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An exploration of collaborative problem-solving skills and cognitive learning outcomes among preservice biology teachers in biochemistry

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Abstract

Background: Biochemistry involves complex concepts requiring collaborative problem-solving skills (CPSS) and higher-order cognitive abilities. Preliminary observations indicated difficulties in collaborative participation, hypothesis formulation, and solution development among preservice Biology teachers.
Aim: This study explored students' social and cognitive CPSS, cognitive learning outcomes, and existing Biochemistry instructional practices.
Methods: A descriptive needs analysis involved 50 fourth-semester Biology Education students selected through convenience sampling and five Biochemistry lecturers at Universitas Negeri Malang. Data were collected through a social CPSS questionnaire, cognitive CPSS and learning outcomes tests, semi-structured interviews, and Semester Learning Plan (RPS) analysis. Quantitative data were analyzed descriptively, while qualitative evidence was examined to identify instructional needs and curriculum alignment.
Results: Social CPSS averaged 64.75%, with transactive memory highest (66.8%) and action lowest (63.2%). Cognitive CPSS averaged 63.47%, with relationships highest (71.8%) and hypothesis formulation lowest (49.8%). Cognitive learning outcomes averaged 66.73%, with stronger performance at C1–C3 and the lowest score at C6 (38%). Lecturer interviews revealed variations in student participation and Problem-Based Learning (PBL) implementation. RPS analysis identified incomplete documentation of alignment between learning outcomes, instructional activities, resources, assessments, and systematic PBL stages.
Conclusion: The findings highlight instructional needs concerning active collaboration, hypothesis formulation, higher-order cognitive processing, and curriculum alignment. These preliminary findings provide contextual evidence for instructional improvement and future development of structured learning approaches without establishing the effectiveness of any specific instructional medium.

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INTRODUCTION

Biochemistry is an important subject in biology education because it provides fundamental knowledge for understanding biological processes at the molecular level. However, Biochemistry involves abstract, complex, and interconnected concepts that require students to integrate conceptual knowledge, analyze relationships among molecular structures and functions, and apply knowledge to biological problems. Students have been reported to experience difficulties in understanding Biochemistry concepts, particularly those involving molecular structures and metabolic pathways, which are often perceived as abstract and complex (Kurniawati & Jailani, 2020; Yusuf et al., 2021). The complexity of these concepts requires learning processes that not only

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emphasize conceptual understanding but also facilitate students' ability to think critically, solve problems, and collaborate with others. These competencies are consistent with the demands of 21st-century learning, in which students are expected to develop problem-solving and collaborative skills in addressing complex problems (Munali & Alifah, 2025; Choirunisa et al., 2023).

One important competency in this context is Collaborative Problem-Solving Skills (CPSS). CPSS refers to the ability of individuals to work effectively with others to understand problems, exchange information, coordinate activities, and develop solutions to achieve shared goals (Hesse et al., 2015; Graesser et al., 2018). CPSS involves both social and cognitive dimensions. The social dimension includes interaction, negotiation, adaptability, task completion, self-evaluation, and responsibility, whereas the cognitive dimension involves analyzing problems, setting goals, managing resources, organizing information, identifying relationships, and formulating hypotheses (Hesse et al., 2015). The development of CPSS is particularly important in higher education because students are expected to participate actively in collaborative learning and solve increasingly complex academic and professional problems (Andrews-Todd et al., 2023; Graesser et al., 2018). However, students may experience difficulties in developing collaborative problem-solving abilities when learning activities provide limited opportunities for meaningful interaction, shared investigation, and collaborative problem solving (OECD, 2017; Tang et al., 2022).

In addition to CPSS, cognitive learning outcomes are an important indicator of the quality of Biochemistry learning. Cognitive learning outcomes reflect students' abilities to acquire, understand, apply, analyze, evaluate, and create knowledge. The revised Bloom's Taxonomy developed by Anderson and Krathwohl (2001) categorizes cognitive processes into remembering, understanding, applying, analyzing, evaluating, and creating. Learning that primarily emphasizes lower-order cognitive processes may provide insufficient opportunities for students to develop higher-order thinking. Problem-based and blended learning approaches have been reported to provide opportunities for students to engage in more complex cognitive processes and higher-order thinking (Sulistiyani et al., 2025). Therefore, Biochemistry learning should provide students with opportunities to engage in analytical, evaluative, and creative activities that require them to apply concepts to contextual problems and construct solutions.

The learning approach and learning media used in the classroom are important factors in facilitating these competencies. Problem-Based Learning (PBL) provides a potential approach because it positions problems as the starting point of learning and encourages students to investigate problems, gather information, discuss possible explanations, and construct solutions collaboratively. Previous studies have reported that PBL can contribute to the development of students' problem-solving, collaboration, communication, and critical-thinking skills (Choirunisa et al., 2023; Dakabesi, 2025). Research in higher education Biochemistry has also indicated the relevance of PBL for engaging students with complex and authentic problems and supporting active learning experiences (Lavrič et al., 2025). In Biochemistry learning, the implementation of PBL with a scaffolding strategy has also been reported to support students' creative thinking (Ernawati et al., 2022). Thus, PBL provides learning experiences that are relevant to the development of both collaborative problem solving and higher-order cognitive abilities.

Problem-Based Learning (PBL) offers a pedagogical framework for engaging students in contextual problem identification, investigation, information gathering, collaborative reasoning, and solution development. In Biochemistry, these activities can help students connect abstract molecular concepts with biological processes. Digital resources may support access to learning materials and multiple representations (Cook, 2007; Aeni & Widodo, 2022; Saprudin & Pratama, 2025), but a website is not inherently an instructional solution: its value depends on how learning resources and activities are aligned with learning objectives and students' needs. The present study therefore

examines students' CPSS and cognitive learning outcomes alongside evidence about the existing instructional context, rather than assuming in advance that digital delivery is required.

A preliminary needs analysis was conducted among undergraduate Biology Education students at Universitas Negeri Malang who had completed the Biochemistry course. Initial assessment results and lecturer accounts indicated difficulties related to active collaborative participation, independent problem identification, hypothesis formulation, and higher-order cognitive work. The Biochemistry Semester Learning Plan (RPS) was also examined to determine how intended learning outcomes were reflected in planned activities, resources, and assessment. These sources were considered together to characterize the learning context and identify discrepancies between expected competencies and available learning experiences.

Previous studies have examined different aspects of PBL and technology-supported learning in Biochemistry. Bai et al. (2023) investigated the acceptability of fully online and partially online PBL in a large Biochemistry class, while Lavrič et al. (2025) examined PBL in a higher-education Biochemistry course within a veterinary curriculum. Lu and Xie (2024) reviewed educational technology for problem-solving across a range of settings, and Saprudin and Pratama (2025) examined website-based learning media in secondary-school Biology. These studies offer relevant evidence about PBL implementation and digital learning, but the studies cited here do not directly describe the profile of both social and cognitive CPSS together with cognitive learning outcomes among undergraduate Biology Education students studying Biochemistry, interpreted alongside lecturer perspectives and the planned curriculum. The present study addresses this context-specific diagnostic question without claiming that the literature contains no related work.

Accordingly, this study aimed to explore undergraduate preservice Biology teachers' social and cognitive collaborative problem-solving skills and cognitive learning outcomes in Biochemistry, while characterizing the existing instructional context through interviews with five Biochemistry lecturers and analysis of the RPS. Within the broader research and development project, the BioSolve Biochemistry website had already been proposed as a possible learning medium. The present study does not claim that the needs analysis independently established the website as the only or best solution; rather, it provides diagnostic evidence that may inform subsequent instructional-design decisions and the evaluation of possible learning resources.

LITERATURE REVIEW

Biochemistry constitutes an essential component of preservice Biology teacher education because it establishes the molecular foundations necessary for explaining biological structures, metabolic processes, and physiological mechanisms. Understanding biochemical phenomena requires students to integrate knowledge across molecular interactions, enzymatic reactions, metabolic pathways, and cellular regulatory systems (Handee et al., 2025; Lang & Bodner, 2020). However, the abstract and interconnected characteristics of biochemical concepts frequently present considerable challenges for undergraduate students, particularly when theoretical knowledge must be applied to unfamiliar biological situations (Kurniawati & Jailani, 2020; Yusuf et al., 2021). These conceptual difficulties indicate that successful Biochemistry learning requires more than memorizing biochemical terminology, molecular structures, or metabolic sequences. Students must develop the ability to interpret scientific information, establish conceptual relationships, evaluate evidence, and construct scientifically defensible explanations. For preservice Biology teachers, these competencies are particularly important because their future professional responsibilities involve transforming complex scientific knowledge into meaningful and accessible learning experiences (Diem et al., 2024; Dragnić-Cindrić & Anderson, 2025; Hogan & O'Flaherty, 2021; Mandikonza, 2022;

Steinwachs & Martens, 2025). Contemporary science education therefore increasingly emphasizes instructional practices that integrate conceptual understanding with critical thinking, scientific reasoning, and collaborative problem-solving competencies (Munali & Alifah, 2025). Collaborative learning environments may provide opportunities for students to negotiate scientific interpretations, compare alternative explanations, and develop shared understandings of complex biochemical phenomena. Nevertheless, the educational value of collaboration depends on the extent to which learning activities encourage meaningful cognitive engagement rather than merely assigning students to work in groups. Consequently, examining collaborative problem-solving skills alongside cognitive learning outcomes provides a relevant theoretical foundation for understanding the instructional needs of preservice Biology teachers in Biochemistry education.

Collaborative Problem-Solving Skills (CPSS) represent a multidimensional competency involving the coordinated application of social interaction and cognitive reasoning to achieve shared problem-solving objectives (Hesse et al., 2015; Graesser et al., 2018). Hesse et al. (2015) conceptualized collaborative problem solving through interconnected social and cognitive dimensions that describe how individuals communicate, coordinate responsibilities, process information, and construct solutions within collaborative environments. The social dimension encompasses several competencies, including action, interaction, task completion, adaptive responsiveness, audience awareness, negotiation, self-evaluation, transactive memory, and responsibility initiative (Hesse et al., 2015). These competencies enable group members to establish productive interactions, recognize individual contributions, manage disagreements, and maintain collective responsibility throughout problem-solving activities. Graesser et al. (2018) emphasized that effective collaborative problem solving involves more than interpersonal communication because successful collaboration also requires coordinated reasoning and shared regulation of problem-solving processes. Similarly, He et al. (2023) highlighted the importance of students' roles and participation patterns in shaping collaborative problem-solving competencies within educational environments. The cognitive dimension includes organizing information, establishing goals, managing resources, demonstrating flexibility, gathering evidence, applying systematic reasoning, identifying relationships, developing contingency rules, and formulating hypotheses (Hesse et al., 2015). These processes are particularly relevant to Biochemistry because scientific problems frequently require students to connect molecular mechanisms with observable biological phenomena and evaluate competing explanations. Research by Andrews-Todd et al. (2023) further demonstrated the importance of examining collaborative problem-solving competencies across different task conditions, indicating that collaborative performance should be understood through the specific cognitive and interactive demands of learning activities. Accordingly, evaluating both dimensions of CPSS offers a comprehensive framework for identifying students' relative strengths and difficulties in collaborative biochemical problem solving without assuming that social participation necessarily reflects cognitive proficiency.

Cognitive learning outcomes constitute another fundamental dimension of educational achievement because they reflect the extent to which students acquire, organize, apply, and transform disciplinary knowledge. Anderson and Krathwohl (2001) classified cognitive processes into six hierarchical categories: remembering (C1), understanding (C2), applying (C3), analyzing (C4), evaluating (C5), and creating (C6). Within Biochemistry education, lower-order cognitive processes support students' recognition of biochemical terminology, comprehension of molecular functions, and application of established scientific principles. Higher-order cognitive processes, meanwhile, involve interpreting complex biochemical relationships, evaluating experimental evidence, and developing explanations or solutions to unfamiliar scientific problems. The distinction between these cognitive levels is particularly relevant because students may demonstrate satisfactory conceptual recall while experiencing difficulties when required to formulate hypotheses

or justify scientific conclusions. Ernawati et al. (2022) examined creative thinking in Biochemistry learning through Problem-Based Learning (PBL) supported by scaffolding, highlighting the relevance of structured problem-solving experiences to cognitively demanding learning activities. Similarly, Sulistiyani et al. (2025) investigated higher-order thinking within blended problem-based learning, providing additional evidence concerning the relationship between instructional approaches and complex cognitive engagement. Although collaborative problem solving and cognitive learning outcomes represent distinct constructs, both involve reasoning processes associated with information interpretation, evidence evaluation, and solution development. Ceballos et al. (2026) emphasized the relevance of collaborative problem-solving design features and processes to higher-order thinking, suggesting that productive collaboration requires opportunities for meaningful cognitive participation. Therefore, examining cognitive learning outcomes alongside social and cognitive CPSS may provide complementary information about students' learning profiles, although their statistical relationships and causal connections require separate empirical investigation.

Problem-Based Learning (PBL) provides a pedagogical framework that may support the integration of collaborative interaction, scientific inquiry, and higher-order cognitive processing in Biochemistry education (Ernawati et al., 2022; Lavrič et al., 2025). This approach organizes learning around meaningful problems that encourage students to identify relevant information, formulate investigative questions, examine alternative explanations, and construct evidence-based solutions. Unlike instructional practices primarily emphasizing the transmission of established knowledge, PBL creates opportunities for students to participate actively in determining how scientific problems should be investigated and resolved (Almulla, 2020; He et al., 2023; Sukackė et al., 2022). Choirunisa et al. (2023) discussed the contribution of PBL to students' collaboration and communication skills, while Dakabesi (2025) examined its relevance to developing problem-solving competencies. Within higher education, Lavrič et al. (2025) investigated PBL in a Biochemistry course, demonstrating its applicability to learning environments involving complex biochemical knowledge and authentic scientific problems. Bai et al. (2023) additionally examined the acceptability of fully online and partially online PBL in large Biochemistry classes, indicating that problem-oriented learning can be organized through different instructional delivery formats. These studies provide a theoretical and empirical rationale for considering PBL when designing learning experiences that require collaborative investigation and scientific reasoning. Nevertheless, the implementation of PBL requires careful attention to problem characteristics, instructional guidance, collaborative responsibilities, learning resources, and assessment procedures. Research concerning educational technology further suggests that digital resources should be integrated with appropriate instructional strategies rather than treated as independent solutions to learning difficulties (Lu & Xie, 2024). Consequently, the potential contribution of PBL to Biochemistry education should be considered in relation to students' demonstrated learning needs and the alignment between intended competencies, instructional activities, and assessment practices.

A systematic needs analysis provides an important foundation for identifying discrepancies between expected learning competencies, students' existing abilities, and the instructional opportunities available within educational environments (Lee & Owens, 2004). Lee and Owens (2004) positioned needs assessment and analysis as essential stages of instructional development because educational interventions should be informed by evidence concerning learners, learning conditions, and intended outcomes. In Biochemistry education, such analysis can incorporate students' collaborative problem-solving profiles, cognitive achievement, lecturers' instructional experiences, and documented curriculum requirements. Previous investigations have examined particular aspects of Biochemistry learning, including conceptual difficulties, PBL implementation, creative thinking, and the acceptability of online instructional approaches (Yusuf et al., 2021; Ernawati et al., 2022; Bai et al., 2023; Lavrič et al., 2025). Other studies have explored collaborative

problem-solving competencies and educational technologies across broader learning contexts, offering conceptual insights without necessarily addressing the specific instructional conditions of preservice Biology teachers studying Biochemistry (Andrews-Todd et al., 2023; Lu & Xie, 2024). Although these contributions establish relevant theoretical foundations, the literature considered in this study provides limited context-specific evidence integrating social CPSS, cognitive CPSS, cognitive learning outcomes, lecturer perspectives, and documented curriculum alignment within a single preliminary investigation. Examining these components together may clarify whether instructional expectations are adequately represented in planned learning activities and whether students experience particular difficulties in collaboration, hypothesis formulation, and higher-order cognitive processing. Furthermore, analyzing the Semester Learning Plan (RPS) can identify how problem-oriented learning objectives correspond to instructional strategies, learning resources, assessment components, and documented PBL characteristics. Such evidence may inform subsequent instructional refinement, including consideration of structured PBL activities or supplementary digital learning resources, without establishing the superiority or effectiveness of any particular intervention. Therefore, the present study addresses this context-specific research need by exploring collaborative problem-solving skills and cognitive learning outcomes among preservice Biology teachers in Biochemistry while incorporating lecturers' perspectives and curriculum documentation to establish an evidence-informed foundation for future instructional development.

METHOD

Research Design

This study employed a descriptive preliminary needs-analysis design within the needs assessment and analysis phase of the multimedia research and development model proposed by Lee and Owens (2004). Specifically, the study focused on identifying existing learning conditions and instructional needs before the subsequent instructional design, development, and evaluation stages. The analysis drew on quantitative data from student assessments and qualitative evidence from semi-structured lecturer interviews and analysis of the Biochemistry Semester Learning Plan (RPS). These sources were examined together to identify discrepancies between students' existing competencies, the intended learning outcomes, and the learning experiences provided in the course.

For this study, a learning gap was operationally defined as a discrepancy between the competencies expected in the Biochemistry course and evidence of students' existing performance and learning experiences. Expected competencies were identified from the learning outcomes specified in the RPS, whereas existing competencies were described using students' social and cognitive collaborative problem-solving skills (CPSS) and cognitive learning outcomes. Quantitative scores were interpreted using the predefined performance categories reported in the study. Interview evidence was examined to identify reported difficulties in student participation, problem identification, collaborative investigation, and access to learning resources. The RPS was examined to determine whether intended learning outcomes were reflected in planned instructional activities, learning resources, assessment, and systematic PBL stages. A learning gap was identified when these sources indicated a mismatch between intended competencies and existing performance or learning opportunities.

Within the broader research and development project, the BioSolve Biochemistry website supported by Problem-Based Learning (PBL) had been proposed as the intended instructional medium. Therefore, the purpose of this needs analysis was not to establish that a website was the only suitable solution or to demonstrate its effectiveness. Instead, the findings were used to identify instructional requirements that could inform the design of the proposed website. PBL was considered in relation to the identified need for structured problem investigation, hypothesis

formulation, and collaborative solution development, while the website was considered a possible platform for organizing learning materials and activities. The suitability of this proposed approach relative to alternative instructional media was outside the scope of the present study.

Participants

The student participants were fourth-semester undergraduate students in the Biology Education Program at Universitas Negeri Malang who had completed the Biochemistry course. Three class offerings (G, H, and I) were selected through convenience sampling based on accessibility to the researchers. Eligible students were invited to participate; 50 provided complete responses and were included in the analysis. Students who had not completed Biochemistry or whose responses were incomplete were excluded. The number of eligible students invited was not available in the study records consulted; consequently, a response rate could not be calculated.

The lecturer participants comprised five lecturers who taught Biochemistry in the Biology Education Program at Universitas Negeri Malang. They were selected purposively because of their direct experience with the course and their knowledge of its instructional practices, learning resources, and students' learning difficulties. All five participated in semi-structured interviews.

The sample size was not determined through an a priori statistical power calculation because the study was a descriptive needs analysis rather than a hypothesis-testing study. The 50 complete responses supported descriptive summaries of the participating class offerings but were not intended to produce statistically representative estimates or support population-level inference. The findings should therefore be interpreted as a preliminary profile of the investigated institutional context.

Instruments

Five instruments were used: a social CPSS questionnaire, a cognitive CPSS test, a cognitive learning outcomes test, a semi-structured lecturer interview guide, and a Biochemistry RPS document-analysis sheet. The 15-item social CPSS questionnaire covered nine indicators—action, interaction, task completion/perseverance, adaptive responsiveness, audience awareness, negotiation, self-evaluation, transactive memory, and responsibility initiative—based on the collaborative problem-solving framework described by Hesse et al. (2015). Responses used a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). Item scores were aggregated by indicator and overall, then expressed as percentages of the maximum possible score.

The 18-item cognitive CPSS test assessed nine indicators: organizing/problem analysis, goal setting, resource management, flexibility and ambiguity, information gathering, systematicity, relationships, contingency or "if–then" rules, and hypothesis formulation or "what-if" reasoning. The test items were framed as Biochemistry problem scenarios aligned with these indicators. Responses were evaluated using indicator-specific analytic scoring rubrics. Rubric criteria were scored on a five-point scale, with criterion scores aggregated for each indicator and converted to percentages of the maximum possible score. The indicators were grounded in the collaborative problem-solving framework described by Hesse et al. (2015).

The preliminary cognitive learning outcomes test comprised 10 questions: seven multiple-choice items (Questions 1–5, 8, and 10) and three constructed-response items (Questions 6, 7, and 9). The item blueprint mapped Question 1 to C1 (Remembering), Question 2 to C2 (Understanding), Question 3 to C3 (Applying), Questions 4 and 5 to C4 (Analyzing), Question 6 to C4/C5 subparts, Questions 7–9 to C5 (Evaluating), and Question 10 to C6 (Creating). Multiple-choice responses were scored dichotomously, and constructed responses were scored using item-specific analytic rubrics. Scores were converted to percentages based on the maximum possible score for the relevant level. Coverage across the six levels was uneven, and C6 was represented by only one multiple-choice item; therefore, level-specific comparisons, especially for C6, are exploratory rather than comprehensive

measures of cognitive ability. The classification framework followed the revised Bloom's Taxonomy (Anderson & Krathwohl, 2001).

The semi-structured lecturer interview guide covered teaching practices, student participation, collaborative problem-solving and cognitive learning difficulties, instructional strategies, learning materials, and the availability and use of digital learning resources. The RPS document-analysis sheet examined the alignment of intended learning outcomes with planned activities, instructional strategies, learning resources, assessment, and explicitly documented PBL characteristics. Both instruments were organized around the needs-analysis questions and the learning requirements examined in the study.

The RPS document-analysis sheet was developed to examine the alignment between intended learning outcomes and planned learning activities, instructional strategies, learning resources, and assessment. Particular attention was given to problem-oriented learning outcomes, the representation of PBL stages, and opportunities for collaborative investigation and higher-order cognitive processing. The interview guide and document-analysis sheet were organized around the objectives of the needs analysis and the learning requirements examined in the study.

Validity and Reliability of Instruments

Item-level analysis and internal consistency were examined for the quantitative instruments. Pearson item-total correlations were assessed at a 5% significance level. With 50 respondents, the reported critical correlation value was 0.2787. The original analysis reported that all 15 social CPSS questionnaire items and all 18 cognitive CPSS test items exceeded this threshold. Cronbach's alpha was 0.86 for the social CPSS questionnaire and 0.97 for the cognitive CPSS test. These statistics provide preliminary evidence about item relationships and internal consistency, but they do not independently establish the validity of the instruments.

For the cognitive learning outcomes test, item analysis and reliability estimation were conducted for the seven multiple-choice items only. The reported Cronbach's alpha coefficient was 0.88; this estimate does not establish the reliability of the entire mixed-format test, including its constructed-response items. No separate expert-panel content-validity procedure, content-validity index, or factor-analytic construct-validity analysis was documented for the preliminary instruments. Accordingly, validity claims are limited to the theoretical alignment of the indicators, item-level analyses, and the reported internal-consistency estimates. Further validation is required before these instruments are used for high-stakes or broad comparative interpretations.

Data Collection and Analysis

Student data were collected using the social CPSS questionnaire, cognitive CPSS test, and cognitive learning outcomes test. Quantitative results were summarized using mean scores and indicator-level percentages and were interpreted using the predefined performance categories. For the social questionnaire, item scores were aggregated by indicator and overall. For the cognitive CPSS test, rubric scores were aggregated by indicator and expressed as percentages of the maximum possible score. Cognitive learning outcomes were summarized according to the item blueprint and the six revised Bloom levels, with caution because item coverage differed across levels.

Interview records were read and coded using a descriptive, domain-driven thematic analysis. The predefined domains were student participation and CPSS, cognitive learning difficulties, learning models and activities, learning materials and media, and digital facilities. Within each domain, responses were compared across the five lecturers to identify recurring issues and divergent accounts; the summaries retained differences rather than forcing consensus. The RPS was examined using a structured analysis sheet. Documented SCPL, CPMK, and Sub-CPMK statements were mapped against planned learning activities, resources, assessment components, and explicitly specified PBL stages. Finally, quantitative results, lecturer themes, and documentary evidence were compared to

characterize convergence and differences between assessed performance, reported teaching practices, and the written course plan.

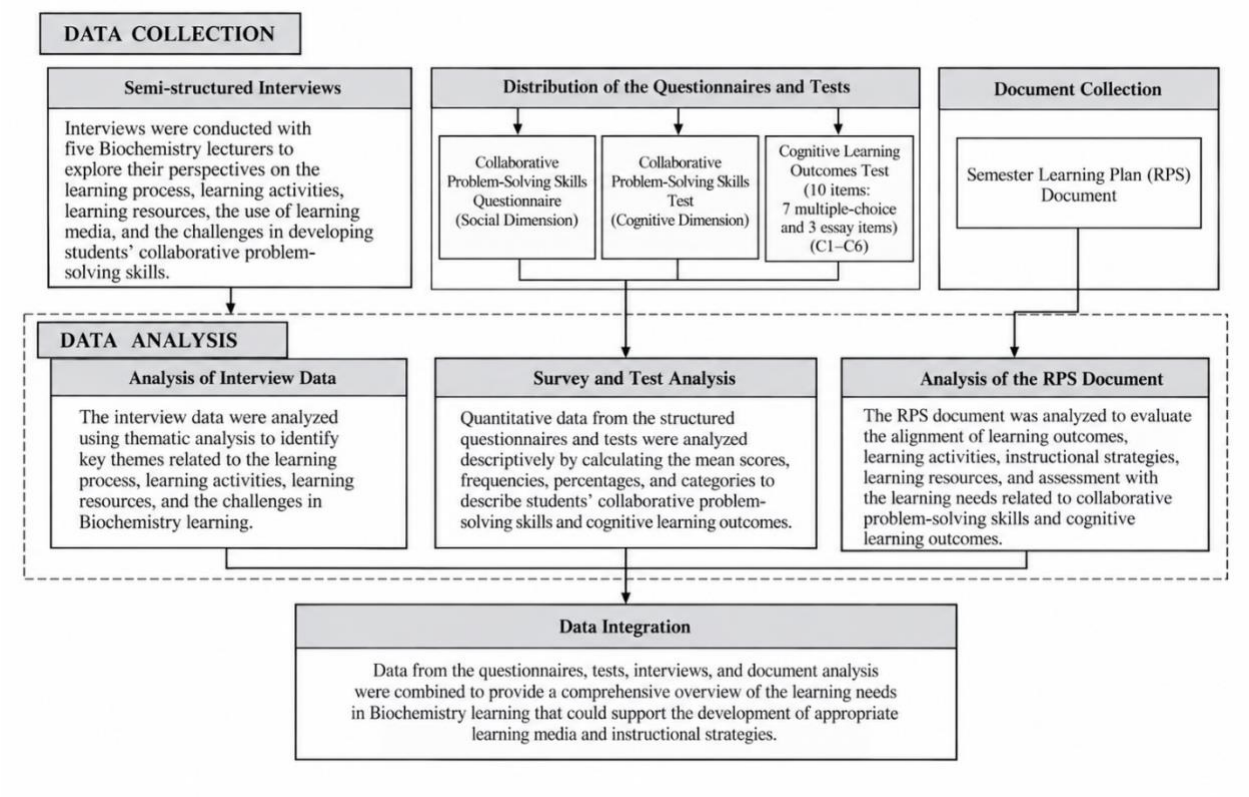


Figure 1. Research Data Collection and Analysis Flow

RESULTS AND DISCUSSION

Results

The needs analysis revealed several important findings regarding students' collaborative problem-solving skills, cognitive learning outcomes, and existing Biochemistry learning conditions. The findings were obtained from student assessments, lecturer interviews, and analysis of the Biochemistry learning documents, which provided complementary information about students' current abilities and the learning experiences provided in the course. The results are presented sequentially, beginning with students' social collaborative problem-solving skills, followed by their cognitive collaborative problem-solving skills and cognitive learning outcomes, and are complemented by findings from lecturer interviews and the analysis of the Semester Learning Plan (RPS).

Social Skills in Collaborative Problem-Solving

The analysis of students' social Collaborative Problem-Solving Skills (CPSS) was conducted based on nine indicators, namely action, interaction, task completion/perseverance, adaptive responsiveness, audience awareness/mutual modelling, negotiation, self-evaluation/metamemory, transactive memory, and responsibility initiative. The results of the analysis for each indicator are presented in Figure 2.

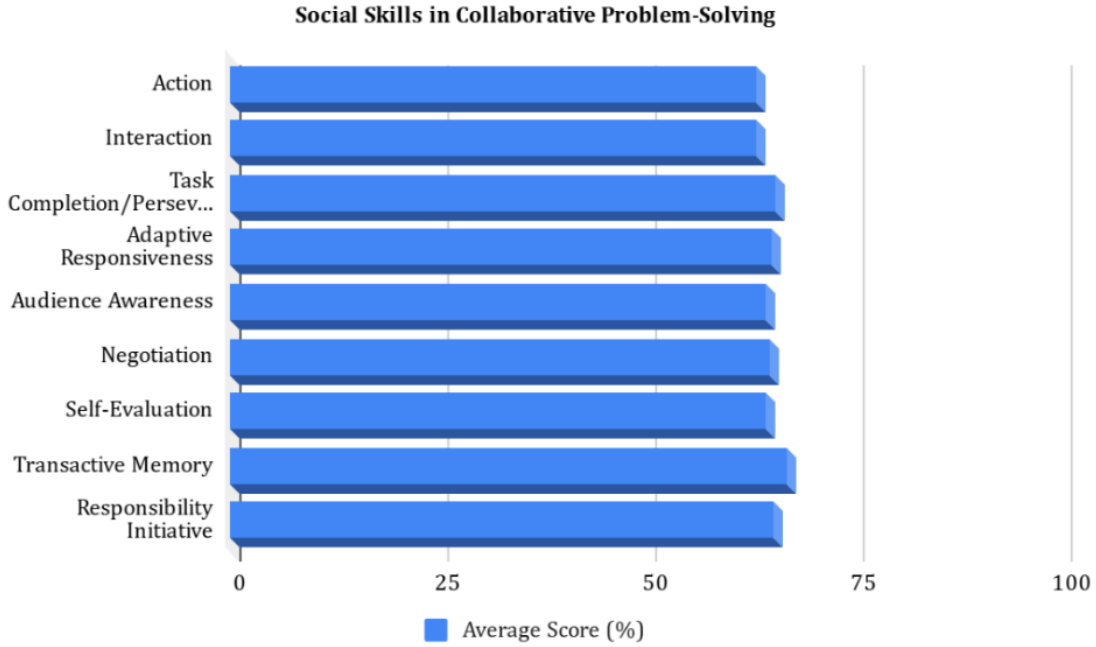


Figure 2. Average Scores for Each Indicator of Social Collaborative Problem-Solving Skills (CPSS)

Figure 2 shows that all indicators of students' social Collaborative Problem-Solving Skills (CPSS) were categorized as moderate. The highest score was obtained for the transactive memory indicator at 66.8%, while the lowest score was found for the action indicator at 63.2%. Overall, students' social CPSS achieved an average score of 64.75%, which was categorized as moderate. These findings indicate that students' ability to establish social collaboration during the problem-solving process still needs to be strengthened, particularly in initiating collaborative actions and developing active contributions to the problem-solving process. Table 1 presents the average scores for each indicator of students' social CPSS in greater detail.

Table 1. Average Score for Each Social Skill Indicator in Collaborative Problem-Solving

No	CPSS Indicator	Average Score (%)	Category
1	Action	63.2	Moderate
2	Interaction	63.33	Moderate
3	Task Completion/Perseverance	65.6	Moderate
4	Adaptive Responsiveness	65	Moderate
5	Audience Awareness	64.4	Moderate
6	Negotiation	64.8	Moderate
7	Self-Evaluation	64.4	Moderate
8	Transactive Memory	66.8	Moderate
9	Responsibility Initiative	65.2	Moderate
Average		**64.75**	**Moderate**

Source: Authors' analysis based on Hesse et al. (2015)

The students' collaborative problem-solving skills (CPSS) were classified based on the percentage scores obtained from the assessment results. The scores were categorized into five levels, namely very good, good, moderate, poor, and very poor. The criteria used to classify the students' collaborative problem-solving skills are presented in Table 2.

Table 2. Criteria for Collaborative Problem-Solving Skills (CPSS)

Percentage (%)	Criteria
X ≥ 85	Very Good
70 ≤ X < 85	Good
55 ≤ X < 70	Moderate
40 ≤ X < 55	Poor
X < 40	Very Poor

Source: Adapted from Sulisetijono (2018, p. 76)

Cognitive Collaborative Problem-Solving Skills

The analysis of students' cognitive Collaborative Problem-Solving Skills (CPSS) was conducted based on nine indicators, namely organizing, goal setting, resource management, flexibility and ambiguity, information gathering, systematicity, relationships, "if–then" rules, and "what-if" hypothesis formulation. The average achievement for each indicator of cognitive CPSS is presented in Figure 3.

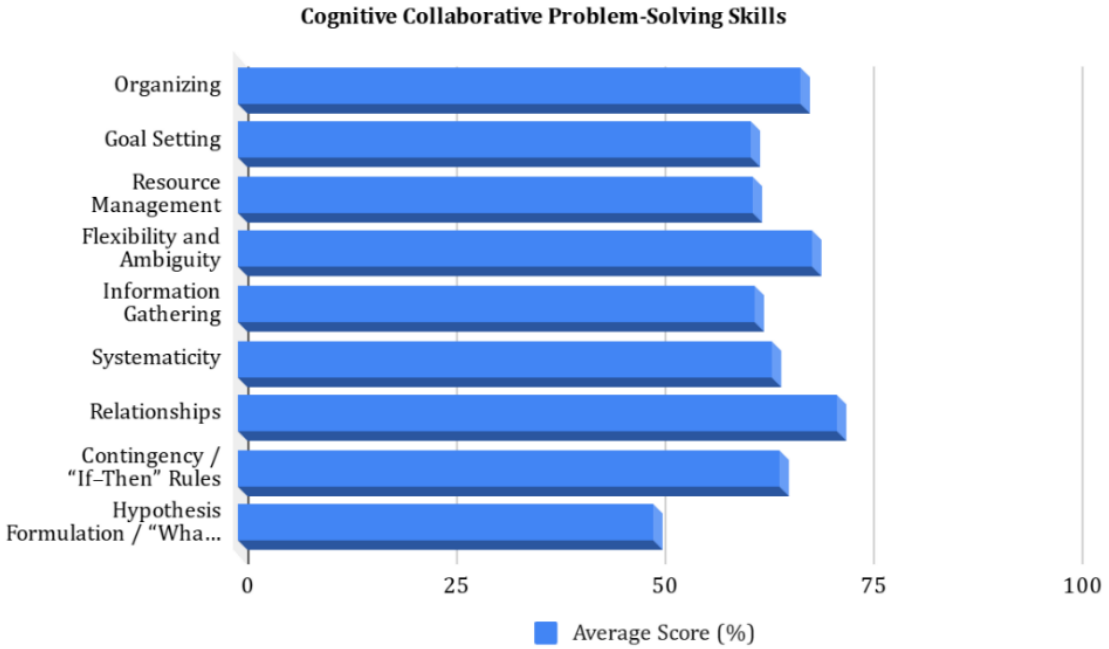


Figure 3. Average Scores for Each Indicator of Cognitive Collaborative Problem-Solving Skills (CPSS)

Based on Figure 3, students' cognitive Collaborative Problem-Solving Skills (CPSS) showed varying levels of achievement across the indicators. The relationships – represents and formulates indicator obtained the highest score of 71.8%, which was categorized as good, whereas the hypothesis: what if – reflects and monitors indicator obtained the lowest score of 49.8%, which was categorized as poor. Overall, students' cognitive CPSS achieved an average score of 63.47%, which was categorized as moderate. These findings indicate that students were relatively capable of understanding conceptual relationships and representing relationships within Biochemistry problems but still experienced difficulties in formulating hypotheses and collaboratively developing possible problem-solving strategies. The average scores and categories for each indicator of students' cognitive CPSS are presented in Table 3.

Table 3. Average Scores for Each Indicator of Cognitive Collaborative Problem-Solving Skills (CPSS)

No	CPS Indicator	Average Score (%)	Category
1	Organizing	67.4	Moderate
2	Goal Setting	61.4	Moderate
3	Resource Management	61.6	Moderate

4	Flexibility and Ambiguity	68.8	Moderate
5	Information Gathering	61.8	Moderate
6	Systematicity	63.8	Moderate
7	Relationships	71.8	Good
8	Contingency / "If–Then" Rules	64.8	Moderate
9	Hypothesis Formulation / "What If …"	49.8	Poor
	Average	**63.47**	**Moderate**

Source: Authors' analysis based on Hesse et al. (2015)

Cognitive Learning Outcomes

The analysis of students' cognitive learning outcomes was conducted based on six levels of cognitive processes, namely C1 Remembering, C2 Understanding, C3 Applying, C4 Analyzing, C5 Evaluating, and C6 Creating. The analysis was conducted to determine students' cognitive achievement at each level of thinking. The average scores for each cognitive level are summarized in Table 4.

Table 4 summarizes students' cognitive learning outcomes across the six cognitive levels. Students demonstrated relatively higher achievement at C1–C3 than at C4–C5, while C6 showed the lowest achievement. The overall mean score was 66.73%, which was categorized as moderate. This pattern suggests that students performed better on remembering, understanding, and applying Biochemistry concepts than on more complex cognitive tasks. However, because C6 was represented by only one item, the result should be interpreted cautiously as a preliminary indication of students' performance at the creating level rather than a comprehensive measure of this cognitive ability.

Table 4. Average Scores for Each Cognitive Level of Learning Outcomes

No	Cognitive Level	Average Score (%)	Category
1	C1 Remembering	74	Good
2	C2 Understanding	76	Good
3	C3 Applying	78	Good
4	C4 Analyzing	66.83	Moderate
5	C5 Evaluating	67.55	Moderate
6	C6 Creating	38	Poor
	Average	**66.73**	**Moderate**

Source: Authors' analysis of preliminary-study test data. Cognitive levels were classified according to the revised Bloom's Taxonomy (Anderson & Krathwohl, 2001).

The cognitive learning outcome scores were classified into five performance categories using the classification formula described by Sulisetijono (2018, p. 76). The formula was applied to the scores obtained in this preliminary study, resulting in the following category thresholds: very good ($X \geq 87.73\%$), good ($70.45\% \leq X < 87.73\%$), moderate ($53.18\% \leq X < 70.45\%$), poor ($35.91\% \leq X < 53.18\%$), and very poor ($X < 35.91\%$). These calculated thresholds were used to classify students' cognitive learning outcomes, as presented in Table 5.

Table 5. Criteria for Cognitive Learning Outcomes

Percentage Range (%)	Category
$X \geq 87.73$	Very Good
$70.45 \leq X < 87.73$	Good
$53.18 \leq X < 70.45$	Moderate
$35.91 \leq X < 53.18$	Poor
$X < 35.91$	Very Poor

Source: Adapted from Sulisetijono (2018, p. 76)

Lecturer Interview Findings

Semi-structured interviews with five Biochemistry lecturers examined student participation, learning difficulties, instructional approaches, learning resources, and digital facilities. Table 6

summarizes the interview findings, including areas of agreement and differences in lecturers' accounts. These findings describe reported teaching practices and perceptions; they do not, by themselves, establish that a particular medium is necessary or effective.

Table 6. Summary of Lecturer Interview Findings

Aspect	Synthesized Interview Findings
Collaborative problem-solving skills (CPSS)	Lecturers described group assignments, presentations, and discussions as common features of Biochemistry teaching, but their assessments of collaboration varied. Some reported good cooperation and communication during presentations or problem-oriented discussions. Others described uneven participation, repeated contributions from a few students, and a need to strengthen independent problem identification, responses to differing opinions, and shared responsibility.
Cognitive learning and problem-solving	Several lecturers reported that students needed prompts to identify problems, set goals, select relevant information, analyze evidence, and develop alternative solutions. Other accounts described students connecting Biochemistry concepts with real-life cases when problems and supporting resources were provided. Overall, the interviews highlighted variation in students' independent problem-solving and in the guidance provided during learning activities.
Learning models and activities	Reported practices varied across lecturers. Some identified PBL as a regular approach involving contextual cases, group discussion, problem analysis, presentations, and feedback. Others reported that PBL was not used intensively in every meeting or was not specifically implemented; their classes relied more on content explanations, PowerPoint presentations, videos, discussions, presentations, summaries, or mind maps. The interviews therefore indicate variation in the implementation of problem-based learning rather than a complete absence of PBL.
Learning materials and instructional media	The reported resources included textbooks, e-books, journal articles, RPS references, handouts, PowerPoint presentations, videos, case-related images, and online information. Some lecturers did not prepare dedicated student worksheets or investigation materials that systematically guided all PBL stages; the use of worksheets varied and, in some cases, depended on the learning activity. One lecturer described the available media as insufficiently varied and highlighted the value of images and biochemical pathways for representing abstract concepts.
Digital resources, facilities, and website perceptions	Lecturers generally described classroom facilities, students' access to personal devices, and internet access as adequate. Digital tools were used for information searches, sharing learning materials, presentations, and online assessment, although the tools used varied across lecturers. A dedicated Biochemistry learning website was not described as an established practice across the interviews. Several lecturers viewed a website as a possible supplementary platform for organizing materials, videos, structured activities, and visual representations. One lecturer also noted the potential to reduce time spent searching for suitable resources, while concerns about students' overreliance on AI were raised.

Across the five interviews, lecturers described differences in student participation and in the frequency and structure of PBL-related activities. Some reported using contextual problems or case-based activities, whereas others described less intensive use of problem-based approaches or

teaching organized mainly around explanations, presentations, and discussions. This variation is important when interpreting the quantitative findings and the planned curriculum, because no single account represented all lecturers.

The Biochemistry RPS contains explicit problem-oriented learning outcomes. SCPL refers to identifying and analyzing scientific problems or phenomena through a careful, critical, and systematic approach; CPMK 2 requires students to identify and analyze Biochemistry problems and design scientific investigations to obtain accurate and accountable data; and Sub-CPMK 2.2 refers to analyzing procedures and problems related to amino acid, protein, and enzyme metabolism based on real scientific phenomena. The RPS also lists learning activities, resources, and assessment components but does not explicitly map them to a complete PBL sequence. This finding concerns the documented plan rather than actual classroom implementation. The documentary evidence and its relationship to PBL characteristics are summarized in Table 7.

Table 7. Documentary Findings from the Biochemistry Semester Learning Plan (RPS)

RPS Component	Documentary Evidence	Interpretation for Needs Analysis
Learning outcomes	The SCPL refers to identifying and analyzing scientific problems or phenomena through a careful, critical, and systematic approach. CPMK 2 requires students to identify and analyze Biochemistry problems and design scientific investigations to obtain accurate and accountable data. Sub-CPMK 2.2 refers to analyzing procedures and problems related to amino acid, protein, and enzyme metabolism based on real scientific phenomena.	These outcomes are consistent with problem-oriented learning and scientific investigation. However, stated outcomes alone do not show how the competencies are translated into a systematic sequence of PBL activities.
Planned learning activities	The course plan lists discussion, analysis, communication of course topics, practical activities, student assignments, and reports.	These activities provide opportunities for discussion, analysis, and communication. The RPS does not explicitly map them to a complete sequence of PBL stages, including problem orientation, student organization, investigation, presentation, and reflection or evaluation.
Learning materials and media	The documented resources include PowerPoint presentations, videos, textbooks, and other references.	These resources support access to Biochemistry content. The RPS does not explicitly show how resources are coordinated to support investigation and problem solving at each PBL stage.
Assessment	The course plan lists participatory activities, project results, assignments, quizzes, and midterm and final examinations.	Several assessment components are documented. However, the RPS does not explicitly map assessment criteria to each PBL stage or specify how collaborative problem-solving competencies are assessed throughout the learning process.

RPS Component	Documentary Evidence	Interpretation for Needs Analysis
Alignment among outcomes, activities, and assessment	Problem-oriented competencies appear in the SCPL, CPMK, and Sub-CPMK, while activities, resources, and assessment components are listed in the course plan.	The documented components provide a basis for problem-oriented learning, but their alignment within a systematic PBL sequence is not explicitly demonstrated in the RPS. This finding concerns the written plan and does not establish what occurred in classroom practice.

Discussion

Students' social CPSS profile showed a moderate overall level, with action the lowest indicator and transactive memory the highest. This contrast suggests that students' reported ability to draw on group members' contributions may be stronger than their tendency to initiate collaborative activity. The pattern is relevant to He et al. (2023), whose systematic review identified students' roles in collaborative learning as an important consideration for developing collaborative problem-solving competency. It is also consistent with the broader argument that productive collaboration requires purposeful coordination of contributions, not simply the assignment of group work (Hesse et al., 2015; Graesser et al., 2018). Nevertheless, the action score does not demonstrate that students are generally unaccustomed to collaboration; rather, it identifies initiation of action as a relative weakness in this assessment. The finding suggests considering learning activities that make contributions and responsibilities explicit and create opportunities for students to initiate discussion and coordinate tasks.

Within the cognitive CPSS assessment, the relationships indicator received the highest score, whereas "what-if" hypothesis formulation received the lowest. The contrast points to a specific difficulty with generating hypotheses or alternative possibilities in the assessed problem-solving tasks; it should not be generalized to all aspects of students' reasoning. This profile is compatible with the multidimensional framework of collaborative problem solving, which distinguishes representing and relating information from monitoring, managing, and developing possible solutions (Hesse et al., 2015). Ceballos et al. (2026) likewise emphasize that collaborative problem solving is supported by learning designs that engage students in cognitively demanding processes, not just social interaction. In this context, tasks asking students to state a tentative hypothesis, support it with evidence, and compare competing explanations could directly address the observed weakness. Their value remains a pedagogical implication to be tested, not an effect established by this needs analysis.

The cognitive learning outcomes showed a different pattern across the six levels: performance was relatively higher on C1–C3 items, lower on C4–C5 tasks, and lowest on C6. Because the C6 estimate came from a single item, it should be treated only as an exploratory signal rather than a robust measure of students' creating ability. The finding raises a question about opportunities for integrating knowledge and constructing solutions, but the present instrument cannot establish a broad domain-level deficit in creativity. This pattern can be considered alongside intervention studies reporting that PBL with scaffolding can support creative thinking in Biochemistry (Ernawati et al., 2022) and research examining higher-order thinking in blended problem-based learning (Sulistiyani et al., 2025). Those studies evaluate instructional approaches, whereas the present study provides a baseline profile with unequal item coverage; the results therefore are not directly comparable and do not show that the same intervention effects would occur in this context.

Taken together, the assessment results identify relative weaknesses in initiating collaborative actions, formulating hypotheses, and performance on the single C6 item. Lecturer interviews provide contextual evidence: some lecturers described good cooperation during group

work, while others reported uneven participation and a need for guidance in identifying problems, setting objectives, and conducting deeper analysis. These accounts suggest an association between the measured difficulties and reported learning conditions, but they do not establish that instructional practices caused the performance gaps. RPS analysis adds documentary evidence that problem-oriented outcomes are specified, while the mapping of activities, resources, and assessment to a complete PBL sequence is not explicit. Together, the three sources identify areas for instructional alignment without establishing the necessity or effectiveness of a specific medium.

A systematic PBL sequence is relevant to the needs identified here because it can organize the specific processes implicated by the data: presenting a contextual problem, agreeing on goals and responsibilities, investigating information, formulating and revising hypotheses, evaluating evidence, and developing and presenting solutions. Studies of PBL in higher-education Biochemistry report its use with complex or authentic problems (Lavrič et al., 2025), and Bai et al. (2023) reported the feasibility and acceptability of fully or partially online PBL in a large Biochemistry class. These studies support the pedagogical relevance of PBL, although they do not establish that it will necessarily improve CPSS or cognitive outcomes in the present setting. The needs-analysis findings therefore support considering systematic PBL as an approach that matches the documented learning requirements, with its effects to be examined in subsequent research.

The interviews also suggest that the main issue is not simply access to technology. Lecturers described using textbooks, e-books, journal articles, PowerPoint presentations, videos, images, online information sources, and other digital tools, while the use of a dedicated Biochemistry learning website was not described as an established practice. The organization and instructional use of these resources varied across lecturers. Lu and Xie (2024) found in their systematic review that educational technology for problem-solving is most useful when aligned with instructional guidance, scaffolding, and collaboration rather than added as a stand-alone tool. Thus, a website could be considered as one possible way to coordinate contextual problems, molecular representations, learning resources, and structured tasks; the evidence does not establish that digital delivery is indispensable or superior to alternative media.

Overall, the three data sources point to a need for stronger alignment between intended Biochemistry competencies and learning opportunities for collaboration, hypothesis formulation, evidence analysis, and solution development. The interviews show variation in current practices, while the RPS documents problem-oriented outcomes without explicitly mapping all activities, resources, and assessment to a complete PBL sequence. These findings provide a context-specific basis for refining instructional design requirements; they should not be interpreted as evidence that a particular website or instructional intervention is already effective.

Implications

The lecturer interviews and RPS analysis indicate specific alignment gaps between intended learning outcomes, planned activities, learning resources, and assessment. The RPS states that students should identify and analyze Biochemistry problems and design scientific investigations, but it does not explicitly map its listed discussions, practical work, presentations, and assignments to a complete PBL sequence. Likewise, PowerPoint presentations, videos, textbooks, projects, assignments, quizzes, and examinations are listed, but their roles in supporting and assessing collaborative problem-solving processes at each PBL stage are not specified. Interview accounts further indicate variation in PBL use: some lecturers described contextual or case-based activities, whereas others reported less intensive or no specifically designated PBL implementation. These findings support a pedagogical need for clearer alignment, rather than a conclusion that all existing teaching is non-problem-based.

The observed weaknesses in initiating collaborative actions and formulating hypotheses suggest that systematic PBL activities could provide structured opportunities for problem

identification, shared investigation, evidence-based reasoning, solution development, presentation, and reflection. This rationale is consistent with studies of PBL in higher-education Biochemistry, including online and partially online implementations (Bai et al., 2023; Lavrič et al., 2025). However, this needs analysis does not establish that digital delivery is indispensable or superior to other media. Because lecturers reported using digital resources but did not describe a dedicated website as an established component of Biochemistry teaching, a website may be considered as one possible means of organizing contextual problems, curated resources, collaborative tasks, and assessment within a coherent learning sequence. The suitability and effectiveness of such a medium require evaluation in subsequent research.

Limitations and Suggestions for Future Research

The findings should be interpreted in light of several methodological limitations. First, the study used a descriptive needs-analysis design at a single institution with 50 complete student responses selected from three accessible class offerings; its findings should not be generalized beyond this context without further evidence. The number of eligible students invited was not recorded in the materials available for this analysis, so a response rate could not be calculated and nonresponse effects cannot be assessed. Second, the social CPSS questionnaire relied on students' self-reports, which may reflect perceived rather than observed collaborative behavior. No direct classroom observation was conducted to independently verify the lecturers' accounts or students' self-reported collaboration. Third, instrument evidence was limited to item-level correlations and internal-consistency estimates; no separate expert-panel content-validity procedure or construct-validity analysis was documented. Fourth, the cognitive learning outcomes test had uneven item coverage across the six Bloom levels, with C6 represented by one multiple-choice item. Its score is therefore exploratory and should not be interpreted as a comprehensive measure of creating ability. Finally, prior knowledge, motivation, and learning engagement were not examined in depth, and the study did not test or compare the effectiveness of any instructional medium.

Further research should validate the instruments more comprehensively, refine a learning design in response to the identified needs, and evaluate any proposed medium through studies that assess usability and learning outcomes. Effectiveness testing should use transparent recruitment procedures, adequate item coverage for each cognitive level, and—where feasible—multiple classes or institutions to examine the transferability of the findings.

CONCLUSION

This study explored social and cognitive collaborative problem-solving skills (CPSS) and cognitive learning outcomes among undergraduate Biology Education students who had completed Biochemistry at Universitas Negeri Malang. The assessment identified relative difficulties in initiating collaborative actions and formulating "what-if" hypotheses, while performance on the creating level (C6) was low but based on only one test item and must therefore be interpreted cautiously. Lecturer interviews showed variation in participation and PBL implementation, whereas the RPS documented problem-oriented learning outcomes without explicitly mapping activities, learning resources, and assessment to a complete PBL sequence. Together, the quantitative and qualitative findings identify learning needs concerning collaborative roles, hypothesis formulation, evidence analysis, and alignment between intended outcomes and planned learning experiences.

The findings provide context-specific evidence that can inform instructional planning and subsequent development decisions. Systematic PBL activities may be considered to structure problem identification, collaborative investigation, hypothesis evaluation, and solution development. A website could be one possible means of organizing such activities and associated learning

resources, but this study neither establishes that a website is the only suitable medium nor demonstrates the effectiveness of BioSolve. Further research should strengthen instrument evidence and rigorously evaluate any proposed instructional design before claims about its effects on CPSS or cognitive learning outcomes are made.

AUTHOR CONTRIBUTIONS STATEMENT

Ajeng Retno Astrini contributed to the conceptualization of the study, research design, literature review, instrument development, data collection, data analysis, interpretation of findings, and preparation of the original manuscript. Zizah Estuning Erina contributed to the preliminary needs analysis, data collection, organization of research data, and documentation of students' collaborative problem-solving skills, cognitive learning outcomes, and existing Biochemistry learning conditions. Balqis contributed to methodological development, research supervision, data interpretation, manuscript validation, and critical review and revision to strengthen its scientific rigor and academic quality. Murni Saptasari contributed to academic supervision, conceptual and methodological guidance, evaluation of research findings, manuscript review, and critical revisions to improve the coherence, accuracy, and scientific contribution of the study. All authors reviewed and approved the final version of the manuscript.

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