PBL-Based Science Modules Integrating Ethno-STEM and Augmented Reality: An Analysis of Practicality and Effectiveness

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Abstract - *This study aims to analyze the practicality and effectiveness of a Problem-Based Learning (PBL)-based science module integrated with the Ethno-STEM approach and assisted by Augmented Reality (AR) on the subject of Motion and Force for seventh-grade junior high school students. The module was developed as an innovative effort to improve the quality of science learning by linking local cultural contexts and the use of technology. This research uses research and development (R&D) methods including testing practicality and effectiveness. Documents analyzed for practicality include observation sheets for learning implementation, observation sheets for critical thinking skills and digital literacy through LKPD, and questionnaires for teacher and student responses. The effectiveness of the documents analyzed includes the results of pre-tests and post-tests for critical thinking skills and digital literacy of students. Practicality was analyzed using the % practicality formula, and the results of the analysis showed that all components obtained a % practicality value > 60%, which is categorized as practical and very practical. Meanwhile, the effectiveness test used N-Gain, where the N-Gain of critical thinking skills showed a value of 72.41% for the average %N-Gain of the experimental class and 53.83% for the control class. The N-Gain of digital literacy had an average of 68.71% for the experimental class and 24.24% for the control class. Therefore, the PBL model science module based on Ethno-STEM assisted by AR has proven to be practical and effective for use in the learning process at the junior high school level, so that the module can be trusted to be used as a learning resource.*

Keywords: *Practicality And Effectiveness; Science Modules; Problem Based Learning; Ethno-STEM; Augmented Reality*

INTRODUCTION

Science learning should emphasize deep understanding, real-world connections, and the development of critical and creative thinking to face 21st-century challenges. In this era of globalization and rapid technological progress, a solid grasp of science is vital for the younger generation (Amanah, Qayyim, Muliati, et al., 2025). As part of the education system, science education shapes future generations with the knowledge, character, and skills needed for the modern world (Rokhmat et al., 2025). The 21st-century skills include critical thinking, problem-solving, communication, collaboration, and digital literacy (Makhrus et al., 2025); (Margalita et al., 2025). A contextual, skill-based science learning approach can prepare students to adapt, innovate, and contribute to a sustainable future.

Natural Sciences (IPA) is theoretical knowledge obtained through observation, experimentation, and theory formation (Gunawan., Harjono, A., 2015). It aims to build understanding and positive values about science through learning (Suwartiningsih, 2021). Science learning should connect concepts with real life (Zendrato et al., 2022), encouraging exploration and active student engagement. Teachers can achieve this by developing innovative, contextual teaching materials supported by modern technology to enhance understanding and interest in continuous learning.

Science modules are key learning tools that provide structured materials to help students achieve learning objectives (Jusuf & Sobari, 2021). They serve as both information sources and guides that encourage active learning and interaction. Effective science modules enhance understanding and prepare students for real-world challenges (Zendrato et al., 2022). Their development focuses on creating competency-based, relevant materials that connect with daily life and use technology to boost engagement (Pertiwi, 2022). Clear objectives, suitable learning models, and proper evaluation are essential to ensure modules meet educational goals and track progress.

The learning model guides educators in planning instruction from learning materials to evaluation to achieve objectives (Mirdad & Pd, 2020). Problem Based Learning (PBL), developed by Barrows (1996), is a student-centered approach that uses real-world problems to stimulate learning in small groups (Barrows, 1996). PBL helps develop higher-order thinking, problem-solving, independence, cooperation, and active learning. Its process involves group-based problem solving followed by reflection. PBL consists of five phases: problem orientation, organizing students, investigation, developing and presenting solutions, and evaluation (Aryulina & Riyanto, 2016); (Arends, 2014); (Safitri et al., 2023).

The 21st-century skill demands encourage not only understanding science concepts but also applying the integrated STEM approach (science, technology, engineering, and mathematics) (Aisyah et al., 2024). While STEM improves learning quality, excessive focus on technology may weaken cultural values due to limited inclusion of local wisdom (Rahayu et al., 2024); (Usman et al., 2023). Learning that connects culture and science, or ethnoscience, involves analyzing cultural phenomena through scientific principles (Idrus, 2022); (Hasan et al., 2025). Ethno-STEM integrates local wisdom into scientific, technological, engineering, and mathematical contexts (Juniawan et al., 2024), making learning more meaningful, culturally relevant, and creativity-driven through interactive media (Muktiani et al., 2022).

Educational media help teachers present material more clearly (Meidina et al., 2025), and interactive media have been shown to boost student motivation and understanding (Fischer et al., 2022). Abstract material requires higher-order thinking, where students integrate various representations to solve problems (Amanah, Martin, et al., 2025). Despite strong trust in science, misconceptions about its dynamic nature persist (Amanah, Al-qoyyim, et al., 2025). Teachers' application of the inquiry approach greatly affects students' conceptual understanding (Amanah, Qayyim, Jauhari, et al., 2025). Augmented Reality (AR) enhances interactivity and visualization, making abstract concepts easier to grasp and improving critical thinking (Pamorti et al., 2024). AR merges 2D/3D digital content with the real world in real-time, deepening engagement and exploration (Qumillaila et al., 2017).

Product trials are conducted to collect data that can be used as a basis for determining whether the developed product is feasible (referring to the results of the product validity test). Product trials are conducted to measure the extent to which the developed product can achieve the expected goals and objectives (referring to the results of the product's practicality and effectiveness tests). The feasibility of a teaching material is an indicator of whether a teaching material can be said to be feasible if it meets the aspects of validity, effectiveness, and practicality. The module's validity value is assessed by the validator, effectiveness is known from learning outcomes, and practicality is known from student and teacher responses to the module (Puriannto et al., 2022). The practicality test aims to obtain direct feedback from students and teachers, while the effectiveness test aims to evaluate how well the module is used (Hasanah et al., 2025).

This study tested the practicality and effectiveness of a science module integrating Problem-Based Learning (PBL), Ethno-STEM, and Augmented Reality (AR). The module incorporates Banyumulek Pottery as local wisdom, visualized in 3D using the *Assemblr Edu* app. This combination aims to create a holistic learning environment that enhances scientific understanding, critical thinking, and digital literacy while preserving local culture. The Ethno-STEM–based PBL module assisted by AR demonstrates high practicality and effectiveness, producing an innovative and relevant learning tool for improving 21st-century education quality.

RESEARCH METHODS

This study uses a research and development (R&D) method with the main objective of testing the practicality and effectiveness of the Ethno-STEM-based problem-based learning (PBL) science module assisted by augmented reality (AR). The developed module integrates the topic of motion and force with content enrichment based on local cultural values through the Ethno-STEM approach and the insertion of 3D visual materials using AR. This study uses a measuring instrument in the form of a questionnaire and a survey, where the practicality instrument includes an observation sheet for the implementation of learning, an observation sheet for critical thinking skills and digital literacy through student worksheets (LKPD), and a questionnaire for teacher and student responses. The scale used for each instrument is a Likert scale of 1-5. The observation sheet for the implementation of learning consists of 20 statement items, while the observation sheet for critical thinking skills and student digital literacy contains a table of LKPD assessments (covering all indicators of critical thinking skills and digital literacy) from each student. The effectiveness instruments include a critical thinking skills test and a digital literacy questionnaire, which will then analyze the effectiveness of the students' pre-test and post-test results. The critical thinking skills instrument consists of 10 essay questions on motion and force, with two questions for each indicator. The digital literacy instrument consisted of a questionnaire with 20 closed-ended statements, each indicator consisting of five statements. The instrument was tested at a school in Mataram City, selecting two classes as samples.

The research subjects consisted of two groups (classes), namely seventh-grade students of junior high schools in Mataram city. The two groups served as the control and experimental classes. The sample taken in 1 class was 41 students, so the total sample was 82 people. The data collection procedure began by providing different treatments for the two classes, where in the experimental class the learning used the PBL model science module based on Ethno-STEM assisted by AR, while in the control class used textbooks from the government and student worksheets (LKS/LKPD) commonly used in the school. Data collection for initial and final ability data was carried out by administering tests, namely pre-test and post-test (Amanah et al., 2017). In the first meeting, a pre-test was conducted to assess students' critical thinking skills and digital literacy, particularly on the topic of motion and force. In meetings 2-4, treatment was administered according to the conditions expected by the researcher (meeting 4 for material enrichment). The fifth meeting was a post-test, which functioned to assess students' critical thinking skills and digital literacy after being given different treatments. Two observers observed the implementation of the learning and assessed students' critical thinking skills and digital literacy through LKPD. Meanwhile, science teachers at the school were asked to complete a response questionnaire related to the developed module. At the end of the learning, students were also asked to complete a response questionnaire related to the developed module.

Practical data were obtained through observation sheets on learning implementation, observation sheets on students' critical thinking skills and digital literacy, learning implementation questionnaires, and teacher and student response questionnaires. The data were analyzed using the following equation (Wati et al., 2022):

$$\%\ \text{Practicality} = \left(\frac{\text{Total score from assessors}}{\text{Total maximum score}}\right) \times 100\% \quad (1)$$

The criteria for the percentage calculation results can be seen in Table 1 (Arikunto, 2010).

Table 1. Device Practicality Criteria

Percentage	Category
0 – 20%	Not Practical
21 – 40%	Less Practical
41 – 60%	Quite Practical
61 – 80%	Practical
81 – 100%	Very Practical

The criteria for assessing the implementation of learning can be seen in Table 2 (Arifin, 2010).

Table 2. Learning Implementation Criteria

Percentage	Category
0 – 20%	Not Accomplished
21 – 40%	Less Accomplished
41 – 60%	Quite Accomplished
61 – 80%	Accomplished
81 – 100%	Very Accomplished

N-gain analysis measures the effectiveness of learning strategies by measuring students' knowledge acquisition and conceptual understanding before and after learning activities (Ahmad et al., 2025). The effectiveness instruments are pre-test and post-test questions to measure improvements in critical thinking skills and digital literacy. Research data on improvements in critical thinking skills and digital literacy were analyzed using the N-gain test, with the formula (Hake, 1998):

$$\langle g \rangle = \frac{\%\langle G \rangle}{\%\langle G_{max} \rangle} = \frac{\left(\%\langle S_f \rangle - \%\langle S_i \rangle\right)}{\left(100 - \%\langle S_i \rangle\right)} \quad (2)$$

Description:
S_f = Total value after treatment
S_i = Total value before treatment
G_{max} = Maximum average increase

Furthermore, the N-gain values are grouped into three categories as listed in Table 3 (Hake, 1998); (Harianja et al., 2024).

Table 3. N-gain Value Category (Hake, 1998)

N-gain Value (g)	Category
$g \geq 0{,}7$	High
$0{,}3 \leq g < 0{,}7$	Medium
$g < 0{,}3$	Low

The N-gain value obtained by students is then converted into a percentage which is then categorized based on the interpretation of the effectiveness of N-gain as in Table 4 (Hasan et al., 2025); (Nawir et al., 2019):

Table 4. Interpretation of N-gain Effectiveness

N-gain Value (%)	Category
> 76	Very Effective
$56 - 75$	Effective
$40 - 55$	Quite Effective
< 40	Not Effective

Data processing and analysis were carried out using Microsoft Excel which facilitates the calculation of %Practicality and N-Gain quickly and accurately. Evaluation of the analysis results then becomes the basis for the final revision of the module to achieve the quality standards of innovative and contextual science learning. After the test results, it is expected to produce a practical and effective AR-assisted Ethno-STEM-based PBL science module to improve the quality of science learning, especially critical thinking skills and digital literacy of students at the junior high school level by utilizing local cultural richness and current learning technology.

RESULTS AND DISCUSSION

The results of this study present data on the practicality and effectiveness of the PBL model science module based on Ethno-STEM with the help of AR technology that has been tested on seventh grade junior high school students. The module is intended for junior high school students, covers the material of motion and force, and applies the syntax of the PBL model and is based on ethno-STEM with a focus on Banyumulek pottery. In addition, the developed module also utilizes 3D AR technology created through the *Assemblr Edu* application. The module has been tested for validity and reliability. Previous research has successfully proven that the Problem-Based Learning (PBL) based science module combined with the Ethno-STEM approach and supported by Augmented Reality (AR) technology has high validity and reliability (Amanah, Rahayu, et al., 2025).

Results

The research results present an analysis of the practicality and effectiveness of the developed science module. The practicality analyzed includes the percentage of practicality from science teachers and students, the implementation of learning, and observations of critical thinking skills and digital literacy through student worksheets (LKPD). Meanwhile, the effectiveness analyzed is the increase or N-Gain percentage of critical thinking skills and digital literacy.

Module Practicality Analysis

Practicality refers to something related to practice or action, easy and enjoyable to use or apply, and useful and effective in achieving goals. Practicality refers to the ease of using, implementing, or applying something (Milala et al., 2022). Based on the practicality test, the evaluated module had a very high level of practicality from various perspectives. Respondent 1 gave a practicality score of 91.43% and Respondent 2 is 87.14%. Both percentages fall into the "Very Practical" category. This indicates that overall, the module or intervention was deemed very easy to use, relevant, and effective in the teaching context by teachers. These high scores indicate that the learning materials, methods, and tools used in this intervention can be implemented well in the field.

Respondent 1 showed an exceptionally high practicality score in the language aspect (100%), indicating that the language used in the module was very clear, easy to understand, and did not cause ambiguity for teachers. The material aspect (93.33%) was also very high, indicating that the material content was relevant, accurate, and supported the learning process. The interest aspect (86.67%), although slightly lower, was still in the very practical category, meaning the module was quite interesting for users.

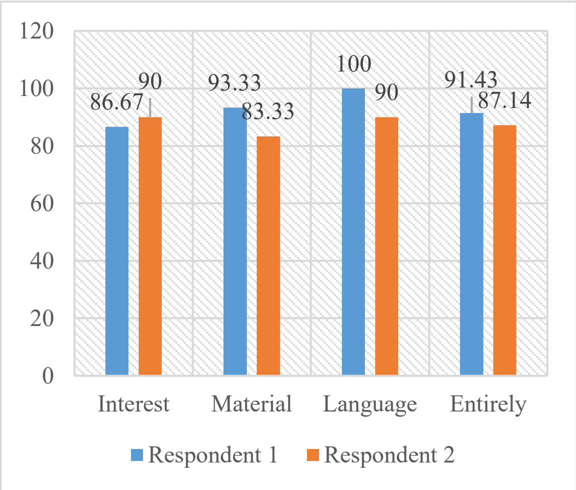

Figure 1. Percentage of Practicality of Natural Science Teachers

Respondent 2 also gave a high rating, especially in the Interest Aspect (90%) and Language Aspect (90%). The Material Aspect (83.33%), although slightly below Respondent 1, still showed that the material was considered practical and useful. It can be seen in Figure 1 that in each category (interest, material, language, and overall) the practicality score for both respondents was always above 80%, with many even above 90%. Consistently, the blue (Respondent 1) and orange (Respondent 2) bars show very strong performance, confirming that this module is well designed to meet the practical needs of science teachers.

The average percentage of students in the practicality test was 78.71%, which is categorized as "Practical." This indicates that the module or intervention provided can be implemented well by the majority of students, although it has not yet reached the "Very Practical" category overall. A closer look at each participant (P1 to P41) through the graph in Figure 2 shows quite diverse fluctuations. Some students showed a very high level of practicality, even reaching 100% at some points (respondents 30, 33, and 40), indicating that for them, implementing the module or intervention was very easy and effective. However, there were also students who had a below average practicality percentage, with the lowest score being around 65.71% (respondent 2), which is still classified as "Practical" but indicates challenges or areas that need improvement.

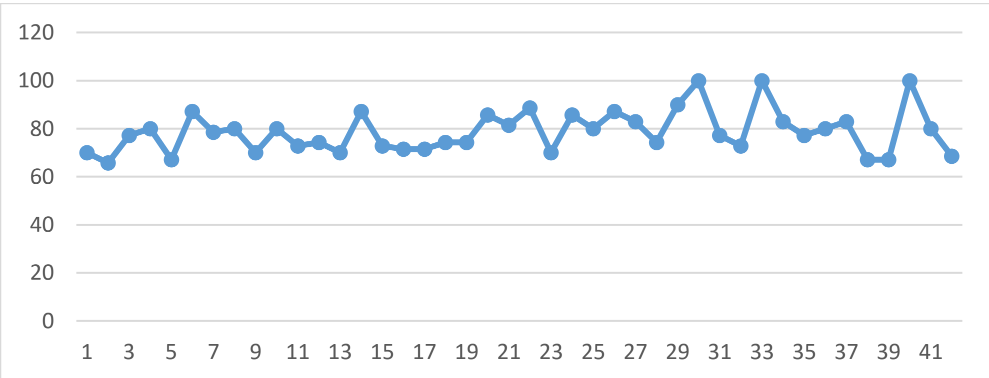

Figure 2. Percentage of Students Practicality

In the interest aspect, the practicality percentage was 80.48% with the "Very Practical" category. This indicates that students felt very interested in the module or intervention provided. The practicality percentage of the material aspect was 76.43% with the "Practical" category. Although it did not reach "Very Practical" like the interest aspect, this figure still shows that the material in the module can be understood and used well by students. The language aspect was 80.24% with the "Very Practical" category. This shows that the language used in the module is very clear, easy to understand, and does not cause confusion for students. Overall, the average practicality percentage was 78.71%, which is included in the "Practical" category. This figure is a synthesis of the three aspects above and shows that the module is generally very good in terms of practicality.

Based on the learning implementation data from two meetings observed by two observers (Figure 3), it can be concluded that the learning process went very well with a very high level of implementation. In the first meeting, the average implementation score reached 89.5%, which falls into the "Very Implemented" category, while in the second meeting, the score increased even higher to 95%, in the same category. This demonstrates consistency and a significant improvement in the quality of learning implementation between the first and second meetings.

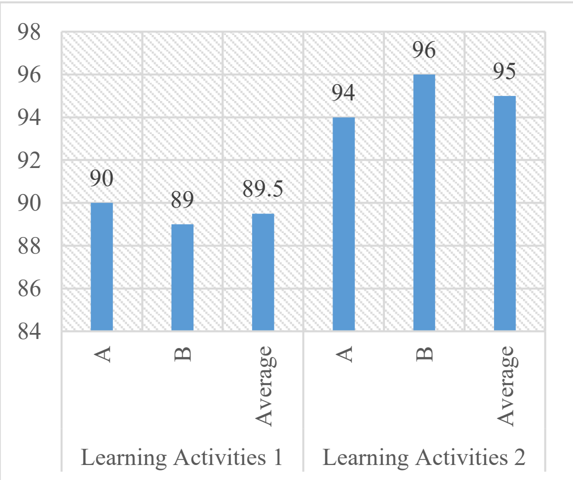

Figure 3. Percentage of Implementation of Experimental Class Learning

In the first learning activity, the two observers provided very consistent, near-perfect assessments. Observer A gave a total score of 90%, while Observer B gave an 89%. Both scores were in the "Very Accomplished" category, indicating that nearly all aspects of the learning were implemented optimally. A difference of only 1% between the two observers indicates high agreement in the assessments, indicating that the data were highly reliable and there were no significant differences in perceptions of the quality of the learning implementation. In the second learning activity, there was a significant increase in the implementation of the learning. Observer A gave a score of 94% and Observer B even higher with a score of 96%. The average completion rate for both assessments reached 95%, which still falls into the "Very Accomplished " category. This improvement can be interpreted as positive progress in implementing the learning, the small 2% difference between the two assessors indicates stability and consistency in the evaluation process.

The practicality test of critical thinking skills through the Student Worksheet (LKPD) was analyzed by the percentage of practicality individually and in groups. There was considerable variation in the percentage of practicality among participants. Although most were in the 70-80% range, some participants achieved 100% (P30, P32, P39) and some were below 70% (P1, P23, P38). This indicates that the level of practicality application is not evenly distributed across individuals. Most students demonstrated a level of practicality that was "Practical" or "Very Practical." However, fluctuations indicate that some individuals may require more attention in understanding or applying concepts. It is important to pay attention to participants with very low or very high scores. Examples of participants with 100% practicality can serve as role models or case studies to understand the factors driving optimal performance. Conversely, participants with low scores need to be identified for the reasons, whether it is due to a lack of understanding, motivation, or challenges in application.

Based on Figure 4, it can be seen that the average practicality score for all groups in LKPD 1 was 75.93%, with an overall rating of "Practical." Although the average was "Practical," there were differences between groups. Groups K3 and K4 showed higher percentages (81.6% and 80.8%) and were categorized as "Very Practical," indicating that there were certain practices or dynamics in these groups that made them more effective. Meanwhile, groups K1 and K5 had the lowest percentages (73.6%), indicating that there are aspects that need improvement in these groups. High-performing groups can be analyzed to identify their key success factors, whether in terms of collaboration, task allocation, or conceptual understanding, which can then be replicated in other groups.

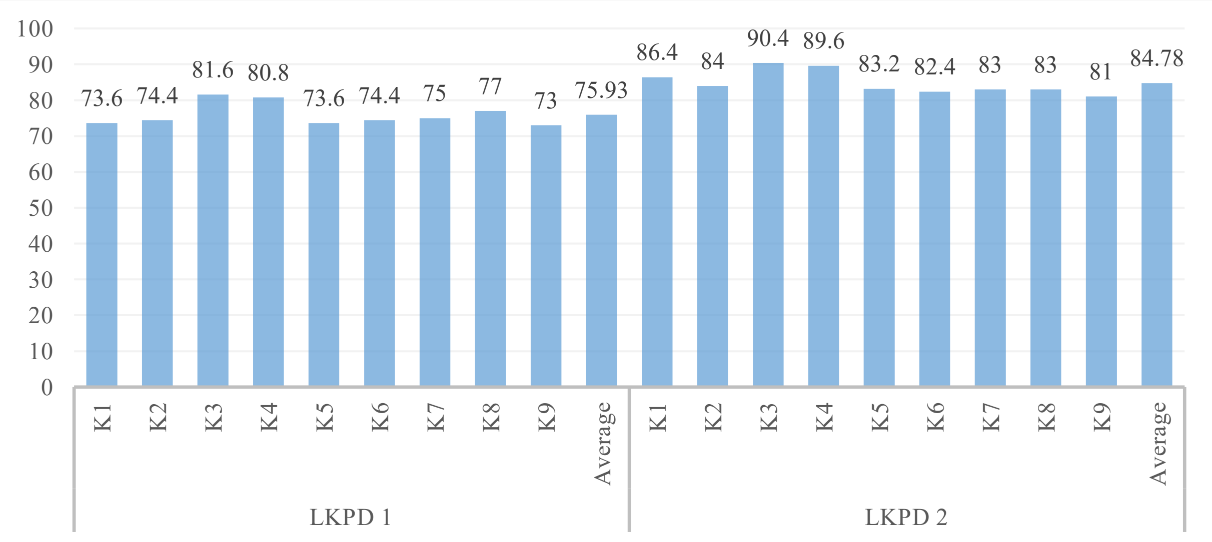

Figure 4. Percentage of Practicality of Students' Critical Thinking Skills

The average practicality of LKPD 2 was 84.78%, significantly higher than that of LKPD 1 (75.93%). This indicates significant improvements or differences in the design, implementation, or conditions that support practicality in LKPD 2. This nearly 9% average difference shifted the overall practicality category to a higher level in LKPD 2. Nearly all critical thinking skill categories (K1 to K9) showed higher practicality percentages in LKPD 2 compared to LKPD 1. Although LKPD 2 demonstrated superior improvement, it remains important to identify which K1-K9 categories performed most prominently or, conversely, lagged behind their maximum potential. For example, in LKPD 2, K3 and K4 had the highest percentages (90.4% and 89.6%, respectively), indicating that these aspects were very strong. Based on the data in Figure 4, there is a continuous improvement in promoting practicality, both at the individual and group levels.

The digital literacy practicality test was analyzed individually and in groups, as was the critical thinking skills test. Most students in both worksheets scored "Practical" or "Very Practical." There were scores of 5 in the "Attitude" aspect, but many scores of 3 in "Information Knowledge" (Likert scale 1-5). This may indicate that positive motivation and behavior have been established, but conceptual understanding still needs to be strengthened. Although the group average showed good results, it is important to observe variation between individuals. Some students consistently scored high (e.g., many 5s), indicating excellent mastery. Conversely, others may have several low scores (e.g., 2 or 3), indicating a need for more attention or a different learning approach. This individual data is invaluable for educators in identifying strengths and areas for improvement in each student. Educators can provide more personalized feedback and appropriate support.

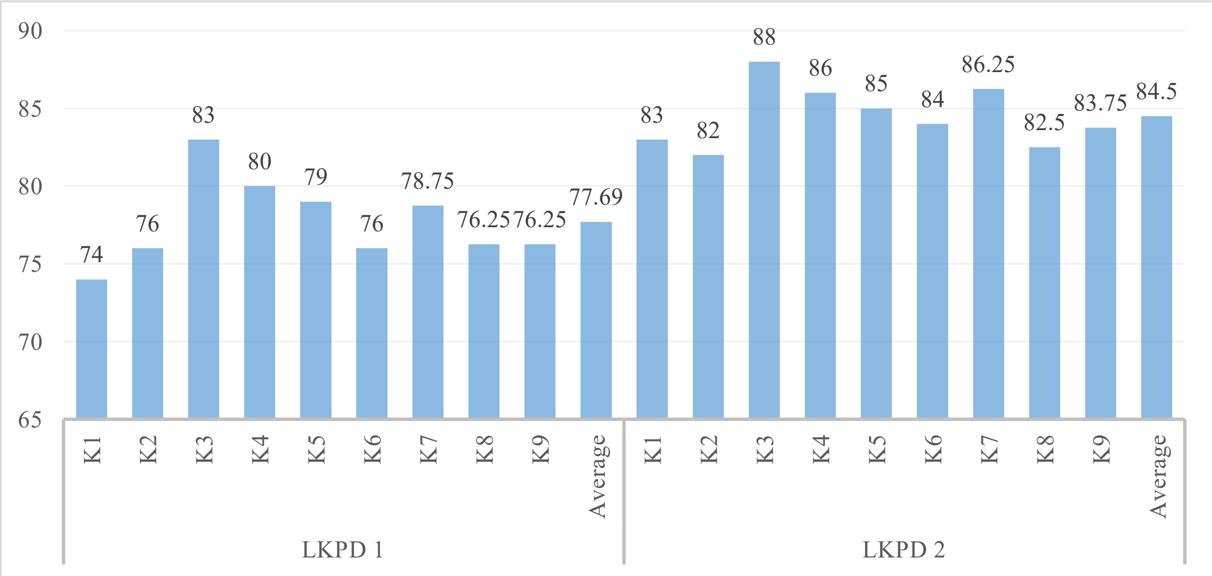

Figure 5. Percentage of Students' Digital Literacy Practicality

The average group practicality percentage was approximately 77.69% with the "Practical" category, while the average group practicality percentage was approximately 84.5% with the "Very Practical" category. The bar graph (Figure 5) clearly shows that the groups in LKPD 2 had a higher percentage of practicality overall, ranging from 82% (K2) to 88% (K3), with an average of 84.5%. Almost all of these groups received the "Very Practical" category. LKPD 2 showed a significantly higher average group practicality (84.5%) compared to LKPD 1 (77.69%). This indicates that students are increasingly practiced in LKPD 2. LKPD 2 consistently showed a higher level of practicality, both individually and in groups, with an average group practicality reaching 84.5% and the majority of groups being in the "Very Practical" category. This implies that there are factors in the design, content, or teaching methods applied in LKPD 2 that are superior in facilitating the development of students' digital literacy.

Module Effectiveness Analysis

The success of a teaching and learning program does not always depend on the sophistication of the media used, but rather on the appropriateness and effectiveness of the media used by the instructor (Milala et al., 2022). Effectiveness is the ability to produce results or achieve predetermined goals, as expected, meaning doing the right thing (Sule & Saefullah, 2010). The word "effectiveness" is derived from the word "effective," which means effect or consequence, while "effectiveness" refers to the success of an action (Daryanto, 2013). Previous research has shown that analyzing N-gain scores for control and experimental classes revealed significant differences in the effectiveness of each intervention, providing deeper insight into how various teaching tools can impact student learning outcomes (Ahmad et al., 2025). This study analyzed the %N-Gain of the control and experimental classes for students' critical thinking skills (CTS) and digital literacy (DL).

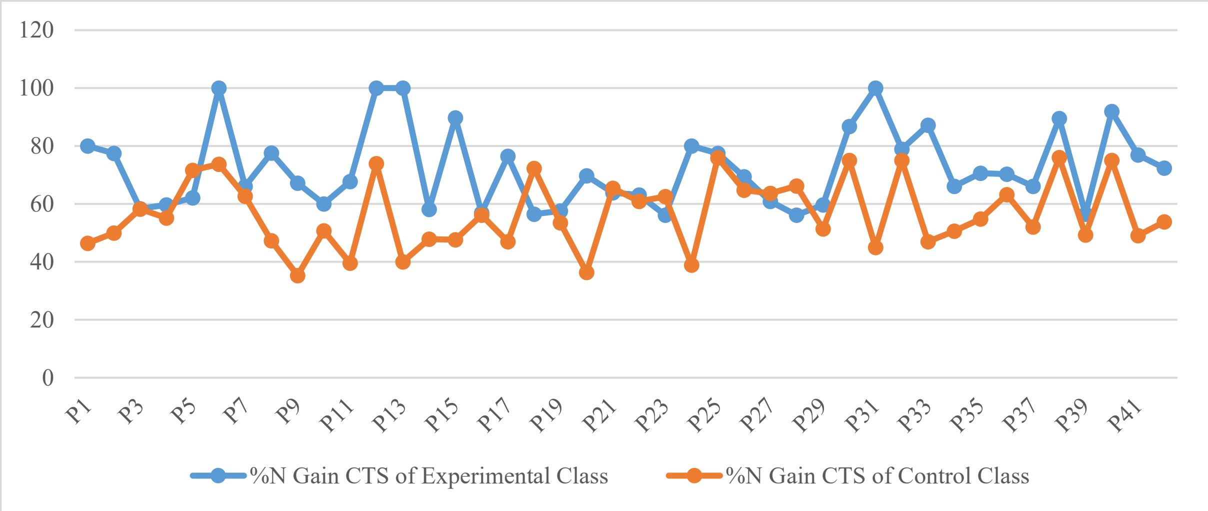

Figure 6. Percentage of N-Gain of Students' Critical Thinking Skills

Figure 6 visually shows that the blue line (experimental group) is predominantly above the orange line (control group) at most observation points (P1 to P41). This demonstrates the module's consistent effectiveness in continuously improving critical thinking skills in the experimental group. Although there are some points where the orange line rises slightly or even equals the blue line, the overall trend is very clear. The % N-Gain test for critical thinking skills clearly shows a difference in performance between the experimental and control groups in improving critical thinking skills (% N-Gain KBK). The experimental group achieved an average % N-Gain of 72.41%. This figure indicates that overall, students in the experimental group experienced a significant increase in their critical thinking skills after receiving treatment using the PBL-based science module integrated with Ethno-STEM and AR assistance.

The control group achieved an average %N-Gain of 53.83%. This increase was also present, but much lower than that of the experimental group. This indicates that conventional learning, or learning without the same module intervention, has a smaller positive impact on improving critical thinking skills. The majority of participants in the experimental class fell into the medium %N-Gain category (60% - 79%). This indicates that most students responded well to the treatment, for example, P2 (77.5%), P7 (66.07%), and P8 (77.61%). Some participants in the control group showed very minimal improvement, even below 40%. This further highlights the importance of effective learning treatments or interventions. The significant average difference (almost 20%) and the experimental group's dominance in both the individual data and the line graph provide strong evidence of the module's effectiveness.

Effectiveness is determined by the percentage of students who pass the knowledge test, which reflects their improvement in digital literacy (Margalita et al., 2025). Unlike the critical thinking skills graph, the digital literacy %N-Gain line graph in Figure 7 visually reinforces this finding. The blue line (experimental group) is consistently well above the orange line (control group) at almost all observation points (P1 to P41). This pattern indicates that the experimental group experienced a more stable and significant increase in digital literacy than the control group. Despite slight fluctuations, the difference between the two groups remains striking. The digital literacy %N-Gain test shows a difference in performance between the experimental and control groups in improving digital literacy. The experimental group achieved an average digital literacy %N-Gain of 68.71%. This figure indicates that overall, students in the experimental group experienced a good improvement in their digital literacy after receiving the treatment.

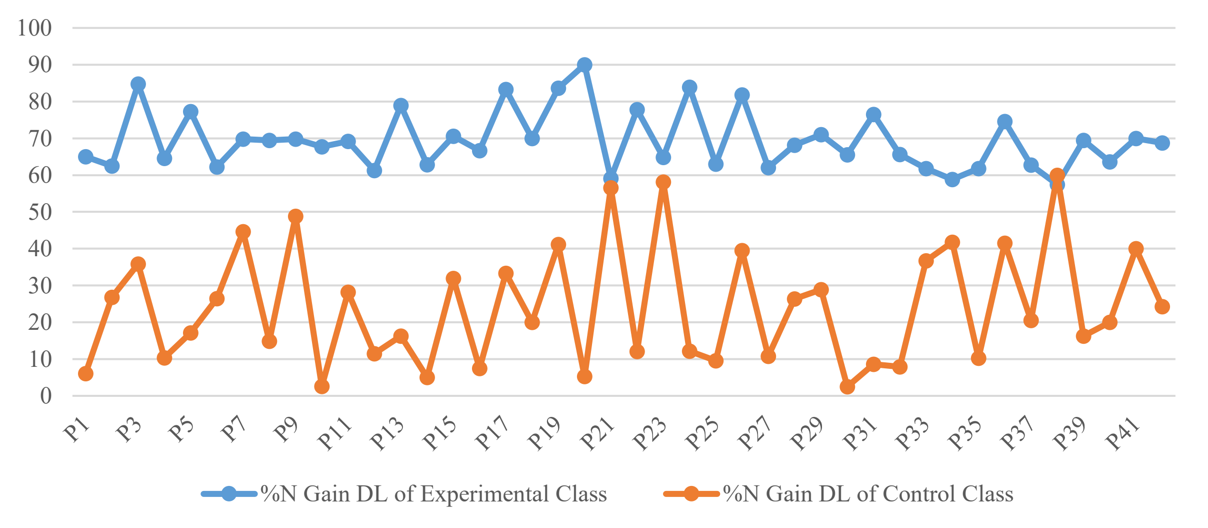

Figure 7. Percentage of N-Gain of Students' Digital Literacy

The control group achieved an average %N-Gain of 24.24% in digital literacy. The increase in the control group was significantly lower than in the experimental group, indicating that without special treatment, digital literacy improvement was not as effective as in the experimental group. Six participants in the experimental group demonstrated excellent digital literacy improvement, with P20 achieving 90% improvement. This demonstrates the effectiveness of treatment for some individuals. Similarly, for critical thinking skills, the majority of participants in the experimental class were in the mid-range (60%-79%). This indicates that most students responded positively, for example, P1 (65%), P2 (62.5%), and P4 (64.58%). Only one participant in the experimental group (P34) demonstrated an increase below 60%, indicating that the intervention was broadly effective. Many participants in the control group demonstrated very minimal improvement, with some achieving only 2.5% and 5%. This strongly highlights the need for well-planned treatment to improve digital literacy. The large mean difference (over 40%) and the dominance of the experimental group's graph indicate that the approach used was highly effective. Individual variation remains, but overall, the evidence suggests that treatment or intervention was highly beneficial for digital literacy development.

Based on the comparison of the two previous analyses, the improvement in Digital Literacy appears much more prominent and significant compared to the improvement in Critical Thinking Skills. This can be seen from the greater average difference in %N-Gain between the experimental and control groups in Digital Literacy. In Critical Thinking Skills, the difference between the experimental group (72.41%) and the control group (53.83%) was around 18.58%. Although this is a good improvement and indicates the effectiveness of the treatment, there were some participants in the control group who still showed quite high N-Gain. In digital literacy, the difference between the experimental group (68.71%) and the control group (24.24%) jumped drastically to around 44.47%. This very striking difference indicates that the intervention provided had a much greater and stronger impact in improving digital literacy compared to critical thinking skills.

Discussion

The 21st-century science learning demands innovation in approaches and media to focus not only on mastering concepts but also on developing critical thinking skills, creativity, collaboration, and digital literacy (Margalita et al., 2025). Technological developments and globalization require learning processes to be more contextual and relevant to students' real lives. Therefore, integrating the Problem-Based Learning (PBL) model with the Ethno-STEM approach and the support of Augmented Reality (AR) technology is a strategic step to deliver meaningful learning oriented toward 21st-century competencies (Amanah, Rahayu, et al., 2025). This approach not only emphasizes mastery of scientific knowledge but also fosters higher-order thinking skills through problem-solving rooted in local culture and the use of interactive technology.

The development of a PBL-based science module integrated with Ethno-STEM and assisted by AR stems from the need for teaching materials that can bridge science with local wisdom. The use of cultural contexts, such as Banyumulek pottery, brings the learning process closer to students' social realities while fostering a sense of pride in local culture. With 3D visualization through the *Assemblr Edu* application, students can understand the concepts of force and motion more concretely, because scientific phenomena are visualized directly in the form of objects that can be observed and manipulated virtually. This strengthens students' cognitive and affective aspects simultaneously, in line with the goals of holistic science learning.

The practicality test results show that this module is very easy to use by teachers and students. The percentage of practicality from teachers reached more than 87%, included in the "very practical" category, while the average practicality of students was 78.71% in the "practical" category. These values indicate that the language, material, and display of the module are considered clear, interesting, and easy to understand. The use of AR media also increased student interest and engagement during the learning process. High practicality indicates that the developed product is not only theoretically valid but can also be implemented well in a real classroom context, supporting the effectiveness of active and interactive science learning.

Observational improvements from Student Worksheet 1 to Student Worksheet 2 demonstrate significant improvements in the practicality and implementation of learning. Student worksheet practicality increased from 75.93% to 84.78% for critical thinking skills, and from 77.69% to 84.5% for digital literacy. This indicates that students are becoming more skilled at using the modules and have a better understanding of the relationships between science, technology, engineering, and mathematics concepts within the local cultural context. The implementation of the PBL model encourages students to actively discuss, collaborate, and reflect after solving problems. This active engagement is a crucial factor in making learning more effective and meaningful.

In terms of effectiveness, the results of the N-Gain analysis showed a significant increase in students' critical thinking skills and digital literacy. The experimental class using the AR-assisted Ethno-STEM module achieved an average N-Gain of 72.41% in critical thinking skills (medium-high category), while the control class only achieved 53.83%. The increase in digital literacy was even more pronounced, namely 68.71% in the experimental class compared to 24.24% in the control class. This difference proves that the integration of the PBL model, cultural context, and AR technology has a real impact on 21st-century understanding and skills, especially in critical thinking skills, problem solving, and mastery of digital technology.

The results of an in-depth analysis of the practicality of the material and the implementation of learning indicate that in general the learning instruments and processes have a very high level of practicality, with the majority being in the "Very Practical" category. This is supported by consistent scores, both from teacher assessments, students, and observations of the implementation of learning. There is a significant increase in practicality in LKPD 2 compared to LKPD 1, both in critical thinking skills and digital literacy. The average group practicality in critical thinking skills increased from 75.93% (LKPD 1) to 84.78% (LKPD 2), and in digital literacy increased from 77.69% (LKPD 1) to 84.5% (LKPD 2). This increase indicates that modifications or improvements in LKPD 2 have succeeded in improving the learning experience to be more optimal and effective in developing both skills. Although individual practicality varies, the data shows that learning is not only practical but also effective in achieving learning objectives, which is also reflected in the excellent percentage of learning implementation in both meetings (average 89.5% and 95%).

Overall, the results of this study confirm that the PBL-based science module with the Ethno-STEM approach and AR support has a high level of practicality and effectiveness. The integration of local wisdom through ethnoscience contributes to cultural preservation and provides a real context in science learning, while AR technology enhances the visualization and interactivity of the material. The combination of the three creates a collaborative, creative, and adaptive learning environment to the demands of the 21st century. Thus, this module can be used as an innovative alternative in improving the quality of science learning at the junior high school level and as a model for developing relevant teaching materials in the Society 5.0 era.

CONCLUSION

Based on research objectives, findings, and discussion, it can be concluded that the science module, a problem-based learning model based on ethno-STEM with augmented reality on the topic of motion and force, has proven to be feasible and effective for use by seventh-grade junior high school students. This module is practical for teachers and students in the learning process. The use of the module has succeeded in significantly improving students' critical thinking skills and digital literacy, which can be seen through the effectiveness test. The module components are complete and in accordance with the needs of modern learning. The module provides an interesting and meaningful learning experience for seventh-grade students. Overall, this learning module meets the research objectives as an innovative, practical and effective open material.

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REFERENCES

Ahmad, M., Erlina, E., Lestari, I., Enawaty, E., & Queiroz, C. C. (2025). The Effectiveness of Uno Kimia Cards in Enhancing Understanding of Molecular Shape Topic Among High School Students. *Jurnal IPA & Pembelajaran IPA*, *9*(1), 90–110. https://doi.org/10.24815/jipi.v9i1.42387

Aisyah, N. S., Kosim, Gunawan, & Gunada, Wayan, I. (2024). Indonesian Journal of STEM Education. *Indonesian Journal of STEM Education*, *6*(2), 86–101.

Amanah, P. D., Al-qoyyim, T. M., Muliati, E., Jauhari, M. T., & Jufri, A. W. (2025). *Junior High School Science Teachers ' Perceptions of Scientists : A Survey & Critical Analysis*. *3*(3), 264–272.

Amanah, P. D., Harjono, A., & Gunada, I. W. (2017). Generatif Berbantuan Scaffolding Dan Advance Organizer. *Jurnal Pendidikan Fisika Dan Teknologi*, *III*(1), 84–91.

Amanah, P. D., Martin, N., & Rokhmat, J. (2025). *Research Trends on the Multiple Representation Learning Model , A Systematic Review (2016-2025)*. *03*(1), 1–14.

Amanah, P. D., Qayyim, T. M. Al, Jauhari, M. T., Muliati, E., Fitratunisyah, & Jufri, A. W. (2025). Validity and Reliability of the INSPIRE: Instrument Perceptions Science Inquiry and Nature of Science. *International Journal of Contextual Science*, *2*(1), 9–16. https://doi.org/10.29303/ijcse.v2i1.936

Amanah, P. D., Qayyim, T. M. Al, Muliati, E., Fitratunisyah, Jauhary, M. T., & Jufri, A. W. (2025). Junior High School Science Teachers ' Perceptions of Science Scientists , Science Subjects , NOS , and NOSI. *International Journal of Contextual Science Education(IJCSE)*, *3*(3), 273–279. https://doi.org/10.29303/ijcse.v3i3.986

Amanah, P. D., Rahayu, S., & Gunawan, G. (2025). Validity and Reliability Analysis of Science Modules Using Problem-Based Learning Models Based on Ethno-STEM Assisted by Augmented Reality. *Kappa Journal*, *9*(2), 213–222. https://doi.org/10.29408/kpj.v9i2.31825

Arends, R. I. (2014). Learning to Teach (Tenth Edition). In *McGraw-Hill Education: Vol. Tenth Edit*.

Arifin, Z. (2010). *Evaluasi pembelajaran* (Bandung (ed.)). PT. Remaja Rosda Karya.

Arikunto, S. (2010). *Dasar-dasar Evaluasi Pendidikan* (Jakarta (ed.)). Bumi Aksara.

Aryulina, D., & Riyanto, R. (2016). a Problem-Based Learning Model in Biology Education Courses To Develop Inquiry Teaching Competency of Preservice Teachers. *Jurnal Cakrawala Pendidikan*, *1*(1), 47–57. https://doi.org/10.21831/cp.v1i1.8364

Barrows, H. S. (1996). Problem-based learning in medicine and beyond: A brief overview. *New Directions for Teaching and Learning*, *1996*(68), 3–12. https://doi.org/10.1002/tl.37219966804

Daryanto. (2013). *Inovasi Pembelajaran Efektif*. Yrama Widya.

Fischer, F., Bauer, E., Seidel, T.,

Schmidmaier, R., Radkowitsch, A., Neuhaus, B. J., Hofer, S, I., Sommerhoff, D., Ufer, S., Kuhn, J., Küchemann, S., Sailer, M., Koenen, J., Gartmeier, M., Berberat, P., Frenzel, A., Heitzmann, N., Holzberger, D., … Fischer, M. R. (2022). Representational scaffolding in digital simulations –learning professional practices in higher education. *Information and Learning Sciences*, *123*(11–12), 645–665. https://doi.org/https://doi.org/10.1108/ILS-06-2022-0076

Gunawan., Harjono, A., dan S. (2015). Multimedia Interaktif dalam Pembelajaran Konsep Listrik bagi Calon Guru. *Jurnal Pendidikan Fisika Dan Teknologi*, *1*(1), 9.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*(1), 64–74. https://doi.org/10.1119/1.18809

Harianja, M. R., Yusup, M., & Siahaan, S. M. (2024). Uji N-Gain pada Efektivitas Penggunaan Game dengan Strategi SGQ untuk Meningkatkan Berpikir Komputasi dalam Literasi Energi.pdf. *Jurnal Intelektualita: Keislaman, Sosial, Dan Sains*, *13*(2), 304–310. https://doi.org/10.19109/intelektualita.v13i2.25168

Hasan, Y., Susilawati, & Andayani, Y. (2025). *Pengembangan E- Modul Berbasis Etnosains Alat Transportasi Cidomo*. *6*(2). https://doi.org/https://doi.org/10.29303/Goescienceed.v6i2.994

Hasanah, R., Gunawan, G., Muntari, M., Rokhmat, J., & Harjono, A. (2025). Development of a Problem-Based Physics Teaching Module to Enhance Students' Science Process Skills. *Jurnal Pendidikan Fisika Dan Teknologi*, *11*(1), 257–271. https://doi.org/10.29303/jpft.v11i1.8384

Idrus, S. W. Al. (2022). Implementasi STEM Terintegrasi Etnosains (Etno-STEM) di Indonesia: Tinjauan Meta Analisis. *Jurnal Ilmiah Profesi Pendidikan*, *7*(4), 2370–2376. https://doi.org/10.29303/jipp.v7i4.879

Juniawan, E. R., Sumarni, W., & Prasetya, A. T. (2024). Development of Ethno-STEM-Loaded Digital Science Teaching Materials the Process of Making Traditional Sidoarjo Snacks Material of Force and Object Motion to Train Science Literacy in Elementary School Students. *Jurnal Penelitian Pendidikan IPA*, *10*(1), 325–337. https://doi.org/10.29303/jppipa.v10i1.5948

Jusuf, H., & Sobari, A. (2021). Pelatihan Pembuatan Modul Pembelajaran untuk Mendukung Pembelajaran Online. *Jurnal Pengabdian Masyarakat*, *2*(1), 33–37.

Makhrus, M., Rahayu, S., Santoso, D., & Annam, S. (2025). Effect of E-Module Based on Sustainable Development Goals (SDGs) with Conceptual Change Model-Cognitive Conflict Approach (CCM-CCA) Integrated with Local Wisdom on Students' Critical Thinking Skills. *Educational Process: International Journal*, *17*. https://doi.org/10.22521/edupij.2025.17.399

Margalita, S., Susantini*, E., Kuntjoro, S., & Ali, M. (2025). Validity and Effectiveness of Problem Based Learning E-Book Integrated with Indigenous Culture to Enhance Digital Literacy Skills in the Society 5.0 Era. *Jurnal IPA & Pembelajaran IPA*, *9*(1), 154–169. https://doi.org/10.24815/jipi.v9i1.42573

Meidina, P. A. N., Ratnasari, Y., Fakhriyah, F., & Kassymova, G. K. (2025). Effectiveness of Project-Based Learning with Economic Needs

Videos on Elementary School Students' Science and Social Science Learning Outcomes. *Jurnal IPA & Pembelajaran IPA*, *9*(3), 815–826. https://doi.org/10.24815/jipi.v9i3.47603

Milala, H. F., Joko, Endryansyah, & Agung, A. I. (2022). Keefektifan Dan Kepraktisan Media Pembelajaran. *Jurnal Pendidikan Elektro*, *11*(02), 195–202.

Mirdad, J., & Pd, M. I. (2020). *Model-Model Pembelajaran (Empat Rumpun Model Pembelajaran)*. *2*(1), 14–23.

Muktiani, N. R., Soegiyanto, Siswantoyo, Rahayu, S., Hermawan, H. A., Juniawan, E. R., Sumarni, W., Prasetya, A. T., Gumilar, N. M. A. R., Sudarmin, Marwoto, P., Kurniawan, H. D., Kuswanto, H., Sofyan, H., Anggereini, E., Muazzomi, N., Larasati, N., Winarto, Sarwi, S., … Sujiono, E. H. (2022). Development of Ethno-STEM-Loaded Digital Science Teaching Materials the Process of Making Traditional Sidoarjo Snacks Material of Force and Object Motion to Train Science Literacy in Elementary School Students. *Jurnal Penelitian Pendidikan IPA*, *11*(1), 37–51. https://doi.org/10.21831/cp.v41i2.49217

Nawir, M., Khaeriyah, H., & Syamsuriyawati. (2019). Efektivitas Model Pembelajaran Kooperatif Tipe Student Facilitator and Explaining terhadap Hasil Belajar Metematika Peserta Didik Kelas VIII SMP Negeri 18 Lau Kabupaten Maros. *Jurnal Ilmiah Pendidikan Matematika*, *2*(Efektivitas Model Pembelajaran Kooperatif), 100–108.

Pamorti, O. A., Winarno, & Suryandari, K. C. (2024). Effectiveness of Augmented Reality Based Learning Media to Improve Critical Thinking Skills on IPAS Material. *Jurnal Penelitian Pendidikan IPA*, *10*(5), 2211–2219. https://doi.org/10.29303/jppipa.v10i5.7139

Pertiwi, H. K. (2022). Developing Science Module of Problem-Based Learning To Improve Critical Thinking Skill. *Physics and Science Education Journal (PSEJ)*, *2*(April), 1–8. https://doi.org/10.30631/psej.v2i1.1213

Puriannto, R., Haryudo, S. I., Joko, & Fransisca, Y. (2022). Keefektifan dan Kepraktisan Modul Pembelajaran Instalasi Penerangan Listrik 1 Fasa Keefektifan dan Kepraktisan Modul Pembelajaran Instalasi untuk Kelas XI TITL SMK Rajasa Surabaya. *Jurnal Pendidikan Teknik Elektro*, *11*(1), 107–115.

Qumillaila, Q., Susanti, B. H., & Zulfiani, Z. (2017). Pengembangan Augmented Reality Versi Android Sebagai Media Pembelajaran Sistem Ekskresi Manusia. *Jurnal Cakrawala Pendidikan*, *36*(1), 57–69. https://doi.org/10.21831/cp.v36i1.9786

Rahayu, S., Gunawan, Harjono, A., Al-Hadi, K., & Kurniadin, M. Z. (2024). Pelatihan Penggunaan Media Fliping Book Terintegrasi Kearifan Lokal Sebagai Sumber Belajar Tambahan Guru. *Jurnal Pengabdian Magister Pendidikan IPA*, *7*(1). https://doi.org/10.29303/jpmpi.v7i1.7919

Rokhmat, J., Gunawan, G., Sukarso, A., Rahmatiah, R., Mahmudah, H., & Amanah, P. D. (2025). Revealing the Weaknesses of Applying Gamification in Science Learning and Overcoming It: A Systematic Review. *TEM Journal*, *14*(3), 2462–2471. https://doi.org/10.18421/tem143-50

Safitri, R., Eka Subekti, E., & Nafiah, U. (2023). Analisis Penerapan Model Problem Based Learning Pada Pembelajaran IPAS Kelas IV Di SD Supriyadi Semarang. *Ulin Nafiah INNOVATIVE: Journal Of Social*

Science Research, *3*, 297–308.

Sule, E. T., & Saefullah, K. (2010). *Pengantar Manajemen* (5th ed.). Kencana.

Suwartiningsih, S. (2021). Penerapan Pembelajaran Berdiferensiasi untuk Meningkatkan Hasil Belajar Siswa pada Mata Pelajaran IPA Pokok Bahasan Tanah dan Keberlangsungan Kehidupan di Kelas IXb Semester Genap SMPN 4 Monta Tahun Pelajaran 2020/2021. *Jurnal Pendidikan Dan Pembelajaran Indonesia (JPPI)*, *1*(2), 80–94. https://doi.org/10.53299/jppi.v1i2.39

Usman, G. B. T., Ali, M. N., & Ahmad, M. Z. (2023). Effectiveness of self learning modules on achievement in biology among secondary school students. *Journal of Turkish Science Education*, *20*(3), 453–467.

Wati, D. K., Saragih, S., & Murni, A. (2022). Validitas dan Praktikalitas Bahan Ajar Matematika Berbantuan FlipHtml5 untuk Memfasilitasi Kemampuan Pemahaman Matematis Siswa Kelas VIII SMP/MTs pada Materi Koordinat Kartesius. *Juring (Journal for Research in Mathematics Learning)*, *5*(4), 287. https://doi.org/10.24014/juring.v5i4.16717

Zendrato, E. D. K., Harefa, A. R., & Lase, N. K. (2022). Pengembangan Modul IPA Berbasis Contextual Teaching and Learning Pada Materi Sistem Pernapasan Manusia. *Educativo: Jurnal Pendidikan*, *1*(2), 446–455. https://doi.org/10.56248/educativo.v1i2.61