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EFFECTIVENESS OF THE E-MODULE 7E CYCLE INTEGRATED TECHNOLOGICAL KNOWLEDGE IN IMPROVING THE SCIENTIFIC REASONING SKILLS OF PROSPECTIVE TEACHER STUDENTS

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Abstract
Scientific reasoning skills are fundamental abilities that prospective teacher students must possess as a foundation for designing and implementing ideal science instruction. However, science instruction predominantly focuses on conceptual mastery and fails to adequately develop students' scientific reasoning skills. The purpose of this study was to analyze the effectiveness of a e-module 7e cycle integrated technological knowledge in enhancing students' scientific reasoning skills. The method used was a quasi-experimental design with two sample classes consisting of an experimental class (40 students) and a control class (38 students). The research instrument consisted of a scientific reasoning test comprising 20 questions covering the ability to analyze cause-and-effect relationships, evaluate scientific evidence and conclusions, and design solutions based on scientific principles. Data were analyzed using the N-gain test, hypothesis testing, and effect size testing. The results showed that the experimental class's N-gain score was 0.71 (high category), while the control class's score was 0.42 (moderate category). The t-test results showed a significance value of 0.000 (p < 0.05) with a calculated t-value of 7.84. This indicates a significant difference in the improvement of scientific reasoning skills between the two classes. The effect size test yielded a Cohen's d value of 1.32, indicating a large effect. The conclusion drawn is that the e-module 7e cycle integrated technological knowledge is effective in enhancing the scientific reasoning skills of prospective teacher students and has the potential to serve as an alternative instructional material for science education in higher education.
Keywords: *e-module; learning cycle; technological knowledge; scientific reasoning skill*

Abstrak
Kemampuan penalaran ilmiah adalah kemampuan dasar yang harus dimiliki mahasiswa calon guru sebagai bekal untuk merancang dan melaksanakan pembelajaran IPA yang ideal. Namun, pembelajaran IPA dominan berfokus pada penguasaan konsep dan kurang melatih penalaran ilmiah mahasiswa. Tujuan penelitian yaitu untuk menganalisis efektivitas e-modul 7e cycle berbasis technological knowledge untuk meningkatkan kemampuan penalaran ilmiah mahasiswa. Metode yang digunakan yaitu kuasi eksperimen dengan dua kelas sampel yang terdiri dari kelas eksperimen (40 mahasiswa) dan kelas kontrol (38 mahasiswa). Instrumen penelitian berupa soal tes penalaran ilmiah yang berjumlah 20 soal mencakup kemampuan menganalisis hubungan sebab akibat, mengevaluasi bukti dan kesimpulan ilmiah, serta merancang solusi berdasarkan prinsip ilmiah. Data dianalisis dengan uji N-gain, uji hipotesis, dan uji effect size. Hasil penelitian menunjukkan nilai N-gain kelas eksperimen sebesar 0,71 kategori tinggi, sedangkan kelas kontrol sebesar 0,42 kategori sedang. Hasil uji t menunjukkan nilai signifikansi 0,000 (p < 0,05) dengan t hitung 7,84. Artinya ada perbedaan peningkatan kemampuan penalaran ilmiah yang signifikan antara kedua kelas. Hasil uji effect size memperoleh nilai Cohen's d sebesar 1,32 dengan interpretasi efek besar. Kesimpulan yang diperoleh yaitu e-modul cycle 7e terintegrasi technological knowledge efektif dalam meningkatkan kemampuan penalaran ilmiah mahasiswa calon guru, serta berpotensi menjadi alternatif bahan ajar untuk pembelajaran sains di perguruan tinggi.
Kata Kunci: e-modul; learning cycle; technological knowledge; kemampuan penalaran ilmiah

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Introduction

The 21st-century educational paradigm demands that higher education institutions prepare graduates who master the subject matter and possess the ability to think critically, creatively, and collaboratively, and to adapt to technological advancements. In the context of science education at the university level, these skills are essential so that students not only understand scientific concepts but are also able to explain, connect, and apply them logically in real-world contexts (Yunita & Mandasari, 2025). Students in the Primary School Teacher Education program are future educators who are expected to teach science in a meaningful way to elementary school students. Instruction is conducted by incorporating three dimensions: scientific and engineering practices, crosscutting concepts, and disciplinary core ideas (Fick & Arias, 2022). These three dimensions require students and prospective teachers to be able to develop scientific reasoning that links theory with practice. If prospective teachers are not trained in scientific reasoning, they will tend to imitate conventional teaching styles that emphasize memorization rather than understanding.

Findings from science courses in the Primary School Teacher Education Program at the Faculty of Teacher Training and Education, Universitas Islam Riau, indicate that students still struggle to develop scientific reasoning. An analysis of learning needs revealed that, on average, students' reasoning skills scored below 60%, with the lowest score being 47. Instruction often focuses on lower-order cognitive aspects, such as memorizing concepts and experimental procedures, without deep reflection. Consequently, students struggle to analyze cause-and-effect relationships, evaluate evidence, and design solutions based on scientific principles.

The low level of students' reasoning skills is further supported by consistent research findings indicating that students still tend to understand concepts in isolation and fail to grasp the scientific significance of the learning activities they have undertaken (Sinaga et al., 2024). Most students are also only able to recall basic definitions and formulas in science material, but cannot yet relate them to the application of concepts in real-life contexts (Fatimah et al., 2024; Susilasari et al., 2025). Teacher-centered learning causes students to take a passive role, preventing the process of knowledge construction from occurring (Jariah, 2022).

In light of these issues, the learning cycle model is considered capable of facilitating effective learning in developing students' scientific reasoning skills. The learning cycle model consists of seven stages: elicit, engage, explore, explain, elaborate, evaluate, and extend (Baybars & Kucukozer, 2018; Miftahuljannah, 2018). Each stage forms a learning structure that enables students to build their understanding gradually and systematically (Simamora et al., 2019). This model aligns with the characteristics of science education in the Primary School Teacher Education Program, which emphasizes active student engagement and the development of scientific reasoning. Research findings (Rusydi & Kosim, 2018) indicate that implementing the 7-stage learning cycle in science courses can enhance students' critical thinking skills by up to 25%. The learning cycle model has also been shown to help students develop a deeper scientific understanding compared to traditional instruction (Komikesari et al., 2020).

In addition, the integration of technological knowledge has become an essential skill that educators must master in the digital age. Prospective teachers must understand how to use and leverage technology to explain science concepts in a more concrete and interactive manner (Suchyadi et al., 2020). The use of technology can enhance independent learning and higher-order thinking skills (Rusni et al., 2023).

Previous research has developed an integrated e-module 7e cycle integrated technological knowledge, which has been validated (Mustika et al., 2025). However, there is currently no concrete evidence regarding its effectiveness in enhancing students' scientific reasoning skills. Therefore, this study focuses on testing the effectiveness of the e-module while analyzing its contribution to improving students' scientific reasoning. Measuring scientific reasoning ability adds value to the novelty of this study because this aspect has received insufficient attention in various studies related to learning at the university level.

Research Methods

The research method used was an experimental method with a quasi-experimental pretest-posttest control design. The study was conducted in the Primary School Teacher Education Program, Faculty of Teacher Training and Education, Universitas Islam Riau. The sample consisted of two classes with a total of 78 students. Details of the sample size in this study are presented in Table 1.

Table 1
Research sample data

Class	Man	Woman
1A (experiment class)	6	34
1B (control class)	4	34
Number	10	68
Total number	78	

The intervention was conducted over four sessions, each lasting 100 minutes. In the experimental class, instruction utilized the e-module 7e cycle integrated technological knowledge. Learning activities followed the instructions outlined in the e-module, namely activating prior knowledge through digital reading materials (elicit), watching instructional videos as a basis for problem identification (engage), formulating problems and gathering information from various sources (explore), presenting answers to the formulated problems (explain), verifying answers through simple demonstration activities (elaborate), assessing conceptual mastery via Google Forms (evaluate), and determining solutions for follow-up tasks (extend). Meanwhile, the control class conducted learning using conventional teaching materials.

The instrument used consists of scientific reasoning test items whose validity and reliability had been previously tested. The validity tests included content validity and construct validity. Content validity was assessed by seeking the opinions of two experts, while construct validity was determined by pilot-testing the questions on a separate sample. The validity test results indicated that 18 items were classified as valid, whereas 2 items were classified as invalid. The invalid items were revised before use. Additionally, a reliability test was conducted to determine the level of consistency of the designed test questions. The reliability test used Cronbach's alpha, yielding an α value of 0.87, which falls into the highly reliable category. Thus, the test consists of 20 valid items. Each correctly answered item is scored 5, while incorrect answers are scored 0. The total score for all items is 100. The test item matrix used can be seen in Table 2.

Table 2. Matrix of scientific reasoning test instruments

Aspects of scientific reasoning	Question indicators	Cognitive level	Question number
Analyzing cause-and-effect relationships	Analyzing the relationship between energy sources and forms of energy conversion	C4	1-3
	Analyzing the conversion of electrical energy into other forms	C4	4-6
Evaluating evidence, variables, and scientific conclusions	Assessing the type of heat transfer and the efficiency of the equipment used	C5	7-10
	Assessing the relationship between force, displacement, and energy in everyday events	C5	11-13
Designing solutions based on scientific principles	Designing alternative energy implementation solutions	C6	14-17
	Designing simple tools based on energy conversion	C6	18-20

Next, the analysis of the effectiveness test data was conducted using two tests: the N-Gain test, hypothesis testing, and effect size analysis. The N-Gain test was designed to determine the extent of improvement in students' reasoning skills after using the e-module. The following is the N-Gain test formula used in (Habiby, 2017).

$$Gain\ Index\ (G) = \frac{Xpo - Xpe}{Xmax - Xpe}$$

Description:
Xpo = post-test average score
Xpe = pre-test average score
Xmax = maximum score

This was followed by hypothesis testing using the t-test, or independent samples t-test. Hypothesis testing was conducted after passing the prerequisite tests, namely the normality test and the homogeneity test. The hypotheses used were:
Ha: There is a difference in the improvement of scientific reasoning skills
Ho: There is no difference in the improvement of scientific reasoning skills

Finally, the effect size test (Cohen's d) was used to determine the magnitude of the effect of the e-module 7e cycle integrated technological knowledge on the improvement of students' scientific reasoning skills. The formula for Cohen's d, adopted from Glass in (Sugiyono, 2023).

$$d = \frac{M_1 - M_2}{SDpooled}$$

With :

$$SD\ pooled = \sqrt{\frac{(n_1 - 1)SD_1^2 + ((n_2 - 1)SD_2^2}{n_1 + n_2 - 2}}$$

Description:
d = Cohen's d
M_1 = mean of the experimental group
M_2 = mean of the control group
SD_{pooled} = pooled standard deviation
SD = standard deviation
n_1 = sample size of the experimental group
n_2 = sample size of the control group

The criteria for interpreting Cohen's d are as follows:
d = 0.20 = small effect
d = 0.50 = moderate effect
d > 0.80 = large effect

Result and Discussion

The primary objective of this study is to test the effectiveness of the e-module 7e cycle integrated technological knowledge. The effectiveness test was conducted using a quasi-experimental method involving an experimental class and a control class. The average pretest and posttest scores for the two classes are presented in Table 3.

Table 3. Average pretest and posttest

No	Class	Average score		Difference	(%) Improvement
		Pre-test	Post-test		
1	Experiment	43,4	83,8	40,4	40%
2	Control	41,9	66,4	20,5	21%

Based on Table 3, the average pretest score for the experimental class was 43.4, while that for the control class was 41.9. The nearly identical average difference indicates that both groups had comparable initial abilities before the intervention was administered. The average posttest scores for both the experimental and control classes also showed an increase. However, the difference in the pretest-posttest improvement was quite significant in the experimental class, at 40%, whereas in the control class it was only 21%. This means that the improvement in scientific reasoning ability in the experimental class, which used the e-module 7e cycle integrated with technological knowledge, was higher than that of the control class, which used conventional teaching materials.

The e-module 7e cycle integrated technological knowledge was developed in accordance with the seven stages of the 7e learning cycle model: elicit, explore, explain, elaborate, evaluate, and extend. Each stage is designed to encourage students to actively construct knowledge through systematic learning experiences. The explore and explain stages encourage students to identify cause-and-effect relationships and evaluate empirical evidence, while the elaborate and extend stages guide students to apply scientific principles in designing solutions to contextual problems (Mustika et al., 2023). Additionally, the integration of technological knowledge within the e-module helps students understand abstract concepts and strengthens the scientific reasoning process (Henriksen et al., 2016). Technology in the e-module functions as a cognitive tool that facilitates the exploration of learning experiences, data analysis, and self-assessment, enabling students to evaluate their own learning progress. In line with the TPACK theory proposed by Mishra and Koehler, the appropriate integration of technology can enhance the quality of learning and conceptual understanding (Valtonen et al., 2017). Furthermore, Schwart also states that the use of digital technology in science education has a positive impact on evidence-based reasoning and argumentation skills (Voogt & McKenney, 2017).

To assess improvements in students' scientific reasoning skills, the effectiveness of the program was first evaluated using the N-gain score. The results of the N-gain test are presented in Table 4.

Table 4. N-Gain Test Results

No	Class	N-Gain score	Category
1	Experiment	0,71	High
2	Control	0,42	Medium

The N-gain score calculations for the experimental class yielded an average in the high category, while those for the control class yielded an average in the moderate category. This indicates that the improvement in scientific reasoning skills among students who learned using the e-module 7e cycle integrated with technological knowledge was greater than that achieved through conventional learning. The high N-gain scores in the experimental class indicate that the improvement occurred not only in quantitative scores but also in the scientific reasoning process, particularly in analyzing cause-and-effect relationships, evaluating evidence, and designing solutions based on scientific principles. However, it is important to understand that, methodologically, N-gain only represents a change in scores relative to initial ability; therefore, statements regarding improvements in reasoning ability must be interpreted with caution and considered in relation to the instructional design employed. In these results, the high effectiveness is likely influenced by the characteristics of the explore and elaborate stages, which help stimulate reasoning abilities..

The use of N-gain in this study also offers analytical advantages because it takes students' initial abilities into account, thereby allowing for a more equitable evaluation of effectiveness compared to using only posttest scores. This is supported by Hake's research (Husnulwati et al., 2019), which states that normalized gain is a sensitive indicator for measuring learning gains in experimental designs. Data analysis continued with prerequisite tests, namely the normality test and the homogeneity test. The results of the normality test can be seen in Table 5.

Table 5. Normality test results

	Shapiro-Wilk		
Group	Sig.	α	Description
Experimental pre-test	0,124	0,05	Normal
Experimental post-test	0,098	0,05	Normal
Control pre-test	0,137	0,05	Normal
Control post-test	0,110	0,05	Normal

Based on Table 5, the significance values obtained were 0.124 for the experimental class pretest, 0.098 for the experimental class posttest, 0.137 for the control class pretest, and 0.110 for the control class posttest. Thus, it is evident that all data in both class groups are normally distributed because the Sig. values are > 0.05. The normality test is a step in quantitative research to ensure that the resulting statistical inferences are valid and unbiased (Sugiyono, 2023). Furthermore, the results of the homogeneity test can be observed in Table 6.

Table 6. Homogeneity test results

Test of Homogeneity of Variance (Levene-Test)			
Data	Sig.	α	Description
Prestest	0,286	0,05	Homogeneous
Posttest	0,312	0,05	Homogeneous

Based on Table 6, the significance value for the pretest was 0.286 and for the posttest was 0.312. These results indicate values greater than 0.05 (Sig > 0.05). It is concluded that the distribution of the data groups used is homogeneous, meaning that the variability of the data between the experimental and control classes is relatively equivalent; thus, the differences in results that emerged after the treatment were not caused by differences in the groups' initial characteristics but rather by the effect of the treatment administered. Field states that the assumption of homogeneity of variances is crucial in comparative analysis between groups because it directly affects the accuracy of the independent t-test results (Hamzah, 2021).

Since both groups met the assumptions of normality and homogeneity, the testing could proceed with hypothesis testing using the independent samples t-test. The hypothesis testing referred to the previously obtained N-gain values. The results of the hypothesis testing are shown in Table 7.

Tabel 7. Hypothesis test results

Data	t-count	Sig. (2-tailed)
N-Gain	7,84	0,000

Based on Table 7, the significance value obtained was 0.000 ($p < 0.05$) with a calculated t-value of 7.84. Thus, the alternative hypothesis (Ha) is accepted, meaning there is a significant difference in the improvement of scientific reasoning skills between the two groups. However, this statistical significance needs to be supplemented with practical interpretation through an effect size test to provide a more comprehensive picture.

The results of the effect size test show a Cohen's d value of 1.32, indicating a large effect. This value indicates that the implementation of the e-module 7e cycle integrated with technological knowledge has a strong and practically meaningful influence on the improvement of students' scientific reasoning skills. Conceptually, the magnitude of the effect size can be explained by the synergy between the learning model and technology integration. The learning cycle model provides a systematic learning framework, while technology enhances the processes of exploration, visualization, and reflection.

This finding is supported by research results (Kwangmuang et al., 2021) which indicates that integrating technology into science learning can enhance higher-order thinking skills. Furthermore, research findings (Megawati, 2024) confirm that project-based and technology-integrated learning can contribute to the improvement of argumentation and evidence-based reasoning skills.

Further analysis of the effect size test results for each aspect of scientific reasoning is presented in Table 8.

Table 8. Summary of effect size test results by aspect of scientific reasoning

Aspects of scientific reasoning	Mean of the experimental	Mean of the control	SDpooled	Cohen's d	Interpretation
Analyzing cause-and-effect relationships	0,73	0,45	0,22	1,28	Large
Evaluating evidence, variables, and scientific conclusions	0,70	0,43	0,22	1,25	Large
Designing solutions based on scientific principles	0,69	0,38	0,22	1,40	Large

Referring to Table 8, it is evident that the highest effect size was found in the ability to design solutions based on scientific principles. This confirms that the elaborate and extended stages in the learning cycle model contribute most significantly to the development of knowledge transfer and application skills. This finding is consistent with research results stating that learning activities emphasizing contextual problem-solving are more effective in improving higher-order thinking skills compared to learning activities that focus solely on conceptual understanding (Chueh & Kao, 2024).

Although the research results indicate high effectiveness, the study still has several limitations, namely the scope of the subjects, which involved only two classes, and the measurement of scientific reasoning ability, which focused only on written tests. These limitations need to be considered in the interpretation of the results and present an opportunity for further research using a more authentic assessment approach.

Conclusion

This study concludes that the use of the e-module 7e cycle integrated technological knowledge has proven effective in improving students' scientific reasoning skills, as evidenced by the differences in N-gain scores and statistical test results between the experimental and control classes. The resulting e-module can serve as an alternative teaching material for science education focused on the development of scientific reasoning. However, the effectiveness tested was limited to written tests and a small sample size. Therefore, further research with a broader sample size and the use of more diverse assessment instruments is needed to obtain a more comprehensive picture of its impact on science learning.

References

Baybars, M. G., & Kucukozer, H. (2018). The Effect of 7E Learning Model on Conceptual Understandings of Prospective Science Teachers on "de Broglie matter waves" Subject. *European Journal of Educational Research*, *7*(2), 387–395. https://doi.org/10.12973/eu-jer.7.2.387

Chueh, H., & Kao, C. (2024). Exploring the Impact of Integrating Problem Based Learning and Agile in the Classroom on Enhancing Professional Competence. *Heliyon*, *10*(3), e24887. https://doi.org/10.1016/j.heliyon.2024.e24887

Fatimah, S., Rusilowati, A., & Susilaningsih, E. (2024). Pengembangan Instrumen Tes Penalaran Ilmiah Berbasis Inkuiri Terintegrasi Etnosains untuk Calon Guru Sekolah Dasar. *Proceeding Seminar Nasional IPA*, 1–14.

Fick, S. ., & Arias, A. . (2022). A Review of Literature that Uses the Lens of the Next Generation Science Crosscutting Concepts. *Journal of Research in Science Teaching*, *59*(6), 883–929. https://doi.org/https://doi.org/10.1002/tea.21747

Habiby, W. N. (2017). *Statistika Pendidikan*. Muhammadiyah University Press.

Hamzah, A. (2021). *Metode Penelitian dan Pengembangan (research & development) uji produk kuantitatif dan kualitatif proses dan hasil dilengkapi contoh proposal pengembangan desain uji kualitatif dan kuantitatif*. CV. Literasi Nusantara Abadi. https://s.id/1DJUw

Henriksen, D., Mishra, P., & Fisser, P. (2016). Infusing Creativity and Technology in 21st Century Education : A Systemic View for Change. *Educational Technology & Society*, *19*(3), 27–37. https://www.jstor.org/stable/jeductechsoci.19.3.27

Husnulwati, S., Sardana, L., & Suryati, S. (2019). Pengembangan E-Modul Pendidikan Kewarganegaraan Berbasis Aplikasi Android. *Indonesian Journal Of Educational Research and Review*, *2*(3), 252. https://doi.org/10.23887/ijerr.v2i3.21013

Jariah, Y. . (2022). *Analisis Kemampuan Penalaran Ilmiah (Scientific Reasoning Ability) Siswa Sekolah Adiwiyata dalam Pemecahan Kasus Isu-Isu Ekologi*. Jakarta: FITK UIN Syarif Hidayatullah.

Komikesari, H., Anggraini, W., Asiah, N., Dewi, P. S., Diani, R., & Yulianto, M. N. (2020). Effect Size Test of 7e Learning cycle model: Conceptual Understanding and Science Process Skills on Senior High School Students. *Journal of Physics: Conference Series*, *1572*(1). https://doi.org/10.1088/1742-6596/1572/1/012023

Kwangmuang, P., Jarutkamolpong, S., Sangboonraung, W., & Daungtod, S. (2021). The Development of Learning Innovation to Enhance Higher Order Thinking Skills for Students in Thailand Junior High Schools. *Heliyon*, *7*(6), e07309. https://doi.org/10.1016/j.heliyon.2021.e07309

Megawati, R. (2024). Integration of Project-Based Learning in Science , Technology , Engineering , and Mathematics to Improve Students ' Biology Practical Skills in Higher Education : A Systematic Review. *Open Education Studies*, *6*(1), 1–13. https://doi.org/https://doi.org/10.1515/edu-2024-0049

Miftahuljannah, N. S. (2018). Efektivitas model pembelajaran learning cycle 7E dengan metode resitasi terhadap pemahaman konsep dan cinta budaya lokal siswa. *Prosding Seminar Nasional Etnomatnesia*, *2*, 258–267. https://jurnal.ustjogja.ac.id/index.php/etnomatnesia/article/view/2324

Mustika, D., Hadiyanti, P. O., & Hidayat, B. (2025). Validity of the Science E-Module Based on the 7E Learning Cycle Model Integrated Technological Knowledge. *Jurnal Pajar: Pendidikan Dan Pengajaran*, *8*(4), 338–347.

https://doi.org/https://doi.org/10.33578/pjr.v8i4.9929

Mustika, D., Rahmi, L., & Miranti, F. (2023). Preliminary Research on 7E Learning Cycle Model-Based Development of the Integrated Technological Knowledge. *Primary : Jurnal Pendidikan Guru Sekolah Dasar*, *12*(1), 81–89. https://doi.org/http://dx.doi.org/10.33578/jpfkip.v12i1.9270

Rusni, I., Fitria, Y., Ahmad, S., & Zen, Z. (2023). Development of E-Modules Oriented by A Science, Technology, Engineering, Art, and Mathematics (STEAM) Approach to Improve High Level Thinking Ability. *JPPIPA: Jurnal Penelitian Pendidikan IPA*, *9*(9), 7179–7188. https://doi.org/10.29303/jppipa.v9i9.5345

Rusydi, A. I., & Kosim, H. (2018). Pengaruh Model Learning Cycle 7E Terhadap Kemampuan Berpikir Kritis Peserta Didik Effect of Learning Cycle Model 7E on the Student Critical Thinking Skills. *J. Pijar MIPA*, *13*(2), 124–131. https://doi.org/https://doi.org/10.29303/jpm.v13i2.741

Simamora, A. H., Sudarma, I. K., & Prabawa, D. G. A. P. (2019). Pengembangan E-Modul Berbasis Proyek Untuk Mata Kuliah Fotografi Di Jurusan Teknologi Pendidikan Fakultas Ilmu Pendidikan Undiksha. *Journal of Education Technology*, *2*(1), 51. https://doi.org/10.23887/jet.v2i1.13809

Sinaga, L., Prima, E. C., Nahadi, & Sriyati, S. (2024). Evaluasi Perkuliahan Zat dan Energi Terintegrasi ESD untuk Meningkatkan Literasi Energi Calon Guru IPA. *Jurnal PIPA: Pendidikan Ilmu Pengetahuan Alam*, *05*(02), 110–122. https://doi.org/https://doi.org/10.56842/jp-ipa

Suchyadi, Y., Safitri, N., & Sunardi, O. (2020). the Use of Multimedia As an Effort To Improve Elementary Teacher Education Study Program College Students' Comprehension Ability and Creative Thinking Skills in Following Science Study Courses. *Jhss (Journal of Humanities and Social Studies)*, *4*(2), 201–205. https://doi.org/10.33751/jhss.v4i2.2549

Sugiyono. (2023). *Metode Penelitian Kuantitatif, Kualitatif, dan Kombinasi (Mixed Methods)*. Alfabeta.

Susilasari, Vebrianto, R., Habibi, M., & Yovita. (2025). Problematika Pembelajaran IPA: Analisis Kesulitan Siswa dalam Memahami Materi dan Solusinya. *Muallima: Jurnal Madrasah Ibtidaiyah*, *10*(2), 81–89. https://doi.org/10.31602/muallimuna.v10i2.18840

Valtonen, T., Sointu, E., Kukkonen, J., Kontkanen, S., Lambert, M. C., & Mäkitalo-Siegl, K. (2017). TPACK updated to measure pre-service teachers' twenty-first century skills. *Australasian Journal of Educational Technology*, *33*(3), 15–31. https://doi.org/10.14742/ajet.3518

Voogt, J., & McKenney, S. (2017). TPACK in Teacher Education: Are We Preparing Teachers to Use Technology for Early Literacy? *Technology, Pedagogy and Education*, *26*(1), 69–83. https://doi.org/10.1080/1475939X.2016.1174730

Yunita, L., & Mandasari, N. (2025). Pendidikan Sains Berorientasi Keterampilan Abad 21 dalam Konteks Pendidikan Tinggi: Review. *Panthera: Jurnal Ilmiah Pendidikan Sains Dan Terapan*, *5*(1), 40–49. https://doi.org/. https://doi.org/10.36312/panthera.v5i1.334 Panthera