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The Effect of Project-Based Learning E-Modules on Student Competence in Developing Science Process Skills Assessment Instruments

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Abstract. Student competence in developing assessment instruments is crucial for ensuring the quality of learning evaluation. This research aims to determine the effect of project-based learning e-modules on student competence in developing science process skills instruments. This study employed a quasi-experimental research design with a nonequivalent control group. The sample was selected using purposive sampling based on students' initial abilities, resulting in 54 students divided into two groups. Data collection instruments included the development of one basic and integrated SPS question by students for each indicator. The research data were analyzed using a t-test with a significance level of 5%. The results demonstrated a significant positive effect of the PjBL e-module on student competence in developing SPS instruments, with the experimental group's average competence being 77.36, which was higher than the control group's average of 62.41. This research is expected to improve the competence of prospective science teachers in developing valid and effective assessment instruments, thereby addressing obstacles such as a lack of understanding of SPS, difficulties in constructing complex questions, and challenges in creating effective distractors.

Keywords: Project-based learning; student competence; science process skills instrument; prospective science teachers

Introduction

Education plays a crucial role in shaping individuals who are competent and adaptable to the demands of the times, thus requiring an innovative learning approach that empowers students holistically (Alrajeh, 2021). The development of SPS is a essential in higher education, enabling students to go beyond conceptual understanding and apply scientific knowledge in problem-solving and formulating innovative solutions (Bicak et al., 2021). SPS are an important link in the success of students as learners (Dolapcioglu & Subası, 2022) and are critical for solving problems and finding practical solutions (Gizaw & Sota, 2023). These skills encompass procedural aspects, scientific thinking habits in experimenting and investigating, scientific inquiry skills, and investigation process skills (Idris et al., 2022). SPS involves a series of cognitive and psychomotor abilities that enable individuals to observe, classify, measure, formulate hypotheses, design experiments, analyze data, and communicate research results effectively (Chakraborty & Kidman, 2022).

Despite the recognized importance of SPS, their development in higher education faces significant challenges. Research indicates that traditional science teaching methods often remain teacher-centered and rely heavily on rote memorization of facts and theories, failing to actively engage learners in the scientific process (Asilevi et al., 2023). The development of SPS enables students to acquire the skills needed to solve everyday problems (Koomson et al., 2024). Studies further reveal that university students often exhibit poor integrated science process skills and struggle to apply scientific concepts to real-world problem-solving situations (Idris et al., 2022; Yusnidar et al., 2024). These vital SPS encompass a series of cognitive and psychomotor abilities, including observation, classification, measurement, hypothesis formulation, experiment design, data analysis, and effective communication of research results (Rustan et al., 2020; Widyaningsih et al., 2020; Yamin & Hartiningsih, 2023)

These pervasive issues highlight an urgent need for transformative learning strategies to effectively cultivate SPS in students (Azfi et al., 2025). The PjBL model offers a promising approach to to address these challenges by facilitating authentic and contextual learning experiences that intrinsically motivate students to actively engage in scientific projects (Fariza & Kusuma, 2024; Markula & Aksela, 2022). The PjBL model is a learner-centered learning model that provides opportunities for students to deeply investigate real-world problems and develop innovative solutions through collaborative projects (Nurhidayah et al., 2021). The integration of a STEM approach within PjBL is particularly relevant, as it emphasizes the interdisciplinary application of knowledge to solve real-world problems, thereby preparing competitive human resources for the global era.

Electronic modules (e-modules) further enhance the implementation of PjBL. E-modules are interactive and flexible digital learning resources with significant potential to support PjBL in higher education (Holisoh et al., 2025; Tian et al., 2023). Well-designed e-modules can provide relevant content, challenging tasks, and constructive feedback, thereby facilitating the effective development of students' SPS (Setiawan et al., 2021; Sudarmin et al., 2019). This is crucial for fostering student competence in designing and developing valid and reliable assessment instruments.

The urgency of this research lies in its contribution to improving student competence in developing SPS instruments, which is an essential aspect in achieving sustainable education goals, particularly sustainable development goals point 4, which is to ensure inclusive, equitable, and quality education and promote lifelong learning opportunities for all (Al-Kuwari et al., 2022; Coomans, 2022). These skills equip graduates with the ability to effectively measure and improve the quality of science learning, in line with global efforts to ensure inclusive and quality education (Hasibuan et al., 2022). In addition, this research supports by asta cita program, particularly in the pillar of developing superior and adaptive human resources by emphasizing the importance of producing students with skills in developing instruments so that they are highly competitive, particularly in improving the quality of teaching and aligning the curriculum so that graduates are ready to contribute to national development and face global challenges (Ramlawati, 2025).

The novelty of this research lies in several aspects. First, it involves the integration of e-modules and PjBL specifically for developing SPS instruments within instrument development courses. Second, it shifts the focus to student competence in developing these instruments, ensuring students can not only utilize but also create robust evaluation tools. Third, it introduces an innovative pedagogical approach to assessment literacy in students (Reynders et al., 2020; Xia et al., 2024). By utilizing PjBL based e-modules, this research aims to produce graduates who are competent in designing valid and reliable assessments. The interactive and flexible nature of e-modules, combined with the disciplinary integration of STEM in PjBL, fosters significant innovation in learning, preparing students with skills relevant to industry needs and technological advancements. Furthermore, the PjBL learning model has the potential to significantly increase student creativity. The strategic use of technology in education, including e-modules, can help

educators make learning more interesting and engage students more effectively (David & Weinstein, 2024). Moreover, digital learning tools have the potential to facilitate independent learning and enhance autonomous learning skills among students.

Methods

This quantitative research employed a quasi-experimental design (Creswell, 2014; Lederman et al., 2023) to determine the effect PJBL based e-modules on students' competence in developing SPS instruments. The research population comprised all 88 students majoring in Science Education at FMIPA Universitas Negeri Makassar who were enrolled in the instrument development course. The sample was determined using purposive sampling based on the students' initial abilities, resulting in two groups: group A22, consisting of 30 students, served as the experimental group, and group C22, with 25 students, served as the control group. The independent variable in this research was PjBL-based e-modules, while the dependent variable is student competence in developing SPS instruments.

The research design utilized was a non-equivalent control group design, as shown in Figure 1. The experimental group was taught using a PjBL-based e-module, whereas the control group was taught using resentation slides, which are common learning media used by lecturers in classroom settings.

G_1	O_1	X	O_2
G_2	O_3	-	O_4

Figure 1. Research Design

Explanation:

X	: PjBLbased e-module
O1 , O3 , O5	: Pre-test
O2 , O4	: Final test
G1	: Experimental group
G2	: Control group

The data collection stage involves students developing one question for each SPS indicator, both basic and integrated. The questions developed by students are assessed using a scoring rubric consisting of four criteria levels, namely scores 1, 2, 3, and 4. This rubric covers several crucial aspects that must be met during the development of questions or instruments, such as: (1) the suitability of the questions with the SPS indicators, (2) the clarity of the question construction, (3) the accuracy of the language used, and (4) the suitability of the questions for use in science learning. Experts have validated both e-module and the rubric. Furthermore, the instruments were used in the data collection stage, which was carried out through a pretest and posttest.

Data were analyzed using descriptive and inferential methods. Descriptive statistics were used to determine the level of implementation of the PjBL e-modules for SPS instruments. This includes reporting the number of samples, sample size, highest score, lowest score, mean score, standard deviation, and variance. Inferential statistical techniques, pecifically a t-test at a 5% significance level, were used to determine the effect of the e-module on students' competence in developing SPS instruments. This analysis was preceded by requirement tests (normality and homogeneity tests) to ensure the appropriateness of the inferential analysis.

Results and Discussion

The research was conducted during three meetings with group A22, the experimental group taught using PjBL based e-module, and group C22, the control group taught using slide presentation media commonly used by lecturers when teaching. Before the treatment, students were given a pre-test that required them to develop test instruments for each basic and integrated SPS indicator.

Descriptive Analysis

The descriptive analysis in this research aimed to describe the students' competence in developing SPS test instruments in both the experimental and control groups. The results of the descriptive analysis are presented in Table 1.

Table 1. Descriptive analysis of student competence in developing SPS

No	Statistics	Experimental group		Control group	
		pre-test	posttest	pretest	posttest
1	Sample size	30	30	24	24
2	Highest score	59.92	100	46.15	91.30
3	Lowest score	42.31	34.38	42.30	36.23
4	Average score	47.96	77.36	44.23	62.41
5	Standard deviation	2.91	17.58	1.32	21.42
6	Variance	12.39	24.77	1.63	17.01

Based on Table 1, the experimental group and control group showed differences in their descriptive statistics. For student competence in developing SPS instruments, the highest pretest score in the experimental group was 59.92, while in the control group it was 46.15. The lowest pretest score was 42.31 in the experimental group and 42.30 in the control group. Regarding post-test scores, the highest score in the experimental group was 100, compared to 91.30 in the control group. The lowest post-test score was 34.38 for the experimental group and 36.23 for the control group. The average pretest score for SPS competence was 47.96 in the experimental group and 45.23 in the control group. For the post-test, the average score in the experimental group was 77.36, while in the control group it was 62.41. The data from the N-Gain analysis of the questions developed based on SPS indicators are shown in Table 2.

Table 2. N-Gain of questions on SPS indicators developed by students

Group	Average score		N-Gain	Category
	pre-test	posttest		
Experiment	47.69	77.36 (high)	0.56	moderate
Control	45.23	62.41 (moderate)	0.29	low

Based on Table 2, the average increase in student competency scores in developing SPS test instruments was 0.56 in the experimental group, which falls into the moderate category. In contrast, the average increase in competency scores in the control group was 0.29, placing it in the low category. The results of the N-Gain analysis for each question developed based on the indicators are presented in Figure 2.

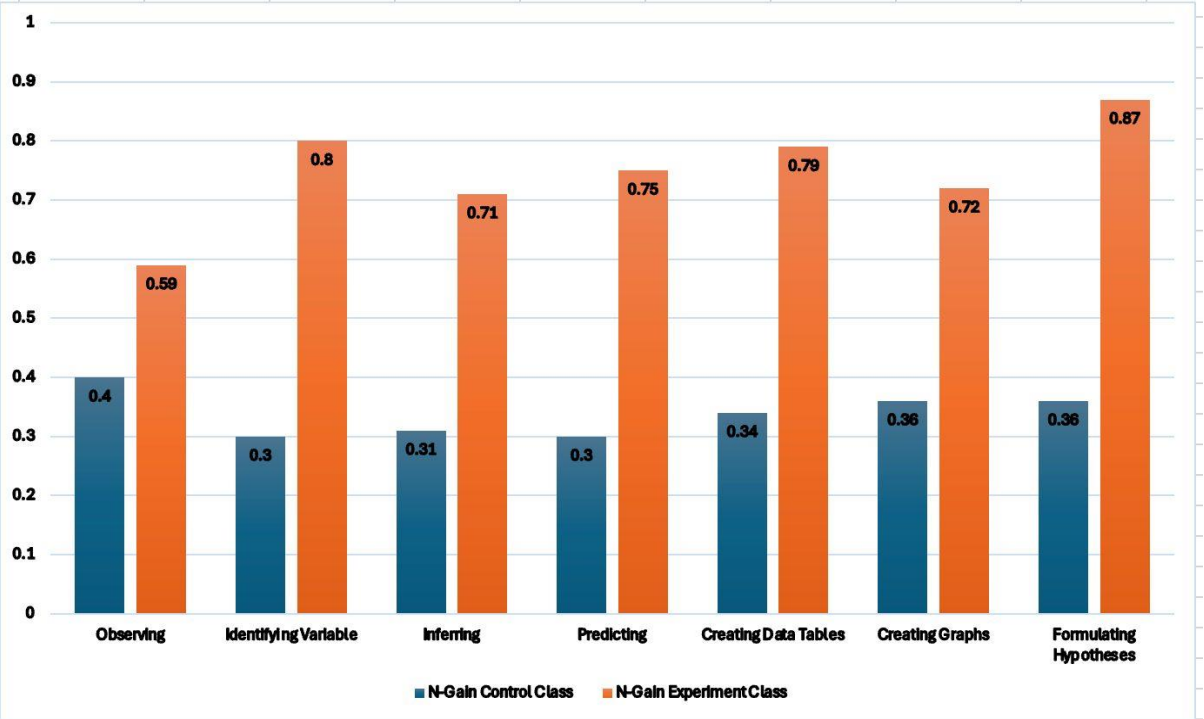


Figure 2. Avarage N-Gain score for each SPS questioning comptence

SPS questions are designed to test students' ability to think and act like scientists, rather than merely measuring their memorization of facts. These questions aim to assess cognitive abilities in processing information, solving problems, and drawing conclusions (Nurulsari et al., 2023).

Based on Figure 2, the lowest N-Gain in students' ability to develop SPS questions was in the observation indicator: 0.59 in moderate category in the experimental group and in the variable identification and prediction indicator: 0.30 in moderate category in the control group. The highest N-Gain was in the hypothesis formulation indicator: 0.87 in high category in the experimental group and the observation indicator: 0.40 in medium category in the control group. The average N-Gain score for each question based on the SPS indicator was 0.75 (high category) in the experimental group and 0.34 (medium category) in the control group.

This significant improvement was attributed to the implementation of a PjBL model-based e-module. The PjBL model encourages students to actively formulate questions, plan investigations, and make predictions. These activities are core skills for hypothesis formulation, thereby facilitating a deep understanding of both hypothesis development and testing in science (Hu et al., 2024). Additionally, the e-module provides interactive resources that support concept exploration and repeated practice, which have been proven to increase student engagement and independent learning (Ricaurte & Viloria, 2020; Yulando et al., 2019). Meanwhile, the observation indicator had the lowest score. This result was attributed to the conventional learning method in the control class, which relied solely on presentation slides and did not provide sufficient opportunities for students to hone their observation skills in depth. Although the experimental group used a PjBL-based e-module, questions related to observation indicators also received relatively low scores, indicating that these basic skills may either be already well-formed or require more intensive practical training outside the e-module format to achieve optimal improvement (Tawil et al., 2023).

Inferential Analysis

The inferential analysis in this research aimed to draw conclusions regarding the effect of PjBL-based e-modules, specifically those developed by students using SPS questions, on both the experimental and control groups.

Normality Test

The results of the normality test for SPS questions developed in the experimental group and control group can be seen in Table 3.

Table 3. Normality test of SPS questions

Normality test	SPS questions	
	experimental	control
N	30	24
statistics	0.967	0.952
Sig.	0.423	0.215
decision	Sig. > 0.05 normally distributed	Sig. > 0.05 normally distributed

Based on Table 3, the results of the Shapiro-Wilk normality test show that the SPS developed by students in the experimental and control groups have a significance value of more than 0.05, so that the competency data in both groups are normally distributed.

Homogeneity Test

The results of the data homogeneity test using Levene's test on the science process skills questions developed by students can be seen in Table 4.

Table 4. Homogeneity test on SPS questions

Data	F	*Sig*	Description
Pretest	1.284	0.289	
Posttest	0.972	0.386	Homogeneous
N-Gain	1.102	0.341	

Based on Table 4, the results of the homogeneity test show that the pretest, posttest, and N-Gain data for the SPS questions developed by students have a significance value of more than 0.05, so it can be concluded that the data variance is homogeneous. Thus, the analysis can be continued using parametric tests.

Hypothesis Testing

The results of the initial analysis for normality, distribution, and homogeneity of variance for both the experimental and control groups were met, followed by a parametric independent sample t-test with a significance level of 0.05. The results of the hypothesis testing on the SPS developed by students on the basic and integrated skill indicators are presented in Table 5.

Table 5. Results of the t-test on SPS questions

t	df	Sig. (2-tailed)	mean difference
2.82	54	0.007*	14.95

(*) significant at α = 0.05

The results of the hypothesis test for SPS based on Table 6 obtained *t*-value of 2.82 with a significance value of α=0.01, so Ho was rejected and H1 was accepted. Consequently, the null hypothesis (H0) was rejected, and the alternative hypothesis (H1) was accepted. These results indicate a statistically significant difference in the ability to create SPS questions between the experimental group and the control group. An average difference of 14.95 highlights the magnitude of this distinction between the two groups.

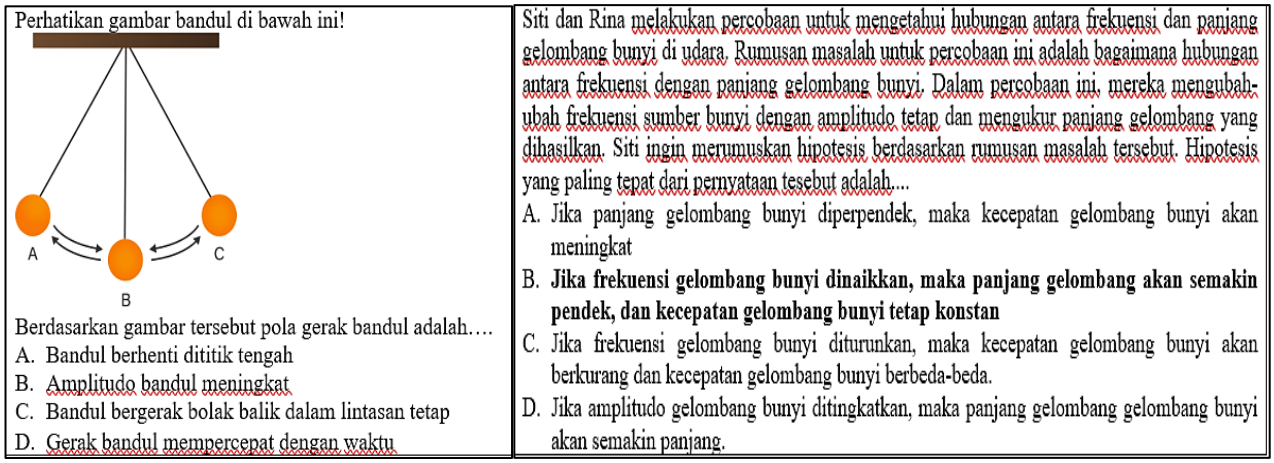
This finding is particularly important given that student competence in developing assessment instruments is a crucial aspect of their learning.

These findings align with previouswhich demonstrates that prospective teacher students' ability to develop HOTS category learning outcome test instruments is relatively good, despite variations in the development of objective and essay questions (Deria et al., 2023). This suggests that students possess the potential to develop question instruments capable of measuring higher-level skills, including SPS. This acquisition is further supported by Tauhidah & Rofi'ah (2023), who reveal that the development of SPS test instruments not only facilitates accurate measurement but also requires a careful validation process before the instruments can be used effectively.

The increase in student scores for creating SPS questions in the experimental group, compared to the control group, can be attributed to the implementation of the e-module. This learning model actively involves students in real projects, specifically the development of SPS assessment instruments. The PjBL approach encourages deep learning through direct experience and collaboration, which is essential for building practical competencies such as instrument development (Daineko et al., 2020). Furthermore, the e-module used in this learning also facilitates flexible and interactive access to materials, allowing students to learn independently and repeatedly according to their needs, thereby supporting the improvement of their understanding and skills in designing assessments (Martinho et al., 2023; Yulando et al., 2019).

Unlike the control group, which was only taught using presentation slides commonly used by lecturers when delivering lectures, PjBL with e-module support allows for better differentiation and scaffolding. This aligns with the principle that learning models accommodating diversity are essential (Liang et al., 2025; Palieraki & Koutrouba, 2021). Through the assessment instrument development project, students not only gained theoretical understanding but also critical practical experience in applying SPS concepts to valid and reliable questions. The implementation of PjBL-based E-Modules, therefore, became a key factor in improving students' competence in developing instruments.

SPS questions are designed to test students' ability to think and act like scientists, rather than merely measuring their memorization of facts. These questions encompass both basic and integrated skills, such as observation, variable identification, data interpretation, experimental design, and conclusion drawing (Cansız, 2024). Being context-based and rooted in real-world problems (Chang et al., 2023), they encourage critical and multidimensional thinking (Christensen & Lombardi, 2023). Such questions are specifically formulated to support scientific inquiry and can be assessed through written formats or direct observation (Sholihah et al., 2023). Some constructed question by students can be seen in Figure 3



(a) (b)

Figure 3. SPS questions developed by students

Based on Figure 3, the science process skill indicator in part (a) is observing, while part (b) is formulating hypotheses. Both questions show different approaches in measuring SPS.

Question (a) tests the ability to visually observe a described phenomenon. Observation skills in science should involve the use of the senses to gather information directly from an object or event. In this context, this question tests the visual interpretation of a static image. The available answer choices are indeed related to the characteristics of pendulum motion. However, the pendulum image provided in the question is incorrect due to an error in depicting the pendulum's direction. This interferes with observation skills, an indicator of science process skills, as students will have difficulty correctly observing the phenomenon. For example, if an arrow shows the pendulum continuously moving in one direction without turning back, or depicts the pendulum stopping at the center point, this contradicts the actual motion. Students who rely on this incorrect visualization will form a misguided understanding, and their skills in interpreting visual information (which is essential in science) will be hindered (Ingulfsen et al., 2023). However, this question tests the understanding of the physics concept of simple harmonic motion rather than pure observation skills involving direct data collection.

Based on the N-Gain scores presented in Figure 2, the lowest N-Gain observed in both groups was 0.59 in the experimental group and 0.40 in the control group. This outcome likely occurred because the questions designed to test this indicator, such as example (a), were less effective in stimulating or accurately measuring actual improvements in observation skills. This is supported by Idul & Caro (2022) and Susilowati et al. (2023), who revealed that if the questions on the observation indicator only involve the interpretation of static images or conceptual understanding, their impact on improving observation skills may be limited compared to direct and structured observation activities.

Question (b) presents the research context (the relationship between frequency and wavelength of sound) along with the variables that are changed and measured. Students are required to understand the problem formulation and develop logical and testable hypotheses. The provided answer choices are various forms of hypotheses or statements related to waves, and students must select the most accurate one according to the rules of scientific hypothesis formulation. This serves as a HOTS test in identifying potential cause-and-effect relationships and summarizing them in the form of testable scientific statements. In line with this, the hypothetical formulation indicator showed the highest N-gain of 0.87 in the experimental group. This is consistent with the type of questions developed. The ability to formulate hypotheses is a complex skill that is strongly supported by the PjBL approach applied in the experimental group. PjBL encourages students to formulate research questions, plan experiments, and, most importantly, formulate hypotheses as an integral part of the scientific process (Cansız, 2024). Furthermore, interactive e-modules can provide simulation scenarios or case studies that train students in formulating hypotheses, thereby significantly improving their competence.

Prospective science teachers often face several significant difficulties in constructing SPS questions. These difficulties STEM from conceptual understanding, pedagogical skills, and technical aspects of question construction. This is in line with the results of research that prospective science teachers may have a less than optimal understanding of SPS itself (Nurulsari et al., 2023). This is a fundamental obstacle because, to construct questions that measure science process skills, a prospective teacher must thoroughly master each of their indicators (Bicak et al., 2021). Without a strong understanding, the questions created may not be valid in measuring the intended (Wang, 2023). In addition, the obstacle faced by prospective teacher students in constructing questions is the preparation of complex SPS questions. This is supported by the research findings ofby Hartanto et al. (2023) and Tawil et al. (2023, which indicate that SPS-based test instruments are often extensive, incorporate tables, graphs, or images, are complex and context-based, and include effective distractors in multiple-choice questions. Prospective science teachers generally

face difficulties in constructing this type of question (Christensen & Lombardi, 2023; Holmen, et al., 2023).

Conclusion

Based on data analysis and research results, there is an observable influence of PjBL-based e-modules on student competence in developing SPS assessment instruments. The average competence of prospective science teachers in developing questions in the experimental group after receiving treatment was 77.36, which was categorized as high, while in the control group it was 62.41, categorized as medium. The main obstacles faced by students in formulating questions include a lack of optimal understanding of SPS indicators, difficulties in constructing context-based questions, and challenges in creating effective distractors for multiple-choice questions. This research is expected to contribute to prospective science teachers by improving their competence in developing SPS assessment instruments, as well as in overcoming obstacles related to question formulation.

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