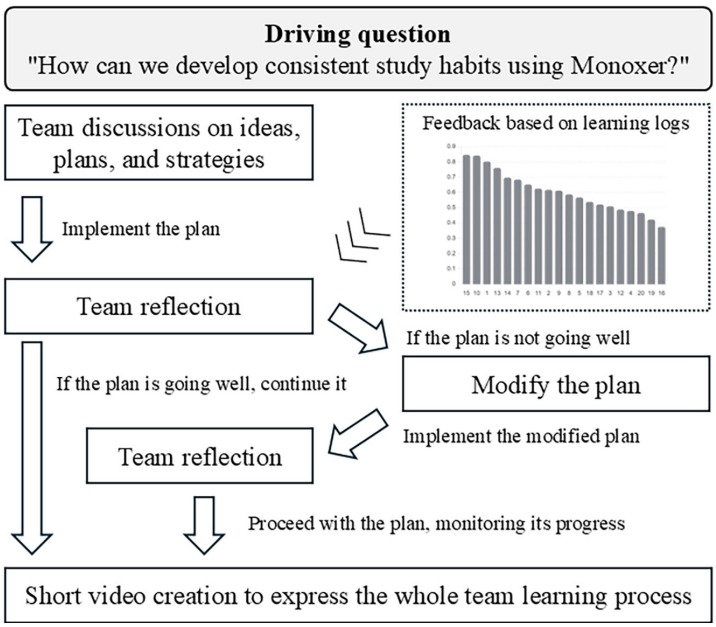

Fig. 2. Project-based blended learning project cycle from a team perspective

As a final product of the project, each team was required to create a YouTube Shorts video, no longer than 60 seconds, expressing their entire learning process within their team. No restrictions were set on the video production method. This task was designed as a reflective activity, prompting each team to look back on and synthesize their entire project journey. In addition, digital video production can provide students with a rich, authentic learning experience, encourage student autonomy, and facilitate team interaction [31]. Expecting these benefits, we incorporated video production as the final product of PBBL. At the end of PBBL, students watched the submitted videos and voted for the ones they were impressed by. Following the voting, an awards ceremony was held for the teams that received the most votes.

3.4 Mobile learning app

In physical therapy education, students are required to memorize a vast amount of medical terminology. For example, in the subject of anatomy alone, they need to memorize the names of approximately 200 bones and more than 600 muscles that compose the human body. Research found that physical therapy students highly valued the flexibility of a mobile learning app introduced to efficiently memorize a large amount of medical terminology, as it allowed them to engage in repeated learning anytime and anywhere [32].

Thus, the college where the current study was conducted introduced Monoxer (Monoxer Inc.), a mobile learning app specialized for long-term memory retention. Monoxer is developed based on scientific evidence in learning science, such as spaced repetition, retrieval practice [33], and the testing effect [34]. The app is equipped with an AI-powered function that adjusts the frequency and difficulty of quizzes based on each student's learning history data, called the adaptive learning function. Learners can access the app via their smartphones or tablets to engage in sessions comprising 20 quizzes. Each session lasts only a few minutes, promoting a flexible learning experience and allowing students to use it during spare moments in daily life.

Figure 3 presents screenshots of Monoxer and demonstrates examples of the adaptive learning function. At the easiest difficulty level, the quiz answer is displayed

faintly on screen, allowing users to simply input the faintly displayed answer for a correct response. When they provide consistent correct answers, the AI automatically raises the difficulty level. For the normal difficulty level, quizzes are presented in a multiple-choice format. At the hardest level, they enter their answers via text input, as shown in the figure on the right.

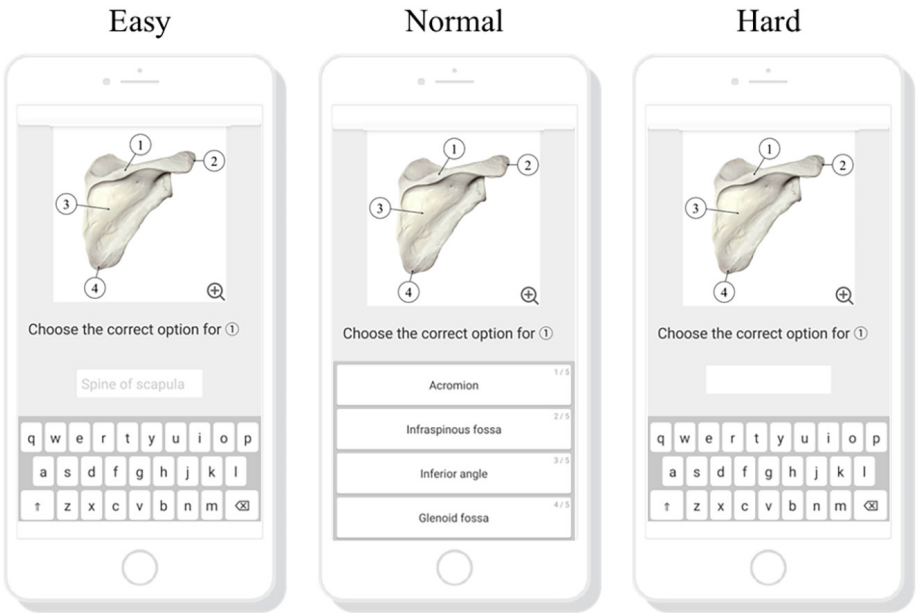

Fig. 3. Screenshots of Monoxer and example of the adaptive learning function

In addition, Monoxer features a study planning function that provides daily learning assignments for effective memory retention within a designated timeframe. The CRA is automatically recorded as a learning log, representing learners' completion rate of daily assignments. We considered the CRA an indicator of consistent study habits. Teachers can monitor each student's learning log in real time using the learning analytics dashboard.

At the start of PBBL, first-year students had approximately six months of experience using Monoxer, while second- and third-year students had approximately 1.5 years of experience.

3.5 Statistical analysis

For RQ1, to examine whether PBBL influences students' self-study time using Monoxer, data on the number of completed daily learning sessions (CDLS) via Monoxer for each student was collected. Then, significance tests were conducted for each grade level to compare the "before PBBL" period with the "during PBBL" period. Although the actual time spent on self-study cannot be obtained from the learning logs, the number of CDLS is considered to reflect self-study time. Based on the results of the Shapiro-Wilk test, a paired t-test was used for the second-year data, and the Wilcoxon signed-rank test was used for the first- and third-year data.

For RQ2, to investigate the association between consistent study habits and academic performance, Spearman's rank correlation coefficients were calculated between the CRA during the PBBL period and the rate of academic test score (raw score/full score) for each grade. Although the academic tests were for different subjects in each grade, the following three characteristics were consistent across tests:

(1) The questions mainly covered the content learned using Monoxer. (2) The questions mainly focused on confirming whether students had memorized the names of terms. (3) The questions were multiple-choice.

For RQ3, to explore key insights students gain through PBBL regarding developing consistent study habits, a qualitative analysis was conducted on the responses of first-year students in their reflection sheets to the question: "What do you think is important for developing consistent study habits?" The analysis was based on the Fogg Behavior Model (FBM), a widely used framework for understanding human behavior change [35]. This model highlights three principal elements as necessary to initiate human action: Motivation (being motivated to take action), ability (the action being easy for the performer), and prompt (having a trigger to initiate the action) [36]. These elements must converge at the same moment for a behavior to occur. The procedure consisted of the following steps: (1) The text was divided into units, each containing one idea. (2) Each unit was categorized into main categories, subcategories, and sub-subcategories based on the FBM. The categories were named by the first author and then finalized through discussion with the second and third authors. (3) The number of units in each category was counted.

Statistical analyses were performed using EZR software, with a significance level set at .05.

4 RESULTS

4.1 RQ1: Changes in completed daily learning sessions via Monoxer

The number of CDLS during the PBBL period significantly increased for first- and third-year students compared to before this period. No significant difference was found for second-year students. The details are as follows:

For first-year students, the number of CDLS sessions was significantly higher during the PBBL period ($M = 1.85$, $SD = 0.99$) than before it ($M = 0.90$, $SD = 0.85$), $p < .001$.

For second-year students, no significant difference was found in the number of CDLS between before. The PBBL period ($M = 2.20$, $SD = 0.90$) and during it ($M = 2.03$, $SD = 0.75$), $p \geq .05$.

For third-year students, the number of CDLS was significantly higher during the PBBL period ($M = 2.73$, $SD = 1.00$) than before it ($M = 1.37$, $SD = 0.94$), $p < .001$.

4.2 RQ2: Relationship between the completion rate of assignments and academic test score rate

A significant positive correlation was found between the CRA during the PBBL period and the rate of academic test score in all grades. The details are as follows:

For first-year students, a significant positive correlation was found between the CRA ($M = 0.54$, $SD = 0.25$) and the rate of academic test score ($M = 0.57$, $SD = 0.13$) ($r = 0.44$), $p < .01$.

For second-year students, a significant positive correlation was found between the CRA ($M = 0.63$, $SD = 0.23$) and the rate of academic test score ($M = 0.70$, $SD = 0.12$) ($r = 0.51$), $p < .01$.

For third-year students, a significant positive correlation was found between the CRA ($M = 0.66$, $SD = 0.20$) and the rate of academic test score ($M = 0.60$, $SD = 0.11$) ($r = 0.36$), $p < .05$.

4.3 RQ3: Qualitative analysis of students' reflection sheets on project-based blended learning

The content of the reflection sheets was categorized into four categories: the three elements of the FBM (motivation, ability, and prompt) and an additional category for reflection (refer to Table 1).

The motivation category was classified into two subcategories: intrinsic and extrinsic motivation. Intrinsic motivation was further categorized into three sub-subcategories: clear goal setting, defined as the importance of understanding one's own current level and setting clear learning goals; subjective valuing of learning content, referring to the importance of considering why the learning content needs to be learned; and expectation of positive emotions from results, representing the expectation of accomplishment upon achieving goals. Furthermore, extrinsic motivation was categorized into two sub-subcategories: Collaborative motivation, emphasizing the importance of learning together and encouraging each other for self-motivation, and avoidance motivation, defined as motivation to avoid causing trouble for group members.

The ability category refers to the principle that a target behavior is less likely to occur when one's ability to perform it is low. It encompasses strategies to lower the difficulty of the behavior itself, such as breaking down the target behavior into smaller steps or starting with simple and easy tasks.

Finally, the prompt category refers to the principle that without an appropriate trigger, behavior will not occur even if both motivation and ability are high. Prompts are classified into the subcategories of environment, time, and reminders. Environment refers to triggers related to preparing the learning environment. Time refers to triggers related to setting a specific time for daily learning. Reminders refer to triggers such as receiving notifications when not studying or placing the learning app in a visible location.

Reflection was extracted as a main category alongside the three FBM elements. This category indicates the importance of regularly monitoring progress toward set goals and engaging in appropriate reflection.

Table 1. Categorization of reflection sheet content

Main Category (Count)	Subcategory (Count)	Sub-Subcategory (Count)	Example Sentences
Motivation (29)	Intrinsic Motivation (15)	Clear Goal Setting (5)	"I think it is important to first understand your own level and set appropriate goals."
		Subjective Valuing of Learning Content (5)	"I think it is important to prioritize thinking about why you are doing it."
		Expectation of Positive Emotions from Learning Results (5)	"The sense of accomplishment when you achieve your goals makes you want to do more."
	Extrinsic Motivation (14)	Collaborative Motivation (12)	"If it's difficult to do it alone, I found that working with friends or encouraging each other with classmates can boost your motivation and make you more productive."
		Avoidance Motivation (2)	"When others are doing it, I feel like I have to do it too. And if I do not do it, I might cause trouble for others, which naturally makes me want to do it too."

(Continued)

Table 1. Categorization of reflection sheet content *(Continued)*

Main Category (Count)	Subcategory (Count)	Sub-Subcategory (Count)	Example Sentences
Ability (13)			"I feel like the act of starting to study requires a lot of motivation and seems like a high hurdle, so I think it's important to start with something easy, like just looking through class materials." "Instead of studying for a long time at once, I think it's better to study consistently every day, even if only for a short time."
Prompt (21)	Environment (5)		"Creating a quiet and focused environment allows you to study efficiently."
	Time (10)		"I think it's important to find a time that you can make into a habit and make sure to study at that time."
	Reminders (6)		"When I get a notification, it makes me feel like I have to do it." "Moving the Monoxer app close to frequently used apps on my smartphone helps me remember."
Reflection (2)			"I think it's important to reflect and evaluate yourself to find areas for improvement."
Unclassifiable (15)			

5 DISCUSSION

This study investigated the effectiveness of our PBBL model, which integrates the mobile learning app Monoxer to foster consistent study habits among first- to third-year Japanese physical therapy students. For RQ1, self-study time via the app, an indicator of consistent study habits, increased during the PBBL period compared to before it for first- and third-year students. One possible interpretation for the lack of a significant difference for second-year students is that their baseline app usage was already relatively high, potentially creating a ceiling effect. However, this does not fully explain the results, as both second- and third-year students had similar durations of prior experience with the app. Thus, the unique dynamics in the mixed-grade teams may also have influenced these results. Therefore, the reasons for this differing impact across student grades require further investigation. For RQ2, analysis of the relationship between self-study time and academic test scores revealed a significant positive correlation across all grades. For RQ3, qualitative analysis of reflection sheets from first-year students indicated that fostering study habits relies on four key elements: the three universal components of the FBM (motivation, ability, and prompt), along with reflection.

Consistent with the findings of this study, previous research on PBBL reported effectiveness regarding students' self-regulated study habits and academic performance. In an empirical study of PBBL among physics students [23], the experimental class introducing PBBL had higher academic test scores and achieved more scientific and technological innovation awards than the control class using traditional teaching methods. The study also suggests that PBBL can help students become more autonomous and self-directed learners. Similarly, research examining the impact of PBBL aimed at developing self-study ability among high school students reported improvement in self-regulated learning skills such as goal setting and determining learning strategies from pre- to post-PBBL implementation [37]. A key contribution

of our study is the use of objective data from the mobile app's learning logs to quantitatively demonstrate the effects of PBBL on self-study habits and academic performance, thereby avoiding the subjective bias of surveys.

The qualitative analysis of first-year students' reflection sheets for RQ3 indicated reflection as a key element for developing consistent study habits, alongside the three elements of the FBM. Notably, students participating in PBBL naturally gained insights into these aspects of the universal behavior model through repeated practice and reflection while working on projects as a team. The PBBL introduced in this study was designed to facilitate both individual and group reflection by utilizing learning logs collected via Monoxer. According to a study investigating the impact of reflection activities on academic procrastination among Japanese university students, implementing weekly reflection activities (e.g., reviewing progress, planning tasks) helped students prone to procrastinate in terms of online assignments [38]. To accelerate the improvement process through frequent cycles of practice and reflection, mobile apps require functions for the easy collection, analysis, processing, and delivery of learning logs. Monoxer fulfills these requirements, making it an optimal learning application for this study. Frequent real-time feedback on learning status provided by Monoxer allows students to regularly monitor their progress toward set goals and engage in appropriate self-evaluation. This data-driven feedback to change students' learning behavior is a critical differentiator from previous PBBL models. While the use of mobile devices in education is becoming ubiquitous, widespread adoption does not always lead to high-quality pedagogical practices [39]. Our PBBL model is therefore valuable in that it demonstrates a practical framework in which a mobile app serves not as a simple add-on, but as a systemically integrated component to foster the data-driven reflection essential for building consistent study habits.

Project-based blended learning combines the strengths of blended learning and PBL. In the PBBL model in this study, there were only two scheduled face-to-face synchronous sessions, with students primarily engaging in self-study asynchronously. This PBBL design reflects the way physical therapists learn after graduation, where self-directed asynchronous learning is central to their ongoing professional development and lifelong learning. The role of synchronous sessions is intended to enhance students' motivation and facilitate peer interaction, thereby compensating for the disadvantages of asynchronous learning. This learning model can bridge the gap between undergraduate education and independent learning after graduation and help students smoothly transition to the continuous learning practices needed in their professional careers.

This PBBL model also directly addresses a key challenge highlighted in international benchmarks on digital education. For instance, the OECD Digital Education Outlook 2023 [40] notes that while the education sector is data-rich, the use of this data to enhance student learning and support teaching is still in its early stages. A major challenge, therefore, is the development of educational models that can effectively utilize data from various digital systems to create more personalized and effective learning experiences. Our PBBL framework leverages objective data from learning logs to provide personalized support and to facilitate the reflective processes crucial for building consistent study habits. This demonstrates its high transferability across various health sciences disciplines, which face similar data-utilization challenges.

6 LIMITATIONS AND FUTURE DIRECTIONS

While the generalizability of this study is limited by its focus on students from a single physical therapy college in Japan, its findings offer important implications for

other health sciences disciplines and broader international contexts. This is because, regardless of the country, foundational subjects including anatomy and physiology are also a mandatory part of the first-year curriculum for various other medical and health professions [41]–[43]. A common challenge in these fields is fostering autonomous study habits for the efficient memorization of vast medical terminology. By utilizing technology to shift students from last-minute cramming to consistent study habits, our PBBL model presents a potentially effective and internationally transferable solution for first-year education across the health sciences. To validate this potential, future work should involve cross-institutional and multi-disciplinary studies, implementing our model with students from nursing, medicine, and other allied health programs, both domestically and internationally. This would enable a robust evaluation of the effectiveness and transferability of the model across diverse educational contexts.

7 DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

In the preparation of this manuscript, Google's Gemini 2.5 was used solely for English language editing and proofreading. The authors confirm their sole responsibility for the content and accuracy of the final paper.

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