Enhancing Vocational Students' Understanding of Macromolecules Properties: A Practical Approach through Laboratory Activities to Support Sustainable Development Goals (SDGs)

Humairah Ansar Tohe[1], Heli Siti Halimatul Munawaroh[1*], R. Riandi[1], Asep Bayu Dani Nandiyanto[1], Atiek Octaria Prajayanti[2], Meli Fiandini[1]

[1]Universitas Pendidikan Indonesia, Bandung, Indonesia
[2]Sekolah Menengah Kejuruan Sangkuriang 1, Cimahi, Indonesia
[1]humairahat@upi.edu, heli@upi.edu, rian@upi.edu, nandiyanto@upi.edu, atiekoctaria@gmail.com, melifiandini19@upi.edu

***Abstract*- This study aims to develop a chemistry experiment design by utilizing simple tools and materials to teach the concept of macromolecules (carbohydrates, lipids, and proteins) to vocational students. The method used in this research is descriptive-quantitative. The research design was pre-test and post-test one group design. The subjects of this study were 23 students of class X vocational school in Cimahi, West Java, Indonesia. Learning was conducted using conventional methods and supported by practicum activities. Laboratory activities were carried out by conducting experiments using simple tools and materials to understand the physical and chemical properties of carbohydrates, lipids, and proteins. The results of the analysis showed that there was an increase between the pretest and post-test scores of students as shown in the N-Gain value obtained of 0.4 with a moderate category, while hypothesis testing with the Wilcoxon test showed that there is an influence between learning activities assisted by practicum activities on the level of student understanding of macromolecular material. The results of this study show that classroom practice activities are very useful in helping students understand the scientific concepts of macromolecules and can connect theory with practice. In-depth concept understanding of macromolecules also impacts on achieving the Sustainable Development Goals (SDGs).**

***Keywords*- Macromolecules, carbohydrates, lipids, proteins, vocational students, laboratory activities, SDGs**

Heli Siti Halimatul Munawaroh
Universitas Pendidikan Indonesia, Bandung, Indonesia
heli@upi.edu

I. INTRODUCTION

The quality of a country can be assessed from its education sector. The quality of learning can be improved through the way teachers teach, the methods used, and the use of learning media (Hardiatun, 2019). The superior quality of education can not be separated from the role of practicum in developing students' deep understanding (Pandeeswari et al., 2024). In science learning, practicum has an inseparable role. Science involves processes and products, and in the context of the process, the involvement of practicum in learning can improve students' critical, creative, and scientific attitudes (Tsybulsky, 2019). Practicum not only provides hands-on experience that enriches students' knowledge, but it is also an important foundation that links theory with practical application in the learning environment. The practical experience offered by practicum is not just an add-on, but an essential part of the overall educational process, allowing students to relate theory to real-world situations (Sari et al., 2017).

Practical activities in science learning have several important roles (Al Husaeni et al., 2024; Ana, 2020; Rosina et al., 2021). These roles include, first, the container in the development of basic skills which include observation or measurement as well as other process skills including recording, table making, graph making, analyzing data, providing conclusions, communication, and teamwork. Second, the laboratory is a place to prove a concept or a law of nature. Thus, it can make the concept clearer. Third, as a place to develop thinking skills through problem-solving activities in laboratory activities for learning how to learn

(Jannah et al., 2022; Nazarov & Jumayev, 2022). Through the practicum, new knowledge will be stored in the long-term memory of students who are directly involved. In addition, lab work is also a learning resource that students can use to learn abstract chemical concepts through visualization.

One of the science subjects in the vocational education curriculum is the Natural and Social Sciences subject (IPAS). This IPAS subject is integrated with chemistry subject, which can not be separated from the implementation of practicum, but chemistry practicum in schools still faces many challenges. Some of them are expensive equipment for chemistry laboratories, incomplete laboratory facilities and infrastructure, and practicum on chemical concepts is mostly abstract. Thus, it is often not done (Damayanti, et al., 2019). This allows for a decrease in students' mastery of concepts. Many reports regarding chemistry education have been well-documented (Barke & Harsh, 2022; Francis & Baba, 2023; Putri et al., 2022; Wirzal & Halim, 2022; Barke & Buechter, 2023; Sombria et al., 2023).

Macromolecules are one of the subjects studied in the chemistry subject. Macromolecules are molecules that form the basic structure of life. The three main classes of macromolecules that are essential for the survival of organisms are carbohydrates, fats, and proteins. Carbohydrates are the main source of energy used by cells in the body. Macromolecules consist of sugar units, such as glucose and fructose, which are linked together to form more complex structures. Fats, or lipids, serve as efficient energy stores and are important components of cell membranes, which consist of fatty acids bound to glycerol. Meanwhile, proteins are the structural and functional pillars of cells, consisting of chains of amino acids that fold into complex three-dimensional structures. Tests for these macromolecules involve special chemical and biochemical methods, such as the Biuret test for proteins, the Benedict test for reducing sugars in carbohydrates, and the Sudan test for fats. Additionally, methods such as chromatography and electrophoresis are used to separate and analyze macromolecules in more detail (Taşğın, 2017; Henggu & Nurdiansyah, 2021).

How to differentiate these three types of macromolecules involves using chemical tests specific to each group. The Biuret test, for example, will produce a purple color if the protein is present, while the Benedict test will show a color varying from green to brick red depending on the amount of reducing sugars in the sample. The Sudan test uses a special reagent to show the presence of fat with a specific color change. Understanding the chemical properties and typical reactions of each biomolecule helps in identifying and differentiating them, which is important for understanding their function and role in chemistry and biochemistry (Tyasna et al., 2022; Pratt, 2011).

Macromolecules include chemical materials that are descriptive (theoretical), which are found in the field that students are only asked to remember and memorize material, even though macromolecular material is very broad in scope. Thus, it takes time and the right way to learn it. Because of its broad scope, this macromolecular material mostly connects one concept with another concept. Thus, it requires higher-level thinking skills (Nurjayadi & Kartika, 2012). As many as 63.64% of students find it difficult to learn macromolecules because the material is difficult to understand and the availability of teaching materials is lacking (Winarti et al., 2019). The fact is also that teachers tend to pay less attention to the characteristics of the material being taught and are generally taught textually or based on the books used (Sudarisman, 2015).

The curriculum in vocational schools is shown in Table 1. Table 1 describes the science education curriculum in chemistry subjects of macromolecules used in vocational schools. This curriculum is necessary to ensure the success of the teaching and learning process (Maryanti et al., 2021; Sukandar et al., 2020).

TABLE I
CURRICULUM FOR SCIENCE EDUCATION (ESPECIALLY FOR CHEMISTRY SUBJECT) IN VOCATIONAL SCHOOL

Core Competency 3 (knowledge)		**Core Competency 4 (skills)**	
3	Understand factual and conceptual knowledge by observing, asking, and trying based on curiosity about himself, God's creatures and their activities, and the objects he encounters at home, at school, and on the playground	4	Presenting factual and conceptual knowledge in clear, systematic, logical, and critical language, in aesthetic work, in movements that reflect healthy children, and in actions that reflect the behavior of children of faith and noble character.
Basic Competencies 3		**Basic Competencies 4**	
3.11	Analyze the structure, nomenclature, properties, and classification of macromolecules	4.11	Analyze the results of searching for information regarding the manufacture and impact of a product from macromolecules

Nowadays, several challenges such as educational disparities, climate change, and social challenges facing humanity are increasing. These challenges must be addressed through educational transformation that considers sustainable development goals (Sachs et al., 2019; Cottafava et al., 2019). An in-depth understanding of macromolecules, such as carbohydrates, lipids, and proteins, plays an important role in vocational education. Students who understand the properties of macromolecules not only have the theoretical knowledge but also the practical foundation required in various industrial sectors. For example, in the food industry, an understanding of the chemical properties of key ingredients such as carbohydrates helps in better food production and processing. In the healthcare sector, an understanding of the structure and function of proteins can lead to the development of more effective treatments. By strengthening this understanding, vocational students not only gain theoretical knowledge but also gain a solid foundation to apply their knowledge in the real-world context of future industries (Jannah et al., 2022).

Education plays a pivotal role in advancing the Sustainable Development Goals (SDGs), as a sustainable future can only be achieved with a strong foundation in education (Kirupa et al., 2024). In addition to its fundamental role in vocational education, a comprehensive understanding of macromolecules significantly contributes to the realization of the SDGs. There is a need for giving new information to support current issues in the sustainable development goals (SDGs) as reported elsewhere (Nurrahmadhani et al., 2024; Makinde et al., 2024; Gemil et al., 2024; Haq et al., 2024; Basnur et al., 2024). Students' ability to understand macromolecules not only impacts the industrial sector but also plays a role in achieving various SDGs targets. This understanding supports the improvement of more efficient agricultural technologies and the development of higher-quality food products in the context of food-related SDGs. Moreover, knowledge of macromolecules supports the development of more advanced and environmentally friendly health therapies, which contribute to public health and overall environmental preservation.

However, the learning process on this macromolecular material mostly only requires students to just know the theory (Jannah et al. 2022). The practicum is still rarely done. Macromolecular practicum at the school level until now still uses common methods to identify the content of carbohydrates, proteins, and lipids in a compound such as the Fehling test and Benedict test to determine carbohydrate content, Biuret test to determine protein content, and solubility tests for lipids (Tyasna et al., 2022). Although it has become a standard applied in chemistry learning. A new testing innovation is needed and not based only on books. Therefore, it is necessary to develop more innovative testing methods that are different from standard tests and can utilize the environment around students. Thus, students can better understand these concepts in a more real context. This study aims to test the content of carbohydrates, proteins, and fats using more innovative test alternatives based on the physical and chemical properties of these macromolecules.

II. METHOD

2.1. Experimental Design

The type of research used in this research is pre-experimental with descriptive-quantitative analysis. The research design used is using a one-group pretest-posttest design, namely by giving a pretest before treatment and giving a posttest after treatment. The treatment in question is to carry out a practicum. Therefore, the results of the treatment can be known more precisely, because it can compare with the situation before being treated.

2.2. Research Subjects

The subjects in this study were X grade students majoring in software engineering at one of the Vocational Schools in Cimahi, West Java, Indonesia, totaling 23 people.

2.3. Treatment Procedure

The procedures carried out in this study consisted of the preparation stage and the implementation stage. The preparation stage includes (i) analyzing the curriculum of science/IPAS subjects in vocational schools; (ii) designing learning scenarios following the selected content; (iii) designing experimental tools used in the learning process, in this case, the tools used in the practicum process; (iv) preparing student worksheets (LKPD) as a guide during practicum; and (v) preparing questions for pretest and posttest. The questions for the pretest and posttest consisted of multiple-choice questions totaling 10 questions, in which the questions were the same.

The implementation stage consists of several steps such as: (i) giving pretests to students. The pretest is used to assess the student's initial level of understanding of the learning material; (ii) presenting brief learning materials related to practicum implementation, namely the basic concepts of macromolecules (carbohydrates, lipids, and proteins), and how to distinguish them; (iii) students carry out practicum activities following the guidelines that have been prepared in the LKPD, the teacher helps provide direction and guidance to students; and (iv) giving a posttest which is carried out to evaluate the extent to which the learning material and practicum carried out can be conveyed effectively, as well as to assess how well students understand the material that has been given.

The macromolecules practicum is designed to be based on simple tools and materials. The practicum aims to differentiate the three types of macromolecules (carbohydrates, lipids, and proteins) based on their physical and chemical properties. The experiment design did not involve standard testing experiments on macromolecules. The experiments consisted of (i) carbohydrates parts, namely solubility tests, gelatinization reactions on starch, and caramelization reactions; (ii) lipid parts, namely solubility tests and emulsion formation; and (iii) protein parts, namely solubility tests and denaturation reactions in proteins which are influenced by temperature and pH.

2.4. Data Analysis

Data analysis techniques used descriptive statistics and inferential statistics. Descriptive statistical analysis includes demographic values. Inferential statistical analysis includes a normality test, hypothesis test, and N-Gain test. This test used SPSS version 26 for Windows. Detailed information regarding the use of SPSS is explained elsewhere (Fiandi et al., 2024). The data analysis carried out in detail is described as follows.

2.4.1. Validity Test

The validity test is a test that shows how the measuring instrument can measure the intended variable. The validity test was carried out with the help of the SPSS version 26 program with the product-moment method. The technique of testing the validity of the instrument with product-moment correlation is by correlating the score of each item with the total score which is the sum of each item score. An instrument is said to be valid, which can be seen from its significance value. If the significance < 0.05 means the item is said to be valid, but if the significance > 0.05 means the item is invalid. This can also be seen by comparing the r count (Pearson correlation value) with the r table. If the value is positive and r count > r table then the item is declared valid, and vice versa. The r table value used refers to a significance level of 0.05 with a two-sided test (two-tailed). The results of the validity test of each question item can be seen in Table 2.

TABLE II
VALIDITY TEST ON THE ITEM QUESTIONS

Type	Results
Number of questions	10
Number of students	23
Valid question number	3, 4, 6, 7, 10
Number of valid questions	1, 2, 5, 8, 9

2.4.2. Reliability Test

The reliability test represents the consistency of scores obtained by the same person when tested using the same test in different situations. An instrument that is considered reliable is an instrument that when used several times to measure the same object will produce the same data. The reliability test can be conducted using the SPSS version 26 software. The reliability test was performed using the Cronbach Alpha method. The reliability test criteria are if the value of $r_{11} < 0.20$ is stated to be very low, the value of $0.20 \leq r_{11} < 0.40$ is stated to be low, the value of $0.40 \leq r_{11} < 0.70$ is stated as medium, value $0.70 \leq r_{11} < 0.90$ is stated as high, and value of $0.90 \leq r_{11} < 1.00$ is stated as very high. The results of the reliability test are shown in Table 3.

TABLE III
RELIABILITY TEST ON THE ITEM QUESTION

Type	Results
r_{count}	0.620
Category	Moderate

2.4.3. Test Item Level of Difficulty

The difficulty level of a question instrument refers to the proportion of students who answer the question correctly out of the total number of students taking the test. It is important to assess the level of difficulty of questions to provide various diagnostic instruments for student learning difficulties and improve assessment in learning activities. As for calculating the level of difficulty of the question items using Equation (1).

$$P = \frac{N_p}{N} \quad (1)$$

where P is the index of difficulty, Np is the number of students who answered correctly, and N is the total number of students taking the test. The criteria for interpreting the level of difficulty of the question is if the value ranges from 0.00 - 0.30 then it is declared a difficult question, if 0.31 - 0.70 then a medium question, if the question is 0.71 - 1.00 then it is declared an easy question. The results of the difficulty level analysis are presented in Table 4.

TABLE IV
TEST OF QUESTION DIFFICULTY LEVEL

Question number	Difficulty index value	Question category
1	0.913	Easy
2	0.957	Easy
3	0.609	Medium
4	0.304	Medium
5	0.957	Easy
6	0.304	Medium
7	0.478	Medium
8	0.826	Easy
9	0.391	Medium
10	0.565	Medium

2.4.4. Pretest and Posttest Learning Outcomes

The assessment was conducted based on the pre-test and post-test results using 10 identical pre-test and post-test questions. The type of questions used were multiple-choice questions with correct or incorrect answers. In short, if the student answers the question correctly then the score is 1, and if the student answers the question incorrectly then the score is 0. This analysis has a maximum score of 10. The correct answer is then calculated using Equation (2).

$$Score = \frac{score\ obtained\ by\ student}{maximum\ score} x\ 100 \quad (2)$$

2.4.5. N-Gain Score

Normalized gain or N-gain score aims to determine the effectiveness of using a treatment in research. The N-gain test is performed by calculating the difference between the pretest value and the posttest value. The N-gain test is calculated using Equation (3).

$$N - Gain = \frac{((post-test\ score)-(pre-test\ score))}{((score\ ideal)-(pre-test\ score))} \quad (3)$$

The results of the N-gain value will then be interpreted according to the criteria shown in Table 5.

TABLE V
N-GAIN CRITERIA CATEGORIES

Limitation	Category
$g > 0.70$	High
$0.30 \leq g \leq 0.70$	Moderate
$g < 0.30$	Low

2.4.6. Normality Test

The normality test is conducted to determine whether the research data is normally distributed or not. The use of parametric and nonparametric statistics depends on the assumptions and type of data to be analyzed. Parametric statistics require many assumptions to be met. The main assumption is that the data to be analyzed must be normally distributed. Meanwhile, nonparametric statistics do not require many assumptions to be met, for example, the data to be analyzed does not have to be normally distributed. After the normality test is carried out, we can continue the next test following the results of the normality test, whether using parametric or non-parametric statistics.

2.4.7. Significance Test

The data analysis carried out in this study is to compare the average pre-test and post-test scores obtained. If the data is normally distributed using parametric statistical tests with paired sample t-tests. However, if the data is not normally distributed using a non-parametric statistical test with the Wilcoxon signed-rank test. Through these two tests, either the paired sample t-test or the Wilcoxon test, it can be used to compare two different conditions or times on the same sample such as the difference in the average value of the experimental class post-test will be known whether it is significantly different or not before and after treatment. The hypotheses in this study are as follows.

H_0 = There is no significant effect between learning activities assisted by laboratory activities on the level of student understanding of macromolecular materials.
H_a = There is a significant effect between learning activities assisted by laboratory activities on the level of student understanding of macromolecular materials.

III. RESULTS AND DISCUSSIONS

3.1. Demographics Data

Demographic data related to the IPAS course grades of a total of 23 students are presented in Table 6. This demographic data is to provide a better understanding of the student composition and support lesson planning.

TABLE XI
STUDENTS' IPAS SUBJECT SCORE

Data Type	Score
Respondent	23
Highest score	90
Lowest score	37
Average	58.14

Based on Table 6, the average score of the IPAS subject for a total of 23 students is 58.14 with the highest score of 90 and the lowest score of 37. The presentation of student scores is shown in Figure 1.

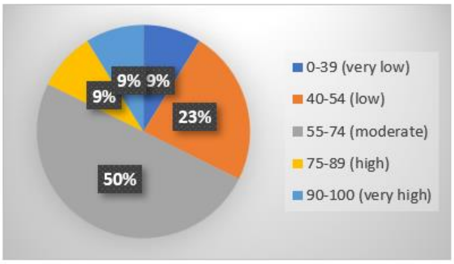

Fig. 1. Percentage Chart of Student Cognitive Learning Outcomes in IPAS Subjects

Figure 1 shows that 50% of the students had moderate cognitive learning outcomes, 9% in each of the high and very high categories, while 23% of the students had scores in the low category, and the remaining 9% in the very low category in the IPAS subject.

3.2. Analysis of Pretest and Postest Scores

The question instruments used in this study are pretest and post-test questions in the form of multiple-choice questions with a total of 10 questions. These two questions are presented similarly. A detailed explanation of the items and Bloom's taxonomy is presented in Table 7.

TABLE VII
PRETEST-POSTTEST ITEM QUESTIONS CATEGORY

No	Problems	Bloom Taxonomy	Score
1	Sucrose solubility in two different solvents	C2	1
2	Relationship between carbohydrate solubility and temperature	C3	1
3	The process of gelatinization is influenced by temperature and the changes that occur in the physical properties of starch	C3	1
4	The caramelization process of sugar	C3	1
5	Solubility of lipid-containing foods in different types of solvents	C2	1
6	Emulsion formation process	C4	1
7	Solubility pattern of proteins in different solvents	C3	1
8	Effect of temperature on protein denaturation	C3	1
9	Effect of temperature and pH on protein denaturation	C4	1
10	Changes that occur in proteins after denaturation	C2	1
Total score			**10**

Meanwhile, the test scores of students' learning outcomes measured by pretest and posttest are presented in Table 8.

TABLE VIII
RESULTS OF DESCRIPTIVE ANALYSIS OF PRETEST AND POSTTEST

Type	Number of Students	Min Value	Max Value	Mean	SD
Pre-test	23	20	70	35.22	15.336
Post-test	23	40	90	63.04	12.946

3.3. Analysis of N-Gain Score

The results of the N-gain test are to determine the extent of the improvement that occurred in the pretest and posttest questions after the treatment, in this case, the laboratory activities were carried out. The N-Gain test results are shown in Table 9.

Table 9 shows that 1 student obtained a low N-Gain score, 20 students obtained moderate N-Gain scores, and 2 students with high N-Gain scores. Therefore, the average N-Gain is 0.4 with a medium category.

3.4. Statistical Analysis of Learning Outcomes

Statistical analysis such a normality test and hypothesis test were conducted. For the normality test use the help of the SPSS version 26 for Windows program with the Shapiro-Wilk test. The requirement for this test is that the data is declared normally distributed if the Sig. value is > 0.05. The results of the normality test are presented in Table 10.

TABLE IX
N-GAIN TEST RESULTS

No	Students' Code	Pre test	Post test	N-Gain Score	Category
1	X1	40	70	0.5	Moderate
2	X2	30	60	0.4	Moderate
3	X3	50	70	0.4	Moderate
4	X4	20	50	0.4	Moderate
5	X5	50	70	0.4	Moderate
6	X6	50	60	0.2	Low
7	X7	20	50	0.4	Moderate
8	X8	70	90	0.7	High
9	X9	60	90	0.8	High
10	X10	30	60	0.4	Moderate
11	X11	30	60	0.4	Moderate
12	X12	30	60	0.4	Moderate
13	X13	30	60	0.4	Moderate
14	X14	30	50	0.3	Moderate
15	X15	20	50	0.4	Moderate
16	X16	20	50	0.4	Moderate
17	X17	20	40	0.3	Moderate
18	X18	20	60	0.5	Moderate
19	X19	20	60	0.5	Moderate
20	X20	30	60	0.4	Moderate
21	X21	30	70	0.6	Moderate
22	X22	50	80	0.6	Moderate
23	X23	60	80	0.5	Moderate
Mean score		31.7	63.0	0.4	Moderate

TABLE X
NORMALITY TEST RESULTS

Type	Shapiro-Wilk			Note
	Statistic	df	Sig.	
Pre-test	0.847	23	0.002	Not normally distributed
Post-test	0.913	23	0.046	Not normally distributed

Based on Table 10, the significance values for the pretest and posttest are 0.002 and 0.046 respectively, both of which show the value of Sig. < 0.05. Therefore, both pretest and posttest data are not normally distributed.

If the normality test results state that the data is not normally distributed, the next test uses a non-parametric statistical test, namely the Wilcoxon signed-rank test. This Wilcoxon test uses SPSS version 26 program. The results of the Wilcoxon test of ranks section are shown in Table 11.

TABLE XI
WILCOXON TEST RESULTS OF RANKS SECTION

		N	Mean Rank	Sum of Ranks
Pretest – Posttest	Negative Ranks	0[a]	70	0.00
	Positive Ranks	23[b]	90	276.00
	Ties	0[c]		
	Total	23		

a. Post Test < Pretest
b. Post Test > Pretest
c. Post Test = Pretest

Based on Table 11, it can be interpreted as follows: (i) Negative ranks or the negative difference between pretest and posttest scores is 0 both in the N value, mean rank, and sum of ranks. This means that there is no decrease from the pretest value to the post-test value; (ii) Positive ranks or the positive difference between the pretest and post-test scores, namely the N value is 23, indicating that 23 students experienced an increase in learning outcomes, with a mean rank of 12.00, and the sum of ranks is 276.00; while (iii) Ties show the similarity of pretest and post-test scores shown at a value of 0. Thus, it is said that there are no similar values between pretest and post-test.

For hypothesis testing the results are presented in Table 12. Table 12 shows that the Asymp. Sig (2-tailed) of 0.000 where the value of Sig. 000 < 0,05. Thus, based on decision-making, if the value of Sig. <0.05, H_0 is rejected and H_a is accepted. It can be concluded that there is an influence between learning activities assisted by practicum activities on the level of student understanding of macromolecular material.

TABLE XII
WILCOXON TEST RESULTS OF TEST STATISTICS

	Pretest – Posttest
Z	-4.299[b]
Asymp. Sig. (2-tailed)	0.000

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks

Based on these findings, learning activities assisted by practicum activities and hands-on experiments have been shown to enhance students' conceptual understanding (Nandiyanto et al., 2020). This result is evidenced by the difference in descriptive analysis values where there is a difference in the mean value and is supported by the N-gain value between the pre-test and post-test results. The N-gain value was obtained with a value of 0.4 which is in the medium category. These results are also in line with the hypothesis test which shows the influence between learning activities assisted by practicum activities on the level of student understanding.

The results of this study indicate that practicum activities contribute to helping students to better understand macromolecular learning materials. Macromolecular learning materials (carbohydrates, fats, and proteins) are materials that are broad in scope and are related to everyday life because they are related to food, health, and disease. So, it needs to be taught to vocational students, even for vocational students in software engineering majors. The design of practicum experiments carried out also utilizes easy and simple tools and materials that students can encounter every day. Thus, learning is more contextual. During the practicum process, students were very enthusiastic and motivated to learn. So, it can be said that learning by utilizing this practicum activity can involve learning to be active and attract their attention. This is supported by the use of simple tools for experiments, increasing student creativity (Wahyu et al., 2018; Ariyanti & Maryanti, 2021). This result is in line with research conducted by Supriatni (2022) that the practicum method makes students able to understand the material well in their memory because they practice it with simple materials and tools and those in their home environment. Thus, students become actively involved in the learning process. Students not only listen but also see what is happening directly.

Conclusion

The results showed that there was a significant effect of student learning outcomes between the learning process assisted by practicum activities on the level of understanding of vocational students on macromolecular material. The results obtained show that vocational students easily understand the material about macromolecules after learning assisted by practicum activities. These results were confirmed using statistical analysis with the N-gain test and non-parametric statistical test with Wilcoxon. Laboratory activities by utilizing simple tools and materials are significantly able to increase knowledge and accelerate the understanding of vocational students. Increased knowledge and understanding are in line with student learning outcomes in IPAS subjects. This study is expected to have an impact on the IPAS learning process, especially on macromolecular material with the help of practicum methods, which are considered to provide useful learning. This study can also have a good impact on the younger generation because understanding well the physical and chemical properties of macromolecules can support the goals of Sustainable Development Goals (SDGs). Practicum activities need to be well-designed, have clear learning objectives, and provide opportunities for students to actively participate to improve linkages with sustainable learning to support the impact of SDGs.

References

Akanle, O., Kayode, D., Abolade, I., & Serpa, S. (2022). Sustainable development goals (SDGs) and remittances in Africa. Cogent Social Sciences, 8(1), 1-6.

Al Husaeni, D. F., Al Husaeni, D. N., Nandiyanto, A. B. D., Rokhman, M., Chalim, S., Chano, J., Al Obaidi, A. S. M., & Roestamy, M. (2024). How technology can change educational research? Definition, factors for improving quality of education and computational bibliometric analysis. ASEAN Journal of Science and Engineering, 4(2), 127-166.

Ana, A. (2020). Trends in expert system development: A practicum content analysis in vocational education for over grow pandemic learning problems. Indonesian Journal of Science and Technology, 5(2), 246-260.

Anderson, K., Ryan, B., Sonntag, W., Kavvada, A., & Friedl, L. (2017). Earth observation in service of the 2030 agenda for sustainable development. Geo-spatial Information Science, 20(2), 77-96.

Ariyanti S, N. D., & Maryanti, R. (2021). Developing the creativity of elementary school students in Cimahi, Indonesia through online learning media during the covid-19 pandemic. Indonesian Journal of Teaching in Science, 2(1), 7-16.

Barke, H. D., & Buechter, J. (2023). Laboratory jargon and misconceptions in chemistry an empirical study. ASEAN Journal of Science and Engineering Education, 3(1), 65-70.

Barke, H. D., & Harsch, N. (2022). Chemical bonding: From simple bond forces to electron pairs. Indonesian Journal of Educational Research and Technology, 2(3), 275-284.

Basnur, J., Putra, M. F. F., Jayusman, S. V. A., & Zulhilmi, Z. (2024). Sustainable packaging: Bioplastics as a low-carbon future step for the sustainable development goals (SDGs). ASEAN Journal for Science and Engineering in Materials, 3(1), 51-58.

Cottafava, D., Cavaglià, G., & Corazza, L. (2019). Education of sustainable development goals through students' active engagement: A transformative learning experience. Sustainability Accounting, Management and Policy Journal, 10(3), 521-544.

Damayanti, N. K. A., Maryam, S., & Subagia, I. W. (2019). Analisis pelaksanaan praktikum kimia. Jurnal Pendidikan Kimia Undiksha, 3(2), 52-60.

Francis, T. T., & Baba, S. J. (2023). Effect of concept mapping teaching approach on students' academic performance in chemistry in senior secondary schools. Indonesian Journal of Educational Research and Technology, 3(1), 69-78.

Fiandini, M., Nandiyanto, A. B. D., Al Husaeni, D. F., Al Husaeni, D. N., & Mushiban, M. (2024). How to calculate statistics for significant difference test using SPSS: Understanding students' comprehension on the concept of steam engines as power plant. Indonesian Journal of Science and Technology, 9(1), 45-108.

Gemil, K. W., Na'ila, D. S., Ardila, N. Z., & Sarahah, Z. U. (2024). The relationship of vocational education skills in agribusiness processing agricultural products in achieving sustainable development goals (SDGs). ASEAN Journal of Science and Engineering Education, 4(2), 181-192.

Hardiatun, H. (2019). Penerapan pembelajaran virtuallab untuk meningkatkan penguasaan konsep dan keterampulan abad 21 peserta didik pada mata pelajaran kimia materi makromolekul di SMA N 1 TUBAN. Jurnal Teladan: Jurnal Ilmu Pendidikan dan Pembelajaran, 4(1), 9-14.

Haq, M. R. I., Nurhaliza, D. V., Rahmat, L. N., & Ruchiat, R. N. A. (2024). The influence of environmentally friendly packaging on consumer interest in implementing zero waste in the food industry to meet sustainable development goals (SDGs) needs. ASEAN Journal of Economic and Economic Education, 3(2), 111-116.

Henggu, K. U., & Nurdiansyah, Y. (2021). Review dari metabolisme karbohidrat, lipid, protein, dan asam nukleat. QUIMICA: Jurnal Kimia Sains dan Terapan, 3(2), 9-17.

Jannah, F. F., Khamidinal, K., & Suprihatiningrum, J. (2022). Pengembangan media virtual lab sebagai alternatif praktikum kimia dalam pembelajaran daring di masa pandemi COVID-19. Jurnal Inovasi Pendidikan Kimia, 16(2), 97-103.

Kirupa P., M., Kritvi, S., & Srimath, N. (2024). Knowledge, Importance and Inclusion of SDG in Engineering Curriculum – A student's perspective. Journal of Engineering Education Transformations, 37(Special Issue 2), 974–979.

Makinde, S. O., Ajani, Y. A., & Abdulrahman, M. R. (2024). Smart learning as transformative impact of technology: A paradigm for accomplishing sustainable development goals (SDGs) in education. Indonesian Journal of Educational Research and Technology, 4(3), 213-224.

Maryanti, R., Nandiyanto, A. B. D., Hufad, A., & Sunardi, S. (2021). Science education for students with special needs in Indonesia: From definition, systematic review, education system, to curriculum. Indonesian Journal of Community and Special Needs Education, 1(1), 1-8.

Nandiyanto, A. B. D., Tiyana, R., Azizah, D. N., & Hofifah, S. N. (2020). Demonstrating the biobriquettes production using variations in particle size and binder concentration using audio-visual to vocational students. Journal of Engineering Education Transformations, 34(Special Issue), 87–94.

Nazarov, S., & Jumayev, B. (2022). Project-based Laboratory Assignments to Support Digital Transformation of Education in Turkmenistan. Journal of Engineering Education Transformations, 36(1), 40–48.

Nurjayadi, M., & Kartika, I. R. (2012). Upaya peningkatan aktivitas mahasiswa pada pembelajaran bilingual biokimia I dengan model pembelajaran cooperative learning tipe student team achievement division (STAD) di jurusan kimia FMIPA UNJ. Jurnal Riset Pendidikan Kimia (JRPK), 2(1), 107-118.

Nurramadhani, A., Riandi, R., Permanasari, A., & Suwarma, I.R. (2024). Low-carbon food consumption for solving climate change mitigation: Literature review with bibliometric and simple calculation application for cultivating sustainability consciousness in facing sustainable development goals (SDGs). Indonesian Journal of Science and Technology, 9(2), 261-286.

Pandeeswari, S. T., Chandrasekaran, J., & Pudumalar, S. (2024). Redesigning Laboratory Courses in Information Technology Program: An Inquiry Based Learning Approach. Journal of Engineering Education Transformations, 37(Special Issue 2), 921–930.

Pratt, C. W. (2011). A biology laboratory exercise using macromolecule assays to distinguish four types of milk. Journal of Microbiology & Biology Education, 12(1), 44-45.

Putri, S. R., Hofifah, S. N., Girsang, G. C. S., & Nandiyanto, A. B.D. (2022). How to identify misconception using certainty of response index (CRI): A study case of mathematical chemistry subject by experimental demonstration of adsorption. Indonesian Journal of Multidiciplinary Research, 2(1), 143-158.

Rosina, H., Virgantina, V., Ayyash, Y., Dwiyanti, V., & Boonsong. S. (2021). Vocational education curriculum: Between vocational education and industrial needs. ASEAN Journal of Science and Engineering Education, 1(2), 105-110.

Sachs, J. D., Schmidt-Traub, G., Mazzucato, M., Messner, D., Nakicenovic, N., & Rockström, J. (2019). Six transformations to achieve the sustainable development goals. Nature sustainability, 2(9), 805-814.

Sari, D. K., Permanasari, A., & Supriyanti, F. M. T. (2017). Profile of students' creative thinking skills on quantitative project-based protein testing using local materials. Jurnal Pendidikan IPA Indonesia, 6(1), 71-75.

Sombria, K. J. F., Celestial, D.L., Jalagat, C. G. M., & Valdez, A. G. (2023). Online learning through google classroom: Effects on students critical thinking skills in chemistry. ASEAN Journal of Science and Engineering Education, 3(2), 193-210.

Sudarisman, S. (2015). Memahami hakikat dan karakteristik pembelajaran biologi dalam upaya menjawab tantangan abad 21 serta optimalisasi implementasi kurikulum 2013. Florea: Jurnal Biologi dan Pembelajarannya, 2(1), 29-35.

Sukandar, A., Hasan, B., & Suartini, T. (2020). Measuring technical drawing capability through online learning as a basic competency for vocational students. Journal of Engineering Education Transformations, 34(Special Issue), 1–6.

Supriatni, E. A. (2022). Penggunaan alat dan bahan dari lingkungan rumah pada praktikum larutan elektrolit dan non elektrolit. SCIENCE: Jurnal

Inovasi Pendidikan Matematika dan IPA, 2(1), 32-36.

Supryadi, & Kamelia, M. (2021). Pengenalan dan pendampingan praktikum berbasis project microscience di masa pandemi covid-19 bagi guru biologi sekolah menengah atas. Penelitian Pendidikan dan Pengabdian, 1(1), 1248-1261.

Taşğın, E. (2017). Macronutrients and micronutrients in nutrition. International Journal of Innovative Research and Reviews, 1(1), 10-15.

Tsybulsky, D., & Muchnik-Rozanov, Y. (2019). The development of student-teachers' professional identity while team-teaching science classes using a project-based learning approach: A multi-level analysis. Teaching and Teacher Education, 79, 48-59.

Tyasna, P. S., Agustin, A. E., Maharani, D., Utami, M. R., and Nurfadhilah, L. (2022). Identification of carbohydrate, protein and fat levels in flour, cheese, milk and yoghurt through several test methods. Jurnal eduhealth, 13(02), 1079-1087.

Wahyu, W., Suryatna, A., & Kamaludin, Y. S. (2018). The suitability of William's creativity indicators with the creativity-based worksheet for the junior high school students on designing simple distillation tool. Journal of Engineering Science and Technology, 13(7), 1959-1966.

Winarti, R., Masriani, M., & Sartika, R. P. (2014). Pengembangan modul biokimia II pada materi metabolisme karbohidrat untuk mahasiswa pendidikan kimia universitas tanjungpura. Jurnal Pendidikan dan Pembelajaran Khatulistiwa (JPPK), 8(1), 1-10.

Wiratma, I. G. L. (2014). Pengelolaan laboratorium kimia pada SMA Negeri di Kota Singaraja (acuan pengembangan model panduan pengelolaan laboratorium kimia berbasis kearifan lokal tri sakti). JPI (Jurnal Pendidikan Indonesia), 3(2), 425-436.

Wirzal, M. D. H., & Halim, N. S. A. (2022). Short play approach for analytical chemistry class. ASEAN Journal of Science and Engineering Education, 2(2), 163-168.