



Protein Metabolism Lectures with Sustainability-Based to Improve Analytical Thinking Skill in Students of Biology Education

Eny Hartadiyati WH^{1*}, Fibria Kaswinarni², Atip Nurwahyunani³

¹²³Universitas PGRI Semarang

Corresponding Author: Eny Hartadiyati WH enyhartadiyati.wh@upgris.ac.id

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ABSTRACT

This study aims to analyze the effect of sustainability-based protein metabolism lectures on the analytical thinking skills of students in the Biology Education department. This experimental research involved 30 Biology Education students from Universitas PGRI Semarang who took the Biochemistry course during the 2023-2024 odd semester. The treatment is sustainability-based protein metabolism lectures carried out for 4 meetings. The data obtained were analyzed using quantitative methods. The average grades for the distinguishing, organizing, and attributing indicators were 82.00, 81.55, and 81.00, respectively. In general, the average grades of students' analytical thinking skills in the post-test of 81.52 is higher than the pre-test grades of 71.58. This is confirmed by the T-dependent test that there is a significant difference in the pre-test and post-test grades ($p < 0.05$). Additionally, the N-gain test indicated a 4.2% increase, placing it in the moderate category. Students' analytical thinking abilities in protein metabolism material are described as follows: in the distinguishing indicator, students recognize and differentiate well. However, errors began to occur in the organizing indicators, and even in the attribution indicators, students experienced difficulties

INTRODUCTION

Problem solving is a skill needed in the 21st century (Binkley, M., et al., 2012). The skill of finding solutions to a problem requires analytical thinking (Asis et al., 2021). Analytical thinking is essential for both professional and everyday life in the 21st century (Art-in, 2014). Based on this, it is important to always get used to analytical thinking in students, including Biology Education students at Universitas PGRI Semarang. Thus, it is important to cultivate analytical thinking in students, including those studying Biology Education at Universitas PGRI Semarang. Embedding sustainability concepts in learning materials can enhance problem-solving skills (E. Hartadiyati et al., 2021), as analytical thinking is a key component of problem-solving. Based on the understanding of the Brundtland World Commission report, sustainability is development that meets the needs of the present generation without sacrificing the ability of future generations to meet their own needs (Kuhlman & Farrington, 2010). Sustainability or widely known as proposed by the United Nations (UN), namely Sustainable Development (Sustainable Development) must be understood by all ages, all groups (Scott, 2015), including students of the Biology Education study program at Universitas PGRI Semarang. The concept of sustainability can be embedded in learning materials (Hartadiyati et al., 2017; Hartadiyati et al., 2020; Hartadiyati et al., 2019). Formally, students get several courses each semester. One of the mandatory courses is Biochemistry, such as the topic of metabolism. In lectures metabolism, students learn the stages of chemical changes and the interactions of anabolism products with the results or relationships between intermediate compounds in the anabolism and catabolism processes. By studying the concept of metabolism, it is hoped that students can also learn how to deal with problems that arise in their bodies and their environment. In the process of lectures from metabolism material, students are expected to be able to critically analyze information or data from various sources about health problems in society such as uric acid, urea that can be used for plant fertilizer, muscle tissue enlargement, obesity, atherosclerosis and all interactions that occur from sources of carbohydrates, lipids and proteins. Based on this, metabolism lectures can be directed so that students have analytical thinking skills in solving problems and are able to analyze health problems that occur in society and in the surrounding environment with their metabolic concepts. At the same time, it is connected with the sustainability mindset that all activities for human life must be profitable but must not damage the environment. Thus, in sustainability-based metabolism lectures, students can practice and develop analytical thinking skills. Based on this, this study aims to analyze the effect of sustainability-based metabolism lectures on the analytical thinking skills of students in the Biology Education study program.

LITERATURE REVIEW

1. Analytical Thinking Skill

Analytical thinking involves elements of further investigation and situations with less well-defined parameters and outcomes and is necessary when ambiguous situations require the learner to identify or create a problem to be solved (Robbins, 2011). Analytical thinking involves the ability to (1) disassemble a problem and understand its parts, (2) explain the function of a system, the reasons why something happens, or problem-solving procedures, (3) compare and contrast two or more things, or (4) evaluate and criticize the characteristics of something (Sternberg, 2006). (Syahri & Ahyana, 2021) analytical thinking is the ability to break down or describe material or information into smaller components so that it is easy to understand. The indicators are (1) making questions about the topic, (2) conducting an investigation about the topic, (3) making a chart to explain the topic. Indicators of analytical thinking according to Bloom in the book *Taxonomy of educational objectives: The Classification of educational goals. Handbook I: Cognitive domain* (1956) in (Syavarizca & Sumaji, 2021) indicators of analytical thinking are analysis of parts of material/elements, analysis of relationships and analysis of organizing organizational principles. The indicators of analyzing (analyzing)/C4 by (Krathwohl, 2002) are differentiating (includes the ability to differentiate between several parts of a structure as a whole in a relevant form, organizing (includes the ability to identify elements of a structure to be interrelated, which is also said to include the ability identifying information into an organized structure), and attributing (determining the point of view or purpose of the structure). Meanwhile, (Art-in, 2014) stated that basically the characteristic of analytical thinking ability is that someone is able to divide or separate elements, then connect and organize them & in their research report uses 3 indicators of analytical thinking, namely (1) differentiating, (2) organizing, (3) connecting (Mayarni & Nopiyanti, 2021).

2. Sustainability-based lectures

Sustainability-based lectures is operationalized in a systematic procedure, starting from the economic, socio-cultural and environmental aspects, all three must be integrated, all three are interconnected and influence each other with the provision that activities in the economic and socio-cultural fields do not damage the environment (environmental sustainability from now on until the future). This is pursued with the dimensions of preventing, maintaining and developing activities. The three aspects of sustainability (economic, social and environmental) and the dimensions of preventing, building and maintaining are carried out using an embedded approach pattern in natural science material, as well as an incorporated pattern as companion material with natural science as the main material (E. Hartadiyati et al., 2017).

That in the embedded approach, assessment is only focused on the main areas and embedded areas are not assessed in learning. The embedded approach in science learning places more emphasis on maintaining the authenticity of the subject matter which is the main area, does not focus on the embedded concept of sustainability, and the material in the embedded approach is not designed to be evaluated or assessed (E. Hartadiyati et al., 2017; Eny Hartadiyati et al., 2022).

3. Protein Metabolism

Bhagavan & Ha, (2015) explain that proteins are constantly undergoing breakdown and synthesis. During growth, although protein storage occurs, the rate of synthesis and breakdown increases. The use of protein from food sources in adults is estimated to be around 300 grams per day. About 100 g is for myofibrillar protein, 30 g is digestive enzymes, 20 g is intestinal cell protein, and 15 g is hemoglobin. The remainder is used for turnover of cellular proteins from various other cells (e.g., hepatocytes, leukocytes, platelets), oxidation of amino acids, and small amounts are lost as free amino acids in the urine. The rate of protein turnover from tissue to tissue varies, and the relative contribution of tissues to total protein turnover is altered by aging, disease, and changes in dietary protein intake. Protein turnover is not completely efficient in reusing amino acids. Some is lost by oxidative catabolism, while others are used in the synthesis of nonprotein metabolites. For this reason, protein is necessary to maintain adequate protein synthesis.

In this research, analytical thinking skills are built through lectures activities regarding protein metabolism by embedding the concept of sustainability, which is called Sustainability-based Lectures. Several studies that have been conducted using Sustainable Development (SDGs) problems or topics and Education for sustainable development (ESDGs) can improve high-level thinking skills such as critical thinking, problem solving skills (Hartadiyati et al., 2019; Hartadiyati et al., 2020; Hartadiyati et al., 2021; dan Permatasari et al., 2024) in this research, sustainability-based lectures to know analytical thinking. It is known that analytical thinking is a stage for critical thinking (Rahardhian, 2022). Based on the literature review, the hypothesis of this research is that sustainability-based lectures on protein metabolism material can improve the analytical thinking skills of biology education students as seen from:

H1: there is a significant difference in pretest and posttest analytical thinking skills ($p < 0.05$).

H2: increase in analytical thinking skills from pretest to posttest can reach a minimum in the medium category.

This research was built with the conceptual framework outlined in Figure 1.

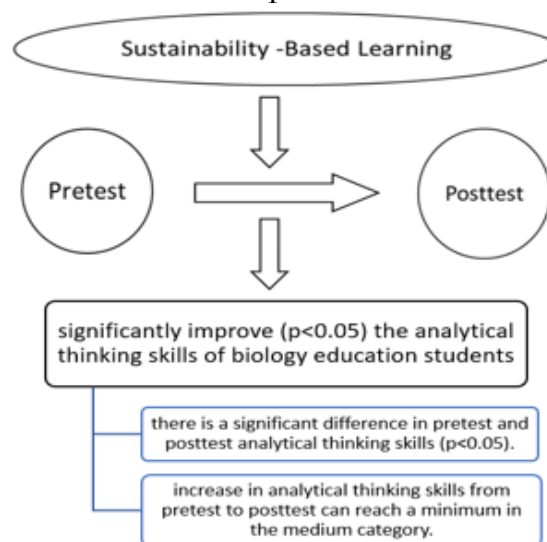


Figure 1. Conceptual Framework

METHODOLOGY

This experimental research involved a saturated sample of 30 Biology Education students at Universitas PGRI Semarang enrolled in the Biochemistry course. The treatment in the form of sustainability-based protein metabolism lectures using collaborative activities was carried out for 4 meetings, each meeting for 100 minutes for theory and 300 minutes for practicum:

1. The first meeting, the formation of original groups: thirty students were divided into 7 original groups, each original group consisting of 4-5 members. In this first meeting, all groups were given the concept of sustainability-based lectures: that activities in the social field must be profitable but must not damage the environment by preventing, maintaining and building, then introducing the context of protein metabolism material that must be mastered by each original group, and each group was guided by the Student Activity Sheet. Furthermore, the original group was divided into expert groups, there were 4 expert groups. The first expert group discussed protein metabolism in muscles, problem: Provide a related analysis of duck farming can contribute to the understanding of protein metabolism in muscle with a sustainability mindset, by sorting from the available images!; the second expert group discussed protein metabolism in the liver: the urea cycle, problem: Provide an analysis of smoked and fresh milkfish from the city of Semarang that can contribute to the understanding of the urea cycle and the oxidation of amino acid carbon skeletons into energy with a sustainability mindset, by sorting from the provided images!; the third expert group discussed the urea cycle and oxidation of the amino acid carbon skeleton into energy, problem: Provide a related analysis of tofu dregs waste can contribute to the understanding of the urea cycle with a sustainability mindset, by sorting from the available images!; the fourth expert group discussed excessive oxidation of amino acids into energy due to lack of carbohydrates, problem: Provide a related analysis of fresh milk from the city of Boyolali which can contribute to the understanding of excessive oxidation of amino acids into energy due to a lack of carbohydrates with a sustainability mindset, by sorting from the available images!.

Sustainability-based lectures treatment uses images contained in worksheet, complete with sustainability-based problems. In this study, using questions combined with reasoning is the key to analytical thinking (Robbins, 2011).

2. The second meeting, still in the expert group: each expert group collaborates for 300 minutes complete with practical activities on protein tests related to the problems presented to solve the problems, presenting the results in powerpoint form.

3. The third meeting, still in the expert group: each expert group collaborates for 100 minutes to process data and present it in digital form, such as infographics, video scribes, powerpoint and so on according to interests and talents.

4. Fourth meeting, the expert group returns to their original group, then elaborates according to their expertise to comprehensively discover protein metabolism.

The essay test was conducted at the beginning and end of protein metabolism lectures to see the increase in analytical thinking, then the data obtained was processed. Data processing was carried out to test the formulated hypothesis, namely whether there was a difference in pretest and posttest grades, and then whether there was an increase in pretest and posttest grades. The grades of each individual is obtained using the formula:

$$x = \text{Grades} = \frac{\text{Score obtained}}{\text{Maximum score}} \times 100$$

The measurement grades before treatment and the final measurement grades of analytical thinking were tested statistically using the Dependent t-test. Dependent t test analysis was carried out at the significance level $\alpha = 0.05$. The basis for decision making in the Dependent t Test is the asymp sig grades. (2-tailed) < 0.05 , then there is a significant difference (H0 is rejected, H1 is accepted); and if the asymp grades is sig. (2-tailed) > 0.05 , then there is no significant difference (H0 is accepted, H1 is rejected).

If the results of the Dependent t-Test (Paired t-Test) show that there is a significant difference, then proceed with analyzing the increase in analytical thinking using the normalized average gain (N Gain) with symbols g using the formula (Hake, 1998) as follows:

$$g = \frac{\text{Average \% posttest} - \text{average \% Pretest}}{100 - \text{Rata-rata \% Pretest}}$$

Gain is then categorized (Hake, 1998) which is presented in Table 1.

Table 1. Categories of Improved Analytical Thinking

Percentage Mean N-Gain (g)	Category
≥ 0.7	High
$0.7 > g \geq 0.3$	Medium
< 0.3	Low

The hypothesis on improving analytical thinking:

1.Ho: there is no significant difference in pretest and posttest analytical thinking grades.

Ha: there is a significant difference in pretest and posttest analytical thinking grades.

2. There is an increase in analytical thinking from pretest to posttest.

Dependent t-test analysis and N gain using SPSS version 21 facilities.

RESULTS

Students' analytical thinking skills on the topic of protein metabolism were measured using a descriptive type test instrument given before and after lectures about protein metabolism. The analytical thinking skills targeted in the lectures of protein metabolism were assessed using indicators of differentiating, organizing, and connecting. These indicators were also used as the basis for developing both the pretest and post-test. The quantitative results of the analytical thinking skills on these indicators are presented in Table 2.

Table 2. The Analytical Thinking Skills Grades

Indicator	Average	
	Pretest	Posttest
Distinguishing	76.95	82.00
Organizing	70.47	81.55
Attributing	67.32	81.00

Table 2 shows that there are differences in the grades of each indicator of analytical thinking skills in the pretest and posttest. The same trend is observed in the post-test grades. However, each indicator shows an increase from pretest to post-test. The same tendency occurs in the posttest grades. However, each indicator shows an increase from pretest to posttest. Additionally, the average and standard deviation are calculated and presented in Figure 2.

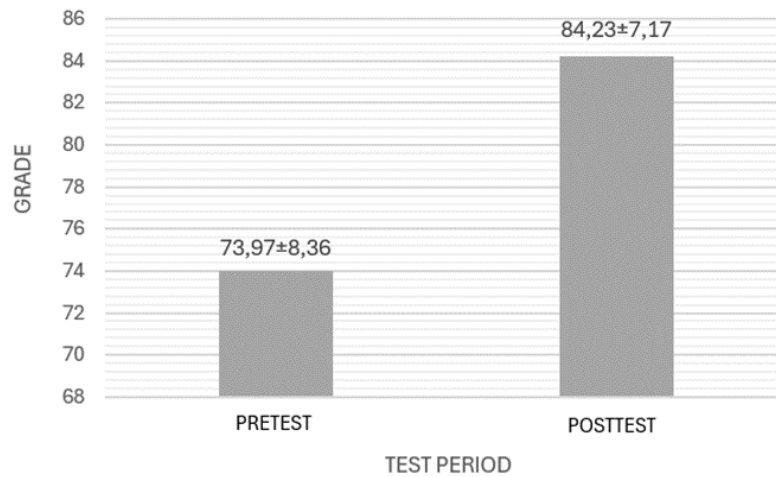


Figure 2. Average and Standard Deviation of Pretest and Posttest Grades Analytical Thinking Skills

Figure 2 shows that the average posttest of 81.52 ± 7.17 is higher than the pretest grades of 71.58 ± 8.36 . The results of the data in Table 2 and Figure 1 were then subjected to statistical analysis using the dependent t-test (Paired t-test) using SPSS 21. The dependent-t test begins by calculating the normality test to see whether the data distribution is normally distributed or not. The results of the normality test can be seen in Table 3.

Table 3. Normality Test for Analytical Thinking Skills

Analytical Thinking Skills	Shapiro-Wilk		
	Statistic	df	Sig.
Pretest	.946	30	.132
Posttest	.948	30	.149

Based on Table 3, it is the Shapiro-Wilk test because the sample is less than 200. The Sig grades of the Shapiro-Wilk pretest data is 0.132 and the posttest data is 0.149. Both are greater than 0.05, so it can be said that the data is normally distributed or means accepting H0. It is known that the decision-making guidelines for the normality test are:

H0 : If Sig. > 0.05 then the data is normally distributed

H1 : If Sig. < 0.05 then the data is not normally distributed

Next, the homogeneity test, the homogeneity results are shown in Table 4.

Table 4. Homogeneity Test for Analytical Thinking Skills

	Lavene Statistic	df1	df2	Sig.
Based on Mean	.459	1	58	.501

Based on Table 4, the Significance (Sig.) Based on Mean is 0.51 > 0.05. Based on this, it can be said that the variance of the posttest and pretest groups is the same or homogeneous or which means accepting H0.

It is known that the decision-making guidelines for the homogeneity test are:

H0: If Significance (Sig.) Based on Mean > 0.05 then the data variance is homogeneous

H1: If Significance (Sig.) Based on Mean < 0.05 then the data variance is not homogeneous

The normality and homogeneity tests of the pretest and posttest data show that the data is normally distributed and homogeneous, so the requirements for the dependent t-test have been met. The pretest and posttest grades are then analyzed whether they are significantly different or not. The results of the dependent t-test (Pair test) are shown in Table 5.

Table 5. Dependent T- Test (Paired Samples Test) of Analitical Thinking Skills

	Paired Differences					
	Means	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair Pretest - Posttest	10.27	4.35	.795	12.914	29	.000

Table 5 shows that Sig. (2-tailed) is 0.000 < 0.05, so H0 is rejected or H1 is accepted. So it can be said that there is a significant difference in the average analytical thinking grades of the pretest and posttest. It is known that the decision-making guidelines in the dependent t-test are:

H0: If the Sig. (2-tailed) > 0.05 then the pretest and posttest are not significantly different

H1: If the Sig. (2-tailed) < 0.05 then the pretest and posttest are significantly different

After it was known that there was a significant difference in the pretest and posttest grades, it was also seen that the posttest of 81.52 ± 7.17 was higher than the pretest of 71.58 ± 8.36 . Furthermore, an N Gain analysis was carried out to see how the increase was. The N Gain a count results used SPSS showed of 0.42% included in the moderate category (Table 1). This can be interpreted as having a significant influence on lectures sustainability-based protein metabolism on improving students' analytical thinking skills in the moderate category.

The post-test results revealed that the analytical thinking skills of biology education students about protein metabolism due to sustainability-based lectures in the distinguishing indicator, students were able to recognize and distinguish well the concept of protein catabolism and anabolism, distinguish the components of the chemical structure of amino acids, namely the carbon skeleton, amine groups and carboxylate groups, amino acid catabolism in the carbon skeleton and amine groups, and recognize the urea cycle and TCA cycle involving amino acids. In the sequencing indicator, however, there was an error in sequencing the emergence of the urea cycle that occurs from amino acid catabolism, the formation of energy from amino acids through the TCA cycle and when sequencing the synthesis process of essential and nonessential amino acids. Furthermore, the attributing indicator, students had difficulty when providing reasoning for a concept of protein catabolism and anabolism from a problem involving the relationship between the components of the chemical structure of amino acids, namely the carbon skeleton, amine groups and carboxylate groups; amino acid catabolism in the carbon skeleton and amine groups; urea cycle and TCA cycle involving amino acids.

DISCUSSION

The results obtained in this study can be explained that the sustainability-based protein metabolism lecture has provided students with a comprehensive lectures experience to equip them with analytical thinking, namely:

(1) Facilitation of activities begins by giving students the opportunity to collaborate optimally because there are activities in the original group and activities in the expert group. So that it will provide many benefits, namely they interact with each other, share ideas, and exchange experiences so that they become more knowledgeable and understand how to work together well, think together positively, and negotiate fairly and during practical activities operate certain tools properly and correctly. They share and give each other their respective experiences which have an impact on improving the quality of their work. At that time, they began to gain new knowledge, new ways of working, and new experiences and even new perspectives that were very useful for them to create new knowledge improvisations, which had a positive impact on finding knowledge, namely protein metabolism. In line with what was explained by Lopes et al., (2018) that collaborative learning can improve high-level thinking, and analytical thinking is one of the high-level thinking (Juliarti et al., 2019). Shofiyah et al., (2022) explain that collaboration skills can improve cognitive learning outcomes and it is known that analytical thinking is part of cognitive learning outcomes;

(2) Sustainability-based lectures provides reasoning that activities in the social field must be profitable but must not damage the environment by preventing, maintaining and building efforts, which are linked to the topic of protein metabolism. In this study, the student lectures process was assisted using Student Worksheets. In the Student Worksheets there is a series of images, complete with sustainability-based problems. In each series of images there are

questions combined with reasoning, questions combined with reasoning are the key to analytical thinking (Robbins, 2011).

This process trains students' analytical thinking according to the indicators of distinguishing, organizing and attributing. For example, a series of images that show a sustainability mindset with reasoning for protein metabolism in muscles. The first step is for students to distinguish each image in a series of images. Then organize it into a sequence of images through logical reasoning according to the sustainability-based is formulated that activities in the social field must be profitable but not damage the environment. After becoming a logical sequence, it is explained by connecting one image to another through reasoning according to the concept of protein metabolism in muscles with a sustainability mindset.

The logical sequence of the series of images is explained by the fact that eggs contain protein which, when consumed, can cause protein metabolism in the muscles to form muscle mass, it is known that muscle mass is synthesized using protein. Three types of muscle mass formation are myofibrillar hypertrophy, sarcoplasmic hypertrophy, and connective tissue hypertrophy (Haun et al., 2019). Wolfe, (2017) explains that muscle protein metabolism during normal conditions, muscle protein will be broken down into free amino acids, as much as 70% of free amino acids are synthesized into muscle protein and 5% are used for energy formation in muscles through oxidation. The remaining 25% is transported to other tissues for 10% protein synthesis and 15% for oxidation, protein metabolism in muscle. Muscle protein synthesis is a metabolic process that describes the incorporation of amino acids into skeletal muscle proteins. Muscle proteins can be classified into contractile myofibrillar proteins (i.e. myosin, actin, tropomyosin, troponin) and energy-producing mitochondrial proteins. Myofibrillar protein synthesis is primarily responsible for changes in skeletal muscle mass after endurance training, while mitochondrial proteins are primarily synthesized in response to endurance-type training (Witard et al., 2022). Wilkinson et al., (2008) stated that skeletal muscle plays an active role in amino acid metabolism. Skeletal muscle is the most important site for the breakdown of the amino acids valine, leucine and iso leucine. Alanine and glutamine are synthesized by the muscles and released into the blood. The blood then transports the nitrogen obtained from the breakdown of amino acids to the liver.

Increased protein intake results in a positive protein balance, meaning it reduces protein degradation and increases protein synthesis. A four-week protein supplementation study in athletes showed significant results in increased protein synthesis (Fern, 1991). Increased protein synthesis causes increased muscle mass and will increase body weight, but if the subject's energy intake is low, it will have a negative impact on increasing muscle mass (Wihelmina et al., 2023). In addition to muscle mass, protein metabolism contributes 2-3% of energy needs in sports lasting several minutes, and increases to 12% after several hours of physical work (Bhagavan & Ha, 2011), namely glutamate enters the TCA cycle as α -ketoglutarate and aspartate or asparagine as oxaloacetate. The role of protein catabolism in supporting glucose and lipid oxidation is more important

than its direct contribution to energy production. With proper training, muscle mass becomes maximal. Eggs that are consumed will produce eggshell waste that can burden the environment, therefore eggshells can be processed into flour and can even be a source of income because they can be used for livestock feed such as ducks eggshells are rich in protein and calcium so that they can provide optimal growth and development of ducks, this will have an impact on optimal duck meat results as a source of protein and a source of income. This series of images provides an understanding of sustainability as well as an understanding of protein metabolism in muscles.

CONCLUSIONS AND RECOMMENDATIONS

Treatment with sustainability-based learning can have a positive influence on analytical thinking skills on the topic of protein metabolism. This is shown by 1. The average score of students' analytical thinking skills in the post-test was 81.52 ± 7.17 , higher than the pre-test of 71.58 ± 8.36 (there was an increase in the pre-test to post-test grades). This was confirmed by the dependent t-test that there was a significant difference in pretest and posttest grades ($p < 0.05$). Followed by the N gain test, it informed that there was an increase of 4.2% or in the medium category.

2. The profile of students' analytical thinking skills because of sustainability-based learning. In the distinguishing indicator, students can recognize and differentiate well about the meaning of protein catabolism and anabolism, differentiating the components that make up the chemical structure of amino acids, namely carbon skeletons, amine groups and amino acid groups. carboxylate, catabolism of amino acids on carbon skeletons and amine groups, protein synthesis and amino acid synthesis as well as recognizing the urea cycle and TCA cycle involving amino acids. However, errors have begun to occur in sequencing the emergence of the urea cycle which occurs from the catabolism of amino acids, the formation of energy from amino acids through the TCA cycle and when sequencing the processes of synthesis of essential and non-essential amino acids. Furthermore, the attributing indicator is that students experience. The suggestion based on the results of this study is that sustainability-based lectures can be a valuable alternative for innovating student lectures. However, it is essential to first develop a thorough understanding of sustainability to ensure it can be effectively embedded in lecture material.

FURTHER STUDY

In this study, the improvement in analytical thinking skills is still in the moderate category. This may be due to the problem stimulation provided through the sequence of images, which were not entirely based on the students' own abilities. As a result, when students encountered multiple logical perspectives, it led to confusion and uncertainty in understanding the concept. Based on this, further research will focus on developing the thinking processes of biology education students, moving from analytical thinking to more advanced critical and creative thinking. This will be facilitated through project-based biochemistry lectures that incorporate a sustainability mindset. The

problems used will be derived from the analysis of situations in students' daily lives, encouraging them to analytically, critically, and creatively identify significant problems and then find appropriate solutions.

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