Students' Responses to TPACK-Based Innovative Teaching Materials for Problem-Solving Learning

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ABSTRACT

Innovative and technologically integrated teaching resources that foster students' active learning and problem-solving abilities are necessary for biology education in the digital age. The purpose of this study was to examine how undergraduate students responded to novel teaching resources that combined problem-solving learning strategies with the Technological Pedagogical Content Knowledge (TPACK) framework in biology education. Seventy undergraduate students participated in the study, which used a descriptive quantitative research approach. Students' opinions about problem-solving exercises, technology integration, learning engagement, and content integration were gauged by the questionnaire. Mean scores and response categories were used in a descriptive analysis of the data. The results indicated that students' responses had an average score of 4.31, which was classified as "High." The statement about digital characteristics that facilitate interactive learning had the highest response (M = 4.40), followed by problem-solving exercises that assist students in critically analysing biological challenges (M = 4.37). The findings show that the use of TPACK-based creative teaching resources combined with problem-solving teaching strategies was well received by the students. Higher education biology learning experiences were made more engaging, dynamic, and meaningful by the instructional materials.

Keyword: TPACK, innovative teaching materials, student responses, problem-solving learning, higher education.

INTRODUCTION

Biology education in the 21st-century requires teaching strategies that emphasise the development of critical thinking, creativity, teamwork, and problem-solving skills. These abilities are essential for students to fully understand biological concepts and apply them in real-world scenarios (Suryanda, 2024). In order to guarantee that students not only comprehend theoretical concepts but also apply them in real-world contexts while also developing critical thinking, creativity, and collaboration skills, learning in the digital age must employ innovative strategies (such as Project-Based Learning, Problem-Based Learning, Cooperative Learning, Discovery Learning, and Inquiry Learning) (Rose et al., 2024).

21st-century abilities, particularly advanced thinking and problem solving for everyday problems, are becoming more and more integrated into national biology curricula (Kapas et al., 2024; Jamil et al., 2024). According to a systematic study, 21st-century abilities including critical thinking, creativity, teamwork, and effective communication are supported by the differentiated learning strategy that uses Problem-Based Learning (PBL), Project-Based Learning (PjBL), and Discovery Learning (Sera et al., 2025). Therefore, in order to satisfy the demands of 21st-century learning, when students are expected not just to acquire knowledge but also to actively construct and use it in meaningful settings, biology education must be more creative, contextual, and student-centered.

Despite these hopes, there are still a number of obstacles in the way of using problem-solving-based learning in biology classrooms. The scarcity of creative teaching resources that successfully combine pedagogical techniques, subject-matter expertise, and technology in a methodical and balanced manner is one of the main problems (Wang et al., 2018). Because of this, a lot of instructional resources are still traditional, teacher-centered, and ineffective at encouraging student participation and a better conceptual grasp of biological processes. According to earlier research, using PBL in biology classes can enhance students' critical thinking and teamwork abilities (Sudrajat et al., 2018). However, there are presently few cutting-edge, technologically advanced teaching resources available in many educational settings to complement these methods.

The Technological Pedagogical Content Knowledge framework offers a solid theoretical foundation for creating cutting-edge instructional materials in order to overcome this difficulty. To generate engaging, meaningful, and context-rich learning experiences, TPACK combines pedagogical expertise, technology understanding, and topic mastery (Fakhriyah et al., 2022). Teaching resources can be created to encourage students' participation, engagement, and cognitive growth through this integration in biology learning activities. Several teaching techniques, such as field-based learning, problem-based learning, simulation, collaborative learning, flipped classrooms, and inquiry-based learning, were found to be successful tactics for optimising student engagement and active learning in a study on mobile biology learning based on TPACK (Wang et al., 2018; Manaf et al., 2025).

Furthermore, PBL and PjBL are well known as teaching strategies that promote engagement and real-world problem-solving exercises. These methods allow students to work together, research biological problems, and create solutions based on actual situations. Therefore, it is thought that integrating TPACK with PBL and PjBL is particularly significant for fostering higher-order thinking abilities and enhancing students' capacity to relate theoretical knowledge to real-world applications in biology education.

Students' reactions to the use of TPACK-based teaching materials in problem-solving learning activities have received little attention, despite the fact that earlier research has mostly concentrated on the creation and application of new teaching materials (Fakhriyah et al., 2022). Students' opinions, motivation, involvement, and acceptance of the instructional materials utilised during the learning process are all reflected in their responses, which makes them significant. Positive student reactions could be a sign that the instructional materials can facilitate meaningful learning experiences and increase students' engagement in problem-solving exercises.

Thus, the purpose of this study is to examine how students react to novel teaching resources based on the TPACK framework combined with problem-solving learning strategies in biology education. The findings of this study are expected to provide insights into the effectiveness and acceptance of technology-integrated teaching materials and contribute to the improvement of innovative biology learning resources in higher education contexts.

METHODOLOGY

This study employed a descriptive quantitative research design to analyze undergraduate students' responses toward innovative teaching materials based on the Technological Pedagogical Content Knowledge framework integrated with problem-solving learning approaches in biology education. The participants of this study consisted of 70 undergraduate students enrolled in biology learning courses. The participants were selected using purposive sampling techniques because they had experienced learning activities using TPACK-based innovative teaching materials integrated with Problem-Based Learning (PBL) and Project-Based Learning (PjBL) approaches.

Data were collected using a student response questionnaire administered after the learning activities were completed. The questionnaire employed a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The instrument measured students' responses regarding content and pedagogical integration, student engagement and learning motivation, as well as technology integration and learning environment (Wang et al., 2018).

The collected data were analyzed descriptively using mean scores and response categories. The interpretation criteria used in this study were as follows: 1.00–1.49 (Very Low), 1.50–2.49 (Low), 2.50–3.49 (Moderate), 3.50–4.49 (High), and 4.50–5.00 (Very High). The research procedures included the implementation of TPACK-based innovative teaching materials during biology learning activities, distribution of response questionnaires to students, and descriptive analysis of students' responses toward the teaching materials.

RESULTS

The results of this study describe undergraduate students' responses toward innovative teaching materials based on the Technological Pedagogical Content Knowledge framework integrated with problem-solving learning approaches in biology education. Data were collected from 70 undergraduate students using a response questionnaire with a five-point Likert scale. The questionnaire measured students' perceptions regarding content integration, learning engagement, technology integration, and problem-solving learning activities. The results of students' responses toward the TPACK-based innovative teaching materials can be observed in Table 1 and Figure 1.

Tabel 1. Students' Responses Toward TPACK-Based Innovative Teaching Materials

No	Statement	Mean	Category
A.	**Content and Pedagogical Integration**		
1	The teaching materials appropriately combine biology content, technology, and learning approaches.	4.33	High
2	The teaching materials help me connect biological concepts with problem-solving activities.	4.27	High
3	The learning activities encourage active participation and meaningful learning experiences.	4.25	High
B.	**Student Engagement and Learning Motivation**		
4	The teaching materials increase my interest and motivation in learning biology.	4.35	High
5	The learning activities support collaboration and classroom interaction.	4.29	High
6	The teaching materials provide engaging and interactive learning experiences.	4.31	High
C.	**Technology Integration and Learning Environment**		
7	The digital features in the teaching materials make learning more interactive.	4.40	High
8	The teaching materials are easy to use during learning activities.	4.28	High
9	The problem-solving activities help me analyze biological problems critically.	4.37	High
10	The teaching materials help me understand biology concepts more easily.	4.34	High
Average		**4.31**	**High**

Description: 1.00-1.49 (Very Low); 1.50-2.49 (Low), 2.50-3.49 (Moderate). 3.50-4.49 (High), 4.50-5.00 (Very High).

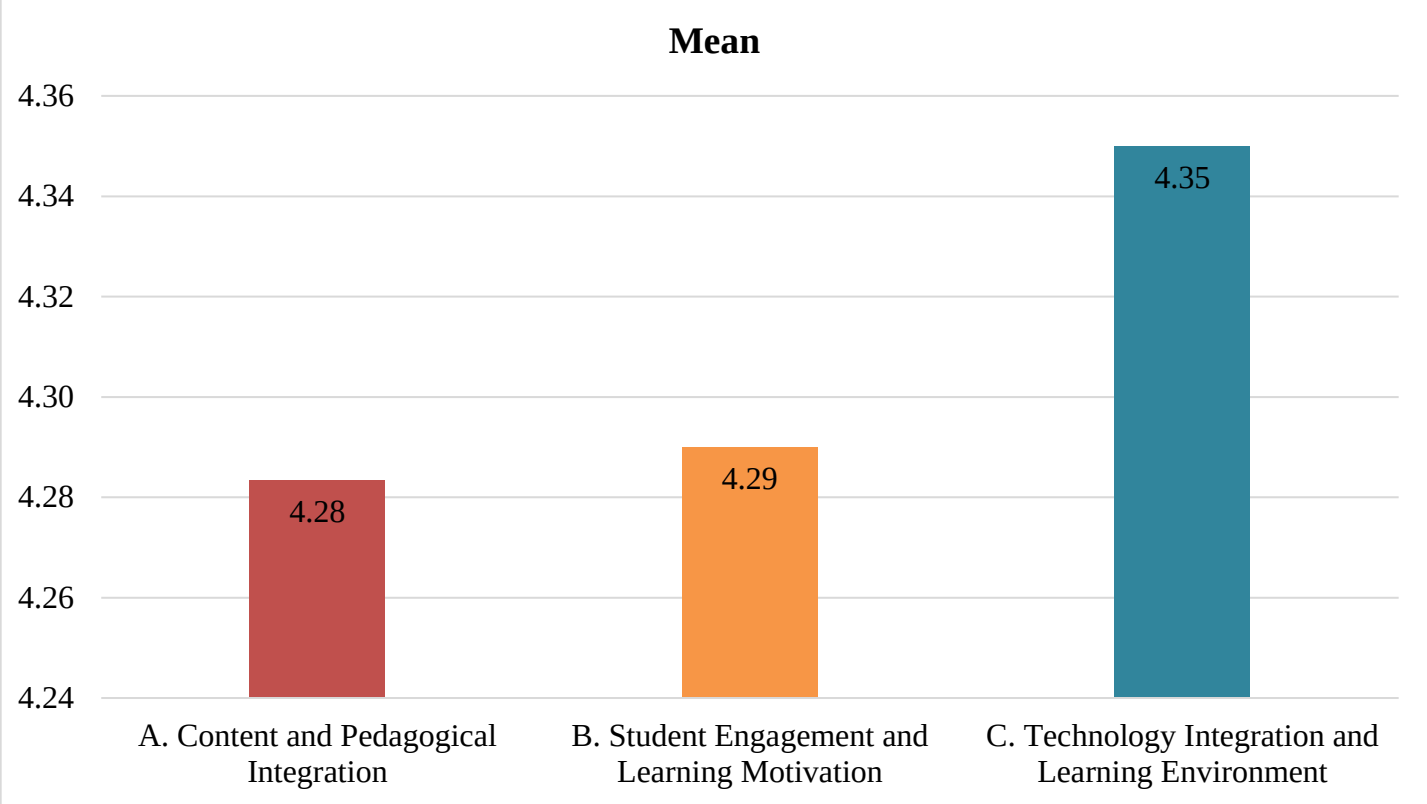

Figure 1. The Results of Students' Responses Toward The TPACK-Based Innovative Teaching Materials.

Based on Table 1 and Figure 1, the overall average score of students' responses was 4.31, categorized as "High." The highest mean score was obtained in the statement related to digital features supporting interactive learning (M = 4.40), followed by problem-solving activities helping students analyze biological problems critically (M = 4.37). Meanwhile, the lowest mean score was found in the statement regarding meaningful learning experiences (M = 4.25), although it still belonged to the "High" category.

The findings indicate that students responded positively toward the implementation of TPACK-based innovative teaching materials integrated with problem-solving learning approaches in biology education. The materials were also considered useful in helping students understand biological concepts more easily and participate actively in classroom discussions and collaborative activities. The findings demonstrate that TPACK-based innovative teaching materials integrated with problem-solving learning approaches were positively accepted by undergraduate students and contributed to active, meaningful, and technology-supported biology learning experiences (Fakhriyah et al., 2022).

DISCUSSION

The findings of this study indicate that undergraduate students showed positive responses toward the implementation of innovative teaching materials based on the Technological Pedagogical Content Knowledge framework integrated with problem-solving learning approaches in biology education. The overall mean score of 4.31 categorized as "High" demonstrates that the teaching materials were well accepted by students and supported meaningful biology learning experiences. These findings support the instrument's suitability for assessing the calibre of cutting-edge biology teaching resources. Teachers' ability, training, and methods of assessment for critical thinking and problem solving are still crucial to the effective implementation of curriculum and tactics (Jamil et al., 2024; Church, 2021; Kasap et al., 2024).

Positive comments on the use of technology, pedagogy, and biological content show that the teaching resources were effective in encouraging student-centered learning (Wang et al., 2018). This finding is consistent with the TPACK framework, which emphasises the integration of pedagogical, technological, and content knowledge to create effective learning environments. This integration allows students to engage more fully in class activities and have a deeper comprehension of biological concepts (Bhoi, 2024).

The fact that the digital features component received the highest score suggests that technology integration was crucial in raising student participation in class activities. Students may be able to better visualise biological topics and create more interesting learning experiences with the aid of interactive digital components. According to earlier research, students' motivation, engagement, and involvement in the classroom can all be enhanced by technology-supported learning settings (Sera et al., 2025).

Additionally, the problem-solving exercises incorporated into the instructional materials were well received by the pupils. The high score in this area suggests that the application of Project-Based Learning (PjBL) and Problem-Based Learning (PBL) strategies inspired students to apply biological ideas in solving real-world situations, think critically, and work with peers. These results are consistent with earlier studies showing that PBL and PjBL successfully foster collaborative learning processes and higher-order thinking abilities (Puspita et al., 2024).

The favourable reactions regarding classroom engagement and learning motivation further suggest that the instructional materials helped to establish dynamic and cooperative learning settings. Students thought that the learning exercises promoted involvement, conversation, and self-directed investigation of biological ideas. In 21st-century biology education, where students are expected to become active learners capable of critical thinking, collaboration, and problem-solving, such learning experiences are crucial (Sudrajat et al., 2018).

None of the reaction indicators attained the "Very High" category, despite all being classified as "High." This implies that there is still room for improvement in order to maximise the instructional materials, especially in terms of improving interactive elements, multimedia integration, and contextual problem-solving exercises. Future research may assess the effects of TPACK-based instructional materials on students' learning outcomes and problem-solving abilities with bigger participant groups (Manaf et al., 2025). The results show that TPACK-based creative teaching resources combined with problem-solving teaching strategies have a great deal of potential to enhance biology instruction in higher education. According to Sudrajat et al. (2018) and Abdieva (2023), students' favourable reactions suggest that the teaching materials can improve student involvement, motivation, interaction, and problem-solving abilities in biology learning activities.

The integration of TPACK enables the combination of technology, pedagogy, and content knowledge in a balanced manner, which is essential for creating meaningful learning experiences (Wang et al., 2018). Integrating innovative technologies in biology class significantly enhances student’s creative abilities, insightful discussions and newfound enthusiasm for biology (Abdieva, 2023). In addition, the incorporation of PBL and PjBL approaches encourages active student engagement, problem-solving abilities, and contextual understanding of biological concepts, which are key competencies in 21st-century learning. Uses authentic problems, group work, and self-directed inquiry to strengthen critical thinking, complex problem solving, collaboration, and communication in science and biology courses (Rose et al., 2024; Awati et al., 2024).

The findings are consistent with previous studies that emphasize the effectiveness of integrating TPACK with inquiry-based and project-based learning approaches to enhance instructional quality and student engagement (Manaf et al., 2025). The use of reliable evaluation instruments further strengthens the credibility of development research, as it ensures that the assessment of teaching materials is consistent and trustworthy. Therefore, the combination of TPACK, PBL, and PjBL not only improves the quality of biology teaching materials but also supports the development of higher-order thinking skills required in modern biology education. Integrated STEM projects significantly boost 21st-century skills, especially problem solving, creative thinking, collaboration, and productivity through real-life tasks (Puspita et al., 2024; Alali, 2024).

The favourable reactions to technology integration point to the significance of creating individualised learning and teacher preparation programs that improve teachers' abilities to incorporate pedagogical, technological, and subject-matter expertise into classroom instruction. In order to enable more interactive, student-centered, and creative learning environments, future educational practices should also take into account the ethical and efficient use of digital technology and artificial intelligence (AI) in teaching and learning processes (Karataş & Ataç, 2025).

This study was restricted to descriptive quantitative analysis based on students' perspectives, despite the favourable answers from the students. The study lacked a control group and did not explicitly examine students'

learning results using experimental techniques like pre-test and post-test evaluations. As a result, rather than directly affecting academic performance or problem-solving abilities, the results mostly represent students' opinions of the teaching resources.

It is advised that future research use experimental or quasi-experimental research methodologies to more thoroughly examine the impact of TPACK-based teaching resources on students' biology accomplishment. Stronger proof of students' learning gains following the use of the teaching materials would be provided by the inclusion of pre-test and post-test assessments. Additionally, using a mixed-methods approach that combines quantitative surveys with interviews or classroom observations may provide more in-depth information about the learning experiences, student engagement, and overall efficacy of TPACK-integrated learning resources.

CONCLUSION

The responses of undergraduate students to novel teaching resources based on the TPACK framework combined with problem-solving learning strategies in biology education were examined in this study. With an overall mean score of 4.31, classified as "High," the results demonstrated that students responded favourably to the use of the educational materials. The characteristics of digital features that facilitated interactive learning and problem-solving exercises that promoted critical analysis of biological challenges received the most replies. These results show that active, interactive, and student-centered learning environments can be supported by integrating technology, pedagogy, and biology content with TPACK-based teaching materials.

Additionally, the use of problem-solving teaching strategies through PBL and PjBL improved students' participation, teamwork, and comprehension of biological concepts. The development of 21st-century abilities in higher education and engaging biology learning experiences can therefore be strongly supported by TPACK-based creative teaching tools. However, this study did not directly test students' learning outcomes using experimental techniques; instead, it was restricted to descriptive quantitative analysis based on students' opinions. Determining the true impact of the teaching materials on students' academic performance and problem-solving abilities is further hampered by the lack of pre-test and post-test assessments and a control group. In order to gain a deeper understanding of instructional effectiveness and student learning outcomes, future research is advised to use experimental or quasi-experimental designs in conjunction with mixed-method approaches, such as interviews and classroom observations.

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