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Development of Interactive E-Modules with STEM-PBL Approach on Ecology and Biodiversity to Improve Critical Thinking Skills and Student Learning Outcomes

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Abstract: The development of Interactive E-Modules with STEM-PBL approach on Ecology and biodiversity materials is needed because of the lack of use of Interactive E-Modules in schools, as well as low critical thinking skills, and student learning outcomes. This study aims to present the characteristics, validity, effectiveness and relationship of critical thinking skills and student learning outcomes. The results of questionnaire analysis using Aiken-V showed that the E-Module was valid from 5 validators, namely material and media experts with an average value of 0.88. The results of students' critical thinking skills are shown by the N-Gain value of 0.58 with moderate. Student learning outcomes are shown by the N-Gain value of 0.57 with a moderate category. Based on the results of this study, it can be concluded that the Interactive E-Module with STEM-PBL approach on ecology and biodiversity material can be used in learning to improve students' critical thinking skills and learning outcomes.

Keywords: Critical thinking; E-Module; Learning outcomes; PBL; STEM

Introduction

The learning process in the 21st century is based on the principles of curriculum design that is simple, easy to understand and implement, focuses on the competencies and character of all students, is flexible, aligned, mutual, and pays attention to the results of the study and feedback. In implementing 21st century learning, students are required to have 4C skills, namely Communication, Collaboration, Critical Thinking and Problem Solving, and Creative and Innovative (Annisa et al., 2023; Mulyasari & Sholikhah, 2021; Widodo & Wardani, 2020). 21st century learning has a close relationship with the SDGS, particularly the 4th goal which emphasizes quality education (Hafshah & Nugraheni, 2024). In the 21st century, education is one of the challenges that must be developed, especially with the 17 goals of the Sustainable Development Goals (SDGS) as the United Nations General Assembly on 2030 Development Agenda, 21st century learning needs to develop 21st century skills and realize the goals of the Sustainable Development Goals (SDGS) to produce human resources who can later contribute to people's lives (Hidayah & Nugraheni, 2024).

One of the efforts to maximize the achievement of 21st century learning skills is to utilize technology effectively in the learning process (Chu et al., 2024; Bernacki et al., 2020). One of them is the use of interactive E-Modules. Interactive E-Modules or electronic modules are modules in digital form, consisting of text, images, or both that contain digital electronics material accompanied by simulations that can and should be used in learning to create a more interesting and interactive learning experience (Zahrotunnisa et al., 2024). E-Modules designed with a STEM approach can improve students' learning

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independence. Research shows that students who use this E-Module are more active in learning and are able to manage their own learning process, which is an important aspect in 21st century education. With the interactive E-Module, students will understand the material better because the learning process developed is not only reading but using several methods (Inanna et al., 2021; Lastri, 2023).

One approach that can be applied to develop interactive E-Modules is the Science, Technology, Engineering and Mathematics (STEM) approach. Research on the implementation of Science, Technology, Engineering, and Mathematics (STEM) in science learning in Indonesia has been an area of interest for a decade (Widiyatmoko et al., 2023). STEM is an acronym for an interdisciplinary learning approach between science, technology, engineering, and mathematics. E-Modules collaborated with the STEM approach can attract student motivation and increase student learning independence, the results showed that the application of the STEM approach in E-Modules encouraged students to engage in active learning through projects and experiments, this method helps students to analyze problems, formulate hypotheses, and evaluate results, which is the essence of critical thinking (Mulyasari & Sholikhah, 2021; Febril et al., 2022). The STEM approach helps students to improve their competencies. Learning with a STEM approach is the right learning to be applied to build 21st century skills Learning with a STEM approach can be packaged in cooperative learning, Problem Based Learning (PBL), Project Based Learning (PBL), and other learning models.

The Problem Based Learning (PBL) model is student-centered learning and triggers activities in the form of investigation and inquiry to train 4C competencies (Irmayani et al., 2022; Dewi et al., 2023). Problem Based Learning (PBL) is a learning model that places real problems as the main context for students to learn, think critically, and develop problem solving skills (Ummah, 2019). This model directs students to actively seek solutions to the problems presented, so that they are encouraged to think independently, work together in groups, and build new knowledge based on experience and relevant information (Irmayani et al., (2022). The application of the PBL model in the classroom places the teacher as a facilitator, not as the main source of knowledge. The teacher is tasked with facilitating discussions, guiding students in identifying problems, formulating questions, seeking information, and finding solutions (Aludin, 2022). Through this approach, students not only gain knowledge, but are also trained in critical thinking, cooperation, and effective communication. Thus, the development of interactive E-Modules with the STEM-PBL approach not only improves students' critical thinking skills but also contributes to better learning outcomes, preparing students to face challenges in the real world with relevant skills in the 21st century.

Critical thinking skills and learning outcomes are two important things that must be developed in learning, especially in the current era. Critical thinking skills enable students to objectively analyze information, evaluate arguments, and make informed decisions (Hidayat et al., 2019; Nurpaisa & Rustan, 2024; Meryastiti et al., 2022). In the context of education, critical thinking not only serves to understand subject matter, but also to prepare students to face challenges in the real world. In the midst of the abundance of information available, critical thinking skills are becoming increasingly vital (Rahardhian, 2022; Nuridayah et al., 2023). E-Modules that use videos, graphics, and other features allow students to interact directly with the subject matter. This interactivity helps students not only remember facts, but also understand basic concepts and the relationships between various ideas. Thus, students can analyze and evaluate information objectively and rationally, which is the essence of critical thinking.

In addition, good learning outcomes are highly dependent on the mastery of critical thinking skills. Research shows that students who have good critical thinking skills tend to have higher learning outcomes they are able to apply acquired knowledge in new and complex situations, as well as show creativity in solving problems, therefore, it becomes important to integrate the development of critical thinking skills in the learning process (Purwaningsih, 2023; Tumulo, 2022; Utami et al., 2019). Approaches such as project-based learning, group discussions, and the use of educational technology such as interactive E-Modules can assist students in honing these skills. Thus, students' critical thinking ability and learning outcomes can be significantly improved, preparing them to become competent individuals ready to face future challenges.

Based on the results of observations at SMP Negeri 15 Kota Kupang, several problems experienced by students were found including; many students have difficulty in understanding basic concepts in various subjects and there is a tendency to memorize rather than understand. This has an impact on students' less than optimal ability to apply knowledge in different contexts. Other problems found were lack of motivation, limited critical thinking skills such as analysis, synthesis, and evaluation and a tendency to passively receive information rather than asking questions or making critical arguments. Of the 30 students, only 10 students (33%) showed good critical thinking skills, 15 students (50%) showed moderate critical thinking skills and 5 students (17%) showed low critical thinking skills, while the aspects assessed were: the ability to analyze

information: 40% good, 40% moderate, 20% low. The ability to evaluate arguments: 30% good, 50% moderate, 20% low, ability to draw conclusions: 35% good, 45% moderate, 20% low, this condition shows the difficulties faced in understanding the basic concepts taught.

The cognitive results of the daily test of Ecology and Biodiversity material in the 2023/2024 academic year showed that only 40% reached the Minimum Passing Criteria (KKM). Mastery of concepts that are not maximized causes the cognitive results obtained by students to be less than optimal. Ecology and biodiversity materials are often considered difficult to understand because of their complexity. By using interactive E-Modules, students have the opportunity to see these concepts in a form that is easier to understand. Graphs, diagrams, videos and animations can help students understand the relationship between species and ecosystems visually, so they can understand the basic concepts better. Therefore, based on this, science learning needs to be packaged in an interesting learning and can also make students more active in science learning, interactive E-Modules specifically designed for this material will help students link theory with practice, so that they can develop better environmental awareness and train students' critical thinking skills. Based on the problems found, it is necessary to develop an interactive E-Module with a STEM-PBL approach on ecology and biodiversity material. The interactive E-Module with STEM-PBL approach is expected to improve students' critical thinking skills and learning outcomes.

Method

This research uses a development model, which is used in this research, namely the ADDIE development model. According to Kurniati et al. (2021). This ADDIE model has 5 stages, namely Analyze, Design, Development, Implementation and Evaluation. This model was chosen because the ADDIE development model is more detail and easy for researchers to understand.

The research subjects consisted of material experts, media experts, teachers and students. The instruments in this study consisted of: questionnaires, expert validation, critical thinking test questions, learning outcome test questions, teacher and student response questionnaires. Data collection was done through observation, documentation, interviews, questionnaires and tests. The data analysis technique in this study consists of quantitative and qualitative data analysis.

Feasibility analysis was conducted by 5 expert validators to obtain input on product feasibility. The assessment was carried out using a Likert scale. The results of the validation score from each validator were analyzed using Aiken's Validity (Aiken's V) theory. The formula used to assess the construct validity of the instrument to be used is as follows:

$$\frac{V=\sum_{r=1}^{n} s]}{n\ x\ (c-lo)} \quad (1)$$

Description:
V : Aiken Index
s : ri-lo
r : The score given by the rater
lo : Lowest assessment score (1)
c : Highest assessment score (4)
n : Number of raters

Aiken's coefficient V is used to measure the level of agreement between raters on an instrument or statement, which reflects the consistency of the assessment of the validators. In this study, the assessment was carried out by five validators who have expertise in the field of material and media, so that the assessment given is more accurate and precise. The validity analysis using Aiken's V coefficient sets the minimum limit of validity at 0.87 with a probability of 0.021 for a rating scale consisting of four categories and five validators. This means that if the V Aiken value obtained is higher than this limit, the instrument can be considered valid and suitable for use in research.

The effectiveness of the product is measured based on the calculation of N-Gain scores, KKM scores, and teacher and student response scores. Students' pretest and posttest scores were analyzed based on the pretest and posttest scores obtained, then the N-Gain test was conducted. This test is used to see the improvement of students' pretest and posttest learning outcomes in qualitative criteria. The test that can provide an overview of the increase in learning outcome scores between before and after the application of the method is the N-Gain test (Sundayana, 2018). The N-Gain formula according to Hake can be seen in equation 1. The criteria applied for N-Gain can be seen in Table 1.

$$\langle g\rangle = \frac{\%\langle G\rangle}{S\%\langle G\rangle maks} = \frac{\%\langle Sf\rangle - \%\langle Si\rangle}{\langle 100\rangle - \%\langle Si\rangle} \quad (2)$$

Table 1. Criteria of N-gain

Interval	Criteria
⟨g⟩ ≥ 0.7	High
0.7 > ⟨g⟩ ≥ 0.3	Medium
⟨g⟩ < 0.3	Low

Result and Discussion

Characteristics of E-Modules with STEM-PBL Approach on Ecology and Biodiversity Material

The product produced in this research and development is an Interactive E-Module with a STEM-PBL approach on Ecology and Biodiversity. The

developed E-Module has several advantages compared to ordinary printed modules that are often used in schools in the learning process. Some of the advantages that characterize the e-book include: (1) The developed E-Module is combined with clear and appropriate pictures, videos and articles; (2) the problems contained in the E-Module are real-life problems; (3) contains the PBL model, (4) integrates elements of science, technology, engineering, and mathematics (STEM).

Figure 1. E-Module cover view

Figure 2. Display of STEM-related information

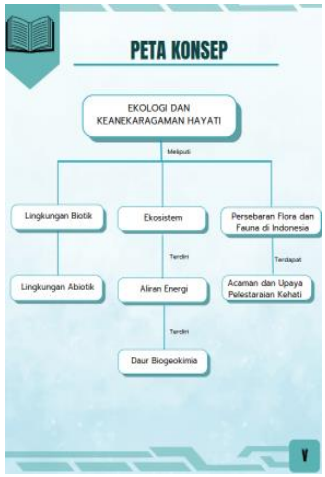

Figure 3. Concept map view

Figure 4. Instructions for use display

The addition of images or illustrations in the development of E-Modules is one of the important components. In figure 1-4 E-Modules are designed with the addition of images is intended to attract students' attention and clarify the meaning of the text presented. This is in accordance with what was stated by Gustiawati et al., (2020) that students tend to prefer learning resources that have many attractive images and colors. Images are a form of graphic media, which can attract more attention and reduce boredom compared to text so that children will be more interested in reading books that have many pictures (Sari & Yustiana, 2021; Supardi, 2020).

Figure 5. Science, Technology-PBL integration patch

Figure 6. Science, Technology-PBL integration patch

Figure 7. Engineering-PBL integration patch

Figure 8. Mathematics-PBL integration patches

Another characteristic contained in the E-Module is the presentation of material packaged with a PBL learning model consisting of five steps. PBL steps are presented sequentially and each learning step is integrated with STEM elements. Muttaqiin (2023) explains that the STEM approach in learning is often combined with learning models. In figures 5 and 6, PBL steps and science elements are combined by directing students to observe news videos or articles about ecosystem problems, then students are directed to analyze an environmental problem contained in the article or news, analyze the causes and impacts of the

problem and conclude it. This is in accordance with what is stated by that activities that can be done with elements of science are observing, classifying, predicting, testing and drawing conclusions (Putri, 2019). In Figures 5 and 6, the technology element contains all the technological equipment that plays a role in overcoming problems related to ecology and biodiversity material. In the PBL step, the technology element is inserted by directing students to use smartphones in finding various facts related to the causes of Ecosystem problems, and directing students to use stationery and smartphones needed to observe and document observations. Technology provides convenience in accessing data and helps all human needs (Sumaji, 2019).

In Figure 7, the technique element contains the methods or techniques used to solve the problem. The technique element has steps in learning such as asking, imagining, planning, making and fixing (Lestari et al., 2020). The technique starts with identifying the problem, then trying to solve the problem (Nurjanah, 2020). Examples of integration of techniques with PBL steps in E-Modules include presenting pictures and videos about the impact of littering on fish organisms, students are asked to determine the right solution to this problem, in Figure 8 the element of math, used to calculate the growth of plants in several treatments. Mathematical elements packed with observation and calculation activities encourage students to be able to analyze and consider further about the truth of a fact. Connecting science learning with math and real life is good to do. This is because mathematics has a role in facilitating the development of science, engineering, business, and technology development (Hasanah et al., 2020).

Feasibility Analysis of Interactive E-Modules with STEM-PBL approach

The E-Modules that have been developed with the various characteristics described above are then tested for validity and readability to determine whether the E-Modules are suitable for use in learning. The feasibility of E-Modules is assessed based on validity tests by material experts, validity tests by media experts, and readability tests by teachers and students. E-Modules can be used in learning if they get at least a valid category in the validity test and at least a decent category in the readability test (Ghozali, 2019; Nirahua et al., 2020; Pratiwi et al., 2020).

The results of media and material validation of these indicators have a total average value of the index coefficient of 0.88 with a probability of 0.021 including the Valid category. This shows that the interactive E-Module with STEM-PBL approach on Ecology and Biodiversity material in the media and material aspects has a Valid category. Meanwhile, the average student readability test obtained 0.95 with the Valid category and the teacher readability test obtained an average score of 0.90 with the valid category.

Table 2. Media and Material Validation Analysis Results

Indicator Rated	V	Category
Media		
E-Module Presentation	0.87	Valid
Feasibility of Graphics	0.88	Valid
Feasibility of Electronic Media	0.88	Valid
Material		
Content Feasibility	0.89	Valid
Language Feasibility	0.89	Valid
Presentation Feasibility	0.88	Valid
Average	0.88	Valid

Analysis of STEM-PBL-Enhanced Interactive E-Modules on Critical Thinking Ability Improvement

The Interactive E-Module with STEM-PBL approach was implemented with the aim to determine its effectiveness in improving students' critical thinking skills. The effectiveness of the E-Module was measured using t-test and N-Gain test to compare two different classes, namely the class taught using the Interactive E-Module with STEM-PBL approach or the experimental class and the class taught using the school module.

Table 3. N-Gain Test Results

Class	Pretest average	Posttest average	N-Gain	Category
Experiment	68.28	87.02	0.58	Medium
Control	59.94	71.40	0.26	Low

The N-Gain test results in the experimental and control classes in Table 3 show that there are differences in the improvement of critical thinking skills in the experimental and control classes. The experimental class obtained an N-Gain value of 0.58 which is included in the medium category. The control class obtained an N-Gain value of 0.26 which is included in the low category. This shows that learning using Interactive E-Modules with a STEM-PBL approach is better in improving students' critical thinking skills.

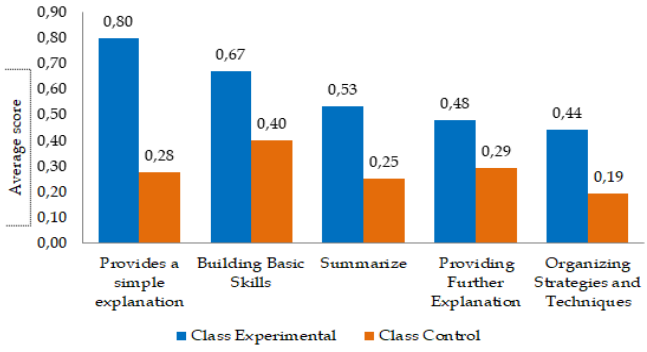

Figure 9. Improvement of critical thinking ability for each indicator

Figure 9 shows that both experimental and control classes experienced an increase in each indicator of critical thinking skills. In the experimental class, the highest increase based on the N-Gain value was in the indicator of Providing a simple explanation with a value of 0.80 with a high category, Building basic skills with an N-Gain value of 0.67 in the medium category, Concluding with an N-Gain value of 0.53 in the medium category, Providing further explanation with an N-gai value of 0.48 in the medium category and Organizing strategies and techniques with an N-Gain value of 0.44 in the medium category. Similarly, in the control class, the highest increase in critical thinking skills was in the indicator of Building basic skills with a value of 0.40 in the Moderate category. As for the other indicators, it did not experience a significant increase and was included in the low category. This shows that there is a difference in the improvement of critical thinking skills in students using interactive E-Modules with a STEM-PBL approach with students who are taught with modules provided by the school.

The increase in students' critical thinking skills in the experimental class which was much higher than the control class showed that learning using Interactive E-Modules with STEM-PBL approach was effective in improving students' critical thinking skills. The high critical thinking skills of students in the experimental class cannot be separated from learning activities that provide opportunities for students to practice critical thinking skills. This is in accordance with what was stated by Agustini et al. (2021) that the application of the PBL model is a learning model that can be utilized to improve students' critical thinking skills.

Analysis of STEM-PBL-Enhanced Interactive E-Modules on Improving Learning Outcomes

In addition to improving students' critical thinking skills, the use of E-Modules in learning is also effective in improving student learning outcomes.

Table 4. N-Gain Test Results

Class	Pretest Average	Posttest Average	N-Gain	Category
Experiment	67.81	86.45	0.57	Medium
Control	57.38	70.55	0.29	Low

The results of the N-Gain test in the experimental and control classes in the table show that both the experimental and control classes experienced an increase in learning outcomes in the moderate category. However, the increase in the experimental class was much higher than the control class. The experimental class obtained an N-Gain value of 0.57, while the control class obtained a value of 0.29. This shows that learning using interactive E-Modules with STEM-PBL effects is better in improving student learning outcomes compared to learning using school modules.

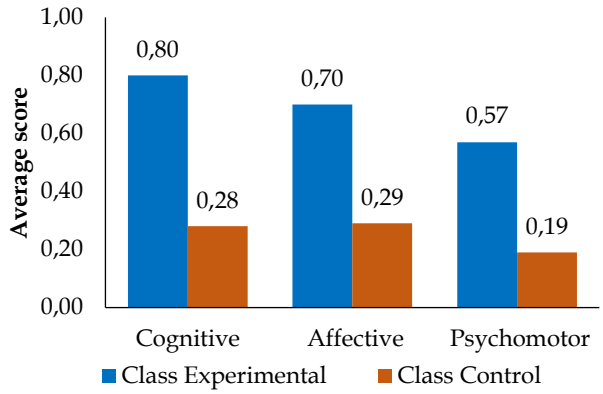

Figure 10. Improvement in student learning outcomes for each indicator

Figure 10 shows that the experimental class experienced an increase in each indicator of learning outcomes compared to the control class. In the experimental class, the highest increase based on the N-Gain value was in the cognitive indicator with a value of 0.80 with a high category, affective with an N-Gain value of 0.70 medium category, and psychomotor with an N-Gain value of 0.57 medium category. Whereas in the control class, the three indicators did not experience a significant increase and included the low category. This shows that there is a difference in the improvement of learning outcomes in students using interactive E-Modules with a STEM-PBL approach with students who are taught with modules provided by the school.

The high student learning outcomes in the experimental class compared to the control class cannot be separated from learning activities that provide opportunities for students to practice critical thinking skills, problem solving skills, and active application of concepts through the STEM-PBL approach. This is in accordance with what was stated by Rahmadani (2019) and Selirowangi (2024) who stated that STEM-integrated Problem-Based Learning (PBL) based learning is able to improve critical thinking and problems solving skills through active involvement of students in solving real-world problems creatively and methodically. In addition, Hazana (2025) added that STEM integration in PBL provides a multidisciplinary context that deepens concept understanding and hones students' critical thinking skills significantly.

Analysis of the Relationship between Critical Thinking Skills and Student Learning Outcomes

The relationship between critical thinking skills and student learning outcomes was tested using the correlation test presented in the table. The correlation test results are presented in Table 5.

Table 5. Correlation Test Results

Variables	N	F	P	α	Decision
Critical Thinking	47	16.347	.000	0.05	There is a
Learning Outcome	47				Correlation

Table 5 shows that the p value of 0.000 is smaller than the α value (p <0.05), this indicates that Ho is rejected so it can be concluded that there is a relationship between critical thinking skills and student learning outcomes. The correlation coefficient value obtained is 16.347 which is included in the Strong category. The value of the correlation coefficient number based on the calculation results is positive. This it can be said that if students' critical thinking skills increase, student learning outcomes will also increase.

The correlation test results show that there is a relationship between critical thinking skills and student learning outcomes. The correlation coefficient based on the calculation results is positive, so the relationship between the two variables is unidirectional. This it can be said that if students' critical thinking skills increase, student learning outcomes will also increase.

Table 6. Test Coefficient of Determination

Model	R	R Square	Asjusted R Square	Std. Error of the Estimate
1	.637a	.405	.380	.14346

Table 6 shows the reliability value or coefficient of determination (R Square) of 0.405 (40.5%). This means that critical thinking skills contribute to learning outcomes by 40.5%, while 59.5% are other factors besides critical thinking skills. The contribution of critical thinking ability to student learning outcomes does not reach 50%. Other factors that contribute to learning outcomes besides the research variables are such as motivation, student personality and environment (Winkel, 2019). This is in line with Syafira et al. (2020) who found a positive correlation between critical thinking and student learning outcomes on psychotropic sub-concepts with the contribution of critical thinking skills to learning outcomes by 24%. Another study at SMA Negeri 1 Cibinong showed a correlation coefficient of 0.954 between critical thinking ability and cognitive learning outcomes on Circulation System material, with a contribution of critical thinking ability of 91% to learning outcomes.

Conclusion

The development of Interactive E-Modules with STEM-PBL approach on Ecology and Biodiversity material produces electronic modules that integrate the concepts of Science, Technology, Engineering, and Mathematics (STEM) with the Problem Based Learning (PBL) model. This E-Module was developed using the ADDIE development model which includes the stages of Analysis, Design, Development, Implementation, and Evaluation. The Interactive E-Module with STEM-PBL approach was assessed as valid by experts in the field of media and materials, with a validity value of 0.88 with a valid category. This Interactive E-Module with STEM-PBL approach has a significant effect in improving critical thinking skills and student learning outcomes. This can be seen from the hypothesis test of the N-Gain increase in both classes. There is a relationship between critical thinking skills and student learning outcomes where if students' critical thinking skills increase, student learning outcomes will also increase. This can be seen from the results of the correlation test and regression test.

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Author Contributions
E.E. and A.W.: initial draft preparation, results, discussion methodology, analysis, conclusions; P.T, M.S, F.Y.T, S.B, and R.T.: Participation in media and material validation process.

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The authors declare no conflict of interest.

References

Agustini, K., Wahyuni, D. S., Mertayasa, I. N. E., Wedhanti, N. K., & Sukrawarpala, W. (2021). Student-centered learning models and learning outcomes: meta-analysis and effect sizes on the students' thesis. *Journal of Physics: Conference Series*, *1810*(1), 012049. https://doi.org/10.1088/1742-6596/1810/1/012049

Annisa, P., Gultom, F., & Debora, M. (2023). Penerapan Optimalisasi Keterampilan 4C (Creative Thinking, Critical Thinking And Problem Solving, Communication, Collaboration) Dalam Pembelajaran Contextual Oral Language Skills. *Jurnal Ilmiah Korpus*, *7*(3), 391–399. https://doi.org/10.33369/jik.v7i3.28743

Bernacki, M. L., Greene, J. A., & Crompton, H. (2020). Mobile technology, learning, and achievement: Advances in understanding and measuring the role of mobile technology in education.

Contemporary Educational Psychology, *60*(November), 101827. https://doi.org/10.1016/j.cedpsych.2019.101827

Chu, T., Wang, L., & Zhang, X. (2024). Digital Futures: How Technologies Shape Today's Education. *Journal of Education, Humanities and Social Sciences*, *33*, 7–11. https://doi.org/10.54097/atrv0492

Dewi, N. N. S. K., Arnyana, I. B. P., & Margunayasa, I. G. (2023). Project Based Learning Berbasis STEM: Meningkatkan Kemampuan Berpikir Kritis dan Hasil Belajar Siswa. *Jurnal Ilmiah Pendidikan Profesi Guru*, *6*(1), 133–143. https://doi.org/10.23887/jippg.v6i1.59857

Febril, A. N., Aradia, F. F., Oktavia, F., & Fitri, R. (2022). Pengaruh Pendekatan STEM Terhadap Kem Ampuan Berpikir Kritis Peserta Didik. *Literature Review The Effect of the STEM Approach on Students' Critical Thinking: Literature Review." Prosiding Seminar Nasional Biologi*, *2*(2), 974–86. https://doi.org/10.24036/prosemnasbio/vol2/533

Ghozali, I. (2019). *Desain Penelitian Kualitatif dan Kuantitatif*. Universitas Diponegoro.

Gustiawati, R., Arief, D., & Zikri, A. (2020). Pengembangan Bahan Ajar Membaca Permulaan dengan Menggunakan Cerita Fabel pada Siswa Sekolah Dasar. *Jurnal Basicedu*, *4*(2), 355–360. https://doi.org/10.31004/basicedu.v4i2.339

Hafshah, D. R., & Nugraheni, N. (2024). Dinamika Kesetaraan Pendidikan Sebagai Fondasi SDGS. *Jurnal Penelitian Pendidikan Indonesia*, *1*(3), 142–50. https://doi.org/10.62017/jppi.v1i3.989.

Hasanah, F., Putra, P. D. A., & Rusdianto. (2022). Identifikasi Kemampuan Siswa SMP dalam Berargumentasi Melalui Pendekatan Pembelajaran Science, Technology, Engineering, and Mathematics (STEM). *Jurnal Literasi Pendidikan Fisika (JLPF)*, *3*(1), 1–9. https://doi.org/10.30872/jlpf.v3i1.974

Hazana, E. M. (2024). Integrasi Pendekatan STEM dalam Pembelajaran IPA untuk Mengembangkan Kreativitas dan Pemecahan Masalah Siswa di SMPN 1 Cigombong. *Bhinneka: Jurnal Bintang Pendidikan Dan Bahasa*, *3*(1), 36–45. https://doi.org/10.59024/bhinneka.v3i1.1130

Hidayah, B. N., & Nugraheni, N. (2024). Peran Pembelajaran Abad 21 Dalam Mewujudkan Sustainable Development Goals (SDGS). *Jurnal Citra Pendidikan*, *4*(2), 1666–1677. https://doi.org/10.38048/jcp.v4i2.3619

Hidayat, F., Akbar, P., & Bernard, M. (2019). Analisis Kemampuan Berfikir Kritis Matematik Serta Kemandiriaan Belajar Siswa SMP Terhadap Materi SPLDV. *Journal on Education*, *1*(2), 515–523. Retrieved from https://jonedu.org/index.php/joe/article/view/106

Kurniati, R. D., Andra, D., & Wayan Distrik, I. (2021). E-module development based on PBL integrated STEM assisted by social media to improve critical thinking skill: A preliminary study. *Journal of Physics: Conference Series*, *1796*(1), 012077. https://doi.org/10.1088/1742-6596/1796/1/012077

Lastri, Y. (2023). Pengembangan Dan Pemanfaatan Bahan Ajar E-Modul Dalam Proses Pembelajaran. *Jurnal Citra Pendidikan*, *3*(3), 1139–1146. https://doi.org/10.38048/jcp.v3i3.1914

Lestari, H., & Rahmawati, I. (2020). Integrated STEM through project based learning and guided inquiry on scientific literacy abilities in terms of selfefficacy levels. *Al Ibtida: Jurnal Pendidikan Guru MI*, *7*(1), 19–32. Retrieved from https://badge.dimensions.ai/details/doi/10.24235/al.ibtida.snj.v7i1.5883?domain=https://syekhnurjati.ac.id.

Meryastiti, V., & Rasyid Ridlo, Z. (2022). Identifikasi Kemampuan Berpikir Kritis pada Pembelajaran IPA Siswa SMP Negeri 1 Glenmore Kabupaten Banyuwangi. *Saintifika*, *24*(1), 20–29. https://doi.org/10.19184/saintifika.v24i1.29659

Mulyasari, P. J., & Sholikhah, N. (2021). Pengembangan E-Modul Berbasis STEM untuk Meningkatan Kemandirian Belajar dalam Pembelajaran Jarak Jauh pada Mata Pelajaran Ekonomi. *Edukatif: Jurnal Ilmu Pendidikan*, *3*(4), 2220–2236. https://doi.org/10.31004/edukatif.v3i4.1158

Muttaqiin, A. (2023). Pendekatan STEM (Science, Technology, Engineering, Mathematics) pada Pembelajaran IPA Untuk Melatih Keterampilan Abad 21. *Jurnal Pendidikan MIPA*, *13*(1), 34–45. https://doi.org/10.37630/jpm.v13i1.819

Nirahua, J., Taihuttu, J., & Sopacua, V. (2020). Pengembangan Bahan Ajar Berbasis Blended Learning Dan Critical Thinking Skill Pada Mata Kuliah Astrofisika Dalam Menyongsong Era Revolusi Industri 4.0. *Jambura Physics Journal*, *2*(1), 24–36. https://doi.org/10.34312/jpj.v2i1.6869

Nuridayah, F., & Sugandi, A. I. (2023). Systematic literature review: pengembangan kemampuan berpikir kritis siswa melalui pembelajaran discovery learning. *JPMI (Jurnal Pembelajaran Matematika Inovatif)*, *6*(5), 2075–2084. https://doi.org/10.22460/jpmi.v6i5.17555.

Nurjanah, N. E. (2020). Pembelajaran Stem Berbasis Loose Parts Untuk Meningkatkan Kreativitas Anak Usia Dini. *Jurnal Ilmiah Kajian Ilmu Anak Dan Media Informasi PUD*, *1*(1), 19–31. https://doi.org/10.33061/jai.v5i1.3672.

Nurpaisa, & Rustan, E. (2024). Strategi Guru dalam

Meningkatkan Kemampuan Berpikir Kritis Siswa di SDN 21 Tadette: Analisis Faktor Pendukung dan Penghambat. *Al Birru: Jurnal Ilmiah Bidang Pendidikan Dasar*, *2*(2), 27–32. Retrieved from https://ssed.or.id/journal/albirru/article/view/214.

Pratiwi, E. T., & Setyaningtyas, E. W. (2020). Kemampuan Berpikir Kritis Siswa Melalui Model Pembelajaran Problem Based Learning dan Model Pembelajaran Project Based Learning. *Jurnal Basicedu*, *4*(2), 379–388. https://doi.org/10.31004/basicedu.v4i2.362

PURWANINGSIH, P. (2023). Peningkatan Hasil Belajar Melalui Model Pembelajaran Penemuan Pada Peserta Didik Kelas Viii Smp Negeri 8 Cikarang Utara Kabupaten Bekasi. *EDUCATOR: Jurnal Inovasi Tenaga Pendidik Dan Kependidikan*, *2*(4), 422–427. https://doi.org/10.51878/educator.v2i4.1929

Putri, S. U. (2019). *Pembelajaran Sains untuk Anak Usia Dini*. UPI Sumedang Press.

Rahardhian, A. (2022). Kajian Kemampuan Berpikir Kritis (Critical Thinking Skill) Dari Sudut Pandang Filsafat. *Jurnal Filsafat Indonesia*, *5*(2), 87–94. https://doi.org/10.23887/jfi.v5i2.42092

Rahmadani, R. (2019). Metode Penerapan Model Pembelajaran Problem Based Learnig (PBL). *Lantanida Journal*, *7*(1), 75. https://doi.org/10.22373/lj.v7i1.4440

Sabtu, A., Sundari, S., & Tamalene, M. N. (2022). Penerapan Model PBL Melalui Pendekatan Stem Dalam Pembelajaran Biologi Untuk Meningkatkan Hasil Belajar Siswa Di SMA Negeri 7 Halmahera Selatan. *Jurnal Bioedukasi*, *5*(2), 107–114. https://doi.org/10.33387/bioedu.v5i2.5229

Sari, Y., & Yustiana, S. (2021). Efektivitas bahan ajar cerita bergambar bemuatan religius terhadap prestasi belajar siswa kelas 1 sekolah dasar. *Jurnal Ilmiah Pendidikan Dasar*, *8*(2), 175. https://doi.org/10.30659/pendas.8.2.175-185

Selirowangi, N. B., Aisyah, N., & Rohmah, L. (2024). Penerapan Model Pembelajaran Problem Based Learning Untuk Meningkatkan Higher Order Thinking Skills (HOTS). *EDUKASIA: Jurnal Pendidikan Dan Pembelajaran*, *5*(1), 31–40. https://doi.org/10.62775/edukasia.v5i1.714

Sumaji. (2019). Implementasi Pendekatan STEM Dalam Pembelajaran Matematika. *Seminar Nasional Pendidikan Matematika Program Studi Pendidikan Matematika Fkip, Universitas Muria Kudus*, 7–15. Retrieved from https://conference.umk.ac.id/index.php/snapmat/article/view/112/132.

Sundayana, H. R. (2016). *Statistika Penelitian Pendidikan*. Garut: STKIP Garut Press.

Supardi. (2020). *Landasan Pengembangan Bahan Ajar*. Sanabil.

Syafira, A., & Effendi, E. (2020). Pengembangan LKPD Terintegrasi STEM-PBL (Science, Technology, Engineering, and Mathematics - Problem Based Learning) Pada Materi Hidrolisis Garam. *Entalpi Pendidikan Kimia*, *1*(1). https://doi.org/10.24036/epk.v1i1.56

Tumulo, T. I. (2022). Meningkatkan Hasil Belajar Siswa Melalui Pendekatan Inquiri Pada Mata Pelajaran Bahasa Inggris Kelas XII SMA Negeri 4 Gorontalo. *Dikmas: Jurnal Pengabdian Masyarakat*, *2*(2), 437–446. https://doi.org/10.37905/dikmas.2.2.437-446.2022

Utami, A. R., Suhendri, & Dian, P. (2019). Hubungan Kreativitas Guru dengan Hasil Belajar Siswa. *Bimbingan Dan Konseling Indonesia*, *04*(2), 56–62. Retrieved from https://ejournal-pasca.undiksha.ac.id/index.php/jurnal_bk/article/view/3050

Utina, H. (2020). Meningkatkan Keterampilan Berpikir Siswa pada Materi Ikatan Kimia melalui Pendekatan STEM PBL Science. *Ideas: Jurnal Pendidikan, Sosial Dan Budaya*, *6*(2), 179. https://doi.org/10.32884/ideas.v6i2.272

Widiyatmoko, A., & Darmawan, M. S. (2023). Implementasi STEM pada pembelajaran IPA di Indonesia: Review artikel tahun 2018-2023. *Seminar Nasional IPA XIII Kecermelangan Pendidikan IPA Untuk Konversi Sumber Daya Alam*, 391–400. Retrieved from https://www.researchgate.net/publication/374697374.

Widodo, S., & Wardani, R. K. (2020). Mengajarkan Keterampilan Abad 21 4C (Communication , Collaboration, Critical Thinking and Problem Solving , Creativity and Innovation. *MODELING: Jurnal Program Studi PGMI*, *7*(September), 185–197. https://doi.org/10.69896/modeling.v7i2.665.

Winkel, W. S. (1996). *Psikologi Pengajaran*. Jakarta: Grafindo.

Zahrotunnisa, Z., Leksono, S. M., & El Islami, R. A. Z. (2024). Pengembangan E-Modul Berorientasi Integrated STEM Education Pada Tema Pencemaran Lingkungan Untuk Melatih Kemandirian Belajar Siswa SMP Kelas VII. *EDUPROXIMA: Jurnal Ilmiah Pendidikan IPA*, *6*(1), 164–175. https://doi.org/10.29100/.v6i1.4344