



# Correlation Analysis between Understanding Biochemistry Concepts and Chemistry Education Students' Problem-Solving Skills through Validated HOTS Instruments

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**Abstract:** Understanding biochemistry concepts and problem-solving skills are essential competencies for chemistry education students in facing the demands of 21st-century science learning. However, empirical evidence regarding the relationship between these competencies measured through Higher Order Thinking Skills (HOTS)-based instruments remains limited. This study aimed to analyze the correlation between students' understanding of biochemistry concepts and their problem-solving skills using validated HOTS instruments. A quantitative correlational design was employed involving 60 Chemistry Education students who had completed the Biochemistry course. Data were collected using a HOTS-based biochemistry concept understanding test and a HOTS-based problem-solving skills test. The instruments were validated by experts and tested for reliability. Data were analyzed using descriptive statistics and Pearson correlation analysis after fulfilling normality and linearity assumptions. The results showed that the mean score of biochemistry concept understanding was 72.35 (SD = 8.42), while the mean score of problem-solving skills was 68.10 (SD = 9.15). The normality and linearity tests indicated that the data met the requirements for parametric analysis. Pearson correlation analysis revealed a positive and significant correlation between biochemistry concept understanding and problem-solving skills ( $r = 0.63$ ,  $p < 0.05$ ). Furthermore, the coefficient of determination ( $r^2 = 0.40$ ) indicated that understanding biochemistry concepts contributed 40% to the variance in students' problem-solving skills. These findings demonstrate that stronger conceptual understanding is associated with better problem-solving performance. In conclusion, understanding biochemistry concepts significantly contributes to the development of students' problem-solving skills. Therefore, integrating HOTS-oriented learning and assessment into biochemistry instruction is recommended to enhance conceptual mastery and higher-order thinking skills among prospective chemistry teachers.

**Keywords:** Biochemistry education; Chemistry teacher education; Conceptual understanding; Higher-order thinking skills; Problem-solving skills

## Introduction

The development of 21st century education requires students not only to master factual knowledge, but also to have high-level thinking skills such as analysis, evaluation, and problem solving (Amanda, 2022; Arofiq, 2024; Karitas & Suwartono, 2023; Sutedjo, 2013). In the context of science education, this ability is

an important foundation in forming prospective teachers who are adaptive, reflective, and able to comprehensively explain scientific phenomena. The Chemistry Education study program, as an institution that produces prospective chemistry teachers, has the responsibility to ensure that students not only understand concepts in a declarative way, but also are

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able to apply these concepts in authentic problematic situations.

Biochemistry is one of the core courses that has complex and abstract characteristics because it discusses chemical processes at the molecular level (Sari et al., 2023; Setiadi, 2013; Suhartono, 2017; Yanuarti et al., 2020). Materials such as biomolecular structures (Khalidah, 2022; Nurjayadi et al., 2023), metabolism (Jim, 2014; Novitasari, 2017; Prihatini & Dewi, 2021), and enzymatic regulation (Asyifa, 2025; Fibriani et al., 2019; Jelmila et al., 2026) demand microscopic representation skills as well as the integration of various chemical and biological concepts. This complexity often causes students to experience misconceptions or partial understandings. In fact, a deep understanding of biochemical concepts is needed so that students are able to explain the relationship between biological processes scientifically and transform them into meaningful learning in schools (Anwar et al., 2018; Astuti et al., 2021; Muhammad et al., 2022; Sulistiany & Darmawan, 2020; Wijayanti & Lestari, 2018).

Theoretically, understanding concepts includes not only the ability to remember and explain definitions, but also the ability to relate concepts, apply them to new contexts, and evaluate solutions to a problem. In the revision of Bloom's Taxonomy, these abilities are included in the category of Higher Order Thinking Skills (HOTS) (Pangestuti et al., 2024; Himmah, 2019; Irma Aryani, 2024; Izzati & Febrian, 2021; Qudsiyah et al., 2023). One of the real indicators of high-level thinking skills is problem-solving skills. Problem-solving in science learning requires students to understand problem situations, design solution strategies, integrate relevant concepts, and evaluate solutions logically and systematically.

Various studies show that a strong conceptual understanding is an important prerequisite for solving science problems. Students who have a well-organized conceptual structure tend to be more effective in identifying important variables, choosing solution strategies, and avoiding conceptual errors. However, in the practice of learning in higher education, the measurement of concept understanding and problem-solving skills often still uses conventional instruments that are oriented towards low-level thinking skills. This has the potential to cause students' cognitive abilities to not be fully captured.

From a cognitive learning perspective, meaningful learning occurs when new knowledge is integrated into existing cognitive structures (Ausubel, 1968). Students who possess well-organized conceptual knowledge are more capable of transferring and applying concepts in unfamiliar situations. This view is supported by constructivist learning theory, which emphasizes that knowledge is actively constructed through interactions

between prior knowledge and new experiences (Piaget, 1972; Vygotsky, 1978). In the context of biochemistry learning, conceptual understanding serves as the foundation for scientific reasoning and facilitates students in analyzing biochemical phenomena and generating appropriate solutions to complex problems.

Furthermore, problem-solving skills are considered one of the most important competencies in science education because they reflect students' ability to apply knowledge, evaluate evidence, and make reasoned decisions. Jonassen (2011) argues that effective problem solving depends on the quality of conceptual knowledge and mental representations possessed by learners. Similarly, Anderson and Krathwohl's revision of Bloom's Taxonomy places analysis, evaluation, and creation as higher-order cognitive processes that are essential for solving authentic scientific problems. Therefore, the development of conceptual understanding and problem-solving skills should be integrated through Higher Order Thinking Skills (HOTS)-oriented learning and assessment.

Instruments based on Higher Order Thinking Skills (HOTS) are designed to measure the ability to analyze, evaluate, and create in more depth (Muchtari et al., 2024; Rahmawati & Faizah, 2023; Sinta et al., 2022; Sukowati & Ekawati, 2024; Zulfayani et al., 2024). The HOTS assessment not only tests the ability to reproduce information, but also requires students to integrate knowledge in new and complex situations. Therefore, the use of HOTS instruments in biochemistry learning is relevant to uncover the relationship between concept understanding and problem-solving skills more authentically.

Although many studies on concept understanding and problem solving in science education have been conducted, research that specifically analyzes the relationship between the two variables in the context of biochemistry learning using validated HOTS instruments is still relatively limited, especially in Chemistry Education students as prospective teachers. This research gap is the basis for the urgency of this study.

Based on this background, this study aims to analyze the relationship between the understanding of biochemistry concepts and the problem-solving skills of Chemistry Education students through validated HOTS instruments. This research is expected to make a theoretical contribution in strengthening the study of the relationship between conceptual structure and problem-solving skills, as well as practical contributions in the development of biochemical learning and assessment oriented to strengthening higher-level thinking skills.

## Method

This study uses a quantitative approach with a correlational design in accordance with the characteristics of chemistry education research that focuses on the relationship between variables.

### Research Subject

The research subject is a student of the Chemistry Education Study Program who has taken a Biochemistry course in the middle semester. The sampling technique uses purposive sampling with consideration of the suitability of the material that has been studied.

### Research Instruments

The research instrument consists of two types of tests based on Higher Order Thinking Skills (HOTS), namely: (1) A biochemical concept understanding test that includes indicators of analyzing concepts, relating concepts to contextual phenomena, and applying concepts in problem-solving. (2) A test of problem-solving skills that includes indicators of understanding problems, designing solution strategies, implementing solutions, and evaluating results. The instrument is developed based on the HOTS indicator and validated through expert judgment. The reliability of the instrument was tested using Cronbach's Alpha coefficient.

### Data Analysis Techniques

The data was analyzed using descriptive statistics to determine the profile of students' concept understanding and problem-solving skills. Prerequisite tests include normality tests and linearity tests. The analysis of the relationship between variables was carried out using the Pearson correlation test with a significance level of 0.05.

### Research Flowchart

Figure 1 Research flowchart illustrating the stages of instrument development, data collection, and correlation analysis between biochemistry concept

understanding and problem-solving skills using validated HOTS instruments.

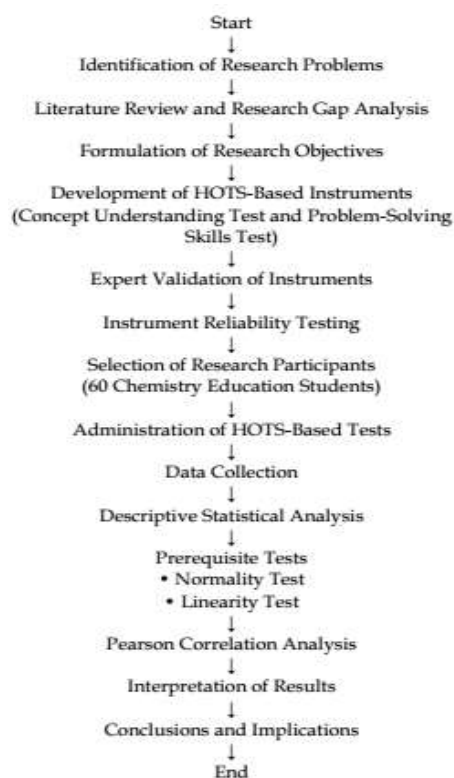


Figure 1. Research flowchart

## Result and Discussion

### Research Results

#### Description of Understanding Biochemical Concepts and Problem-Solving Skills

Descriptive statistical analysis was conducted to describe the profile of biochemistry concept understanding and problem-solving skills of Chemistry Education students. The results of the analysis showed that the average score of students' understanding of biochemistry concepts was 72.35 (SD = 8.42) with a score range of 45–90. Based on the ideal score category interval, this achievement is in the medium to high category.

**Table 1.** Descriptive Statistics Understanding of Biochemical Concepts and Problem Solving Skills of Students

Variable	N	Score Minimum	Maximum Score	Average	Standard Deviation	Category
Understanding biochemical concepts	60	45	90	72.35	8.42	Medium-High
Problem-Solving Skills	60	40	85	68.10	9.15	Medium

Remarks: Categories are determined based on ideal score intervals. The number of research subjects is 60 students of the Chemistry Education Study Program who have taken Biochemistry courses.

Meanwhile, the average score of problem-solving skills was 68.10 (SD = 9.15) with a score range of 40–85 and was in the medium category. These findings indicate that although students have a relatively good

conceptual structure, the ability to implement these concepts in problematic situations is still not optimal.

Comparatively, the standard deviation in both variables shows a relatively homogeneous distribution of data, so that the variation in ability between students

is not too extreme. This shows that students' academic achievements tend to be in a balanced distribution. The following are the results of descriptive statistics on understanding of biochemistry concepts and student problem-solving skills and their graphs.

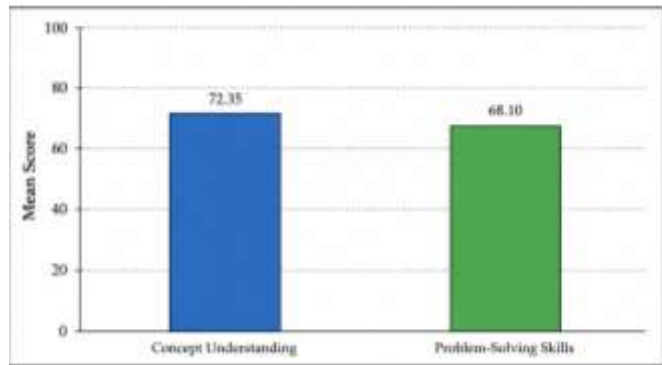


Figure 2. Concept comprehension score

Prerequisite Test Table (Normality & Linearity)

Before the correlation test is carried out, the data is first tested for normality and linearity. The results of the Kolmogorov-Smirnov normality test showed that the data on understanding biochemical concepts ( $p = 0.200$ ) and problem-solving skills ( $p = 0.200$ ) were distributed normally due to the significance value  $> 0.05$ .

Furthermore, the linearity test showed a linearity significance value of  $0.001 (< 0.05)$ , which means that the relationship between the two variables is linear. With the fulfillment of these two prerequisites, Pearson correlation analysis can be performed parametrically.

Table 2. Results of the Data Normality Test (Kolmogorov-Smirnov)

Variable	Statistics K-S	Sig. (p)	Remarks
Understanding Biochemical Concepts	0.094	0.200	Normal
Problem-Solving Skills	0.087	0.200	Normal

Criteria: Data is normally distributed if  $p > 0.05$ .

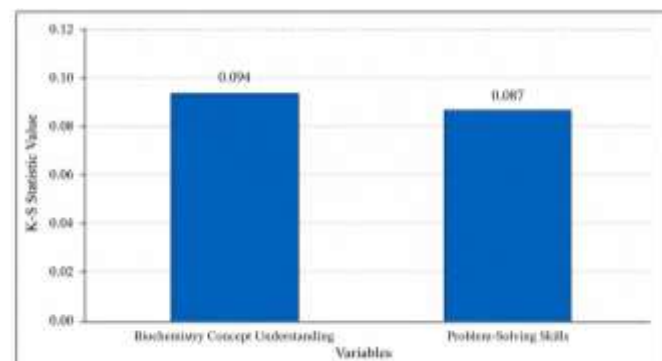


Figure 3. Normality test results

The results of the prerequisite test showed that the data on understanding biochemistry concepts and

problem-solving skills were normally distributed ( $p > 0.05$ ) and had a linear relationship. Thus, the data is eligible for analysis using the Pearson correlation test.

Table 3. Results of the Linearity Test of Intervariable Relationships

Independent Variables	Bound Variables	Mr. Linarites	Remarks
Understanding Biochemical Concepts	Problem-Solving Skills	0.001	Linear

Criteria: Linear relationship if  $\text{Sig.} < 0.05$ .

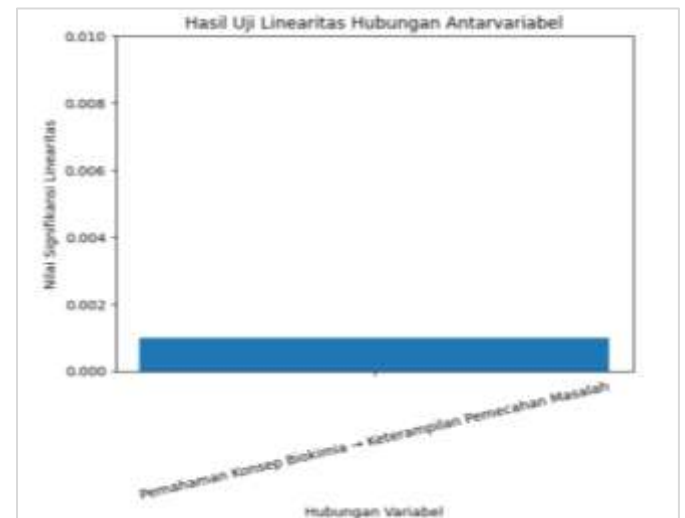


Figure 3. Linearity test results

Relationship Analysis of Concept Understanding and Problem-Solving Skills

The results of the Pearson correlation test showed a correlation coefficient of  $r = 0.63$  with a significance value of  $p < 0.05$ . This value shows a positive and significant relationship between understanding biochemistry concepts and students' problem-solving skills.

Based on the correlation coefficient interpretation criteria, the value of  $r = 0.63$  is included in the category of moderate to strong relationships. This means that students with a higher level of understanding of biochemistry concepts tend to have better problem-solving skills.

Table 4. Pearson Correlation Test Results

Variable	Problem-Solving Skills
Understanding Biochemical Concepts	1 0.63*
Problem-Solving Skills	0.63* 1

Remarks:\* Significant correlation at significance level 0.05 ( $p < 0.05$ )

Quantitatively, a coefficient of determination value ( $r^2$ ) of 0.40 indicates that about 40% variation in problem-solving skills can be explained by an understanding of

biochemical concepts. The rest, at 60%, was influenced by other factors outside of the variables studied, such as learning strategies, motivation, metacognition, or previous learning experiences.

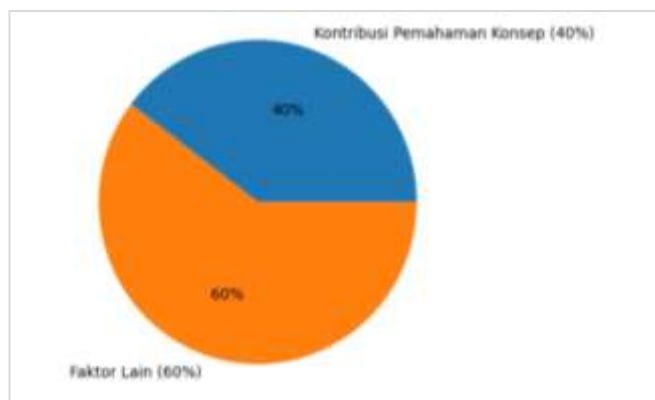


Figure 4. Pearson correlation test results

These findings suggest that college students who have a better understanding of biochemistry concepts tend to have higher problem-solving skills. The results of this study are in line with the opinion of Jonassen (2011) who stated that a strong conceptual understanding is the main prerequisite in solving complex problems in science learning.

In addition, the use of HOTS-based instruments in this study has been proven to be able to reveal students' cognitive abilities in more depth, especially in the aspects of analysis and evaluation. This supports the findings of Brookhart (2010) who stated that HOTS-based assessments are more effective in measuring high-level thinking skills than traditional assessments. Thus, the HOTS instrument not only serves as an evaluation tool, but also as a means to encourage students to develop high-level thinking skills in biochemistry learning.

The results showed that there was a positive and significant relationship between the understanding of biochemistry concepts and the problem-solving skills of Chemistry Education students ( $r = 0.63$ ;  $p < 0.05$ ). These findings indicate that the better the conceptual structure that students have, the higher their ability to solve complex and contextual biochemical problems. The strength of correlation in the medium to strong category shows that conceptual understanding is not just a supporting factor, but is the main foundation in the process of solving scientific problems.

Theoretically, these results are in line with the revised framework of Bloom's Taxonomy proposed by Abdullah et al. (2015), Abdullah et al. (2017), Wardhana et al. (2022), Syafryadin et al. (2021), Venkatraman et al. (2022), which places analysis, evaluation, and creation as forms of higher order thinking skills (HOTS). A deep understanding of concepts allows students to not only

remember information, but also organize knowledge in an integrated structure, thus facilitating the process of concept transfer in new problematic situations. Thus, conceptual understanding serves as a cognitive schema that guides the reasoning process when facing problems.

The findings of this study also support the view of Jonassen (2011) who asserts that problem solving in science learning is highly dependent on the quality of mental representation and the organization of concepts possessed by individuals (Fadillah et al., 2025). Students with a strong conceptual understanding tend to be better able to identify key variables, choose the right solution strategy, and evaluate solutions logically. On the other hand, a superficial or fragmented understanding has the potential to lead to conceptual errors in the problem-solving process.

The value of the determination coefficient ( $r^2 = 0.40$ ) showed that understanding of biochemical concepts contributed 40% to the variation in problem-solving skills. This percentage is classified as substantial in educational research, which is generally influenced by many psychopedagogical variables. This means that despite other factors such as learning motivation, metacognition, learning strategies, and previous academic experience, concept understanding remains a significant determinant in supporting problem-solving performance.

From the perspective of material characteristics, biochemistry is a discipline that demands the integration of various representations (macroscopic, microscopic, and symbolic). This complexity is often a source of student difficulties, as stated by SBretz (2019) that biochemistry learning requires gradual and structured conceptual development. Therefore, when students are able to build a coherent conceptual understanding, these skills directly support the process of analysis and evaluation in solving problems based on biological-molecular phenomena.

The use of HOTS-based instruments in this study also makes an important methodological contribution. The HOTS assessment allows for more authentic measurement of analytical and evaluative abilities than memorization-based tests. Pedagogically, the results of this research have important implications for the development of biochemistry learning in higher education. Learning that is oriented towards delivering material in an expository manner has the potential to produce a superficial and less applicable understanding. In contrast, approaches that integrate problem-based learning, analytical discussions, and HOTS-based assessments can strengthen the relationship between concept mastery and problem-solving skills. This integration is crucial in preparing Chemistry Education students as prospective teachers who not only understand concepts, but are also able to guide students

in solving scientific problems critically and systematically.

Thus, this study strengthens the empirical evidence that understanding of biochemical concepts is a significant predictor of students' problem-solving skills. These results also confirm the importance of learning design and assessment oriented towards strengthening conceptual structures and developing higher-level thinking skills in an integrated manner.

## Conclusion

This study demonstrated a positive and significant relationship between biochemistry concept understanding and problem-solving skills among Chemistry Education students, as indicated by a Pearson correlation coefficient of  $r = 0.63$  ( $p < 0.05$ ). Students showed moderate to high levels of conceptual understanding ( $M = 72.35$ ) and moderate levels of problem-solving skills ( $M = 68.10$ ). The coefficient of determination ( $r^2 = 0.40$ ) revealed that understanding biochemistry concepts contributed 40% to the variance in students' problem-solving skills, indicating that conceptual mastery plays an important role in solving scientific problems. These findings support the view that a strong conceptual foundation facilitates higher-order thinking processes, including analysis, evaluation, and problem-solving. Therefore, integrating HOTS-oriented learning and assessment strategies into biochemistry instruction is essential to enhance both conceptual understanding and problem-solving skills among prospective chemistry teachers.

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## Author Contributions

Conceptualization, M.M. and I.N.; methodology, M.M.; software, M.M.; validation, M.M., and I.N.; formal analysis, M.M.; investigation, M.M.; resources, M.M.; data curation, M.M.; writing—original draft preparation, M.M.; writing—review and editing, M.M.; visualization, M.M.; supervision, M.M.; project administration, M.M.; funding acquisition, I.N. All authors have read and agreed to the published version of the manuscript.

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## Conflicts of Interest

The authors declare no conflict of interest.

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