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The Effectiveness of E-Module Use on the Science Learning Outcomes of Sixth-Grade Primary School Students

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Abstract: This study aimed to examine the effectiveness of an IPAS e-module in improving science learning outcomes of Grade VI students at State Primary School 04 Kota Solok. A quasi-experimental non-equivalent control group pretest–posttest design was used, involving an experimental class that learned with the e-module and a control class that received conventional instruction. Data were collected using pretest and posttest scores and analyzed through prerequisite tests (normality, homogeneity, and initial equivalence), independent-samples t-test, and normalized gain (N-gain). The results showed that the posttest scores of the experimental group were significantly higher than those of the control group ($p < 0.05$). The experimental class achieved an N-gain of 0.68, categorized as moderate and close to the upper limit of the medium range, while the control class obtained an N-gain of 0.29, classified as low. These findings indicate that the e-module substantially improves students' science learning outcomes and supports more effective technology-enhanced IPAS learning in primary schools.

Keywords: E-modules; Elementary education; Learning outcomes; Quasi-experimental study; Science learning

Introduction

The rapid growth of digital technology in the era of Industry 4.0 and human-centred ideas such as Society 5.0 brings both challenges and opportunities for schools. Today, schools are expected to build twenty-first century skills such as critical thinking, collaboration and innovation, while also dealing with learning loss and low basic achievement (Dewanti et al., 2025; Solikah et al., 2024). Technology becomes important in this situation because it can make science learning more interactive and more visual. The use of information and communication technology has changed teaching practices and helped create more engaging and effective learning environments. The use of social media for learning can also support collaboration and increase student participation, which are key for developing twenty-first century skills (Sirisakpanich & Suthasinobol, 2024). At the same time, traditional tests are no longer enough to measure the full range of skills that students need. Newer assessment approaches are being designed to match technological change and national agendas such as Saudi Vision 2030 (Fraidan, 2024). There is also growing awareness that learning assessments must reflect both twenty-first century skills and local wisdom in science education, especially for prospective teachers (Dewanti et al., 2025).

Because of these changes, teacher preparation and curriculum improvement become very important. Teachers who have strong twenty-first century skills can guide students more effectively and create classrooms that really support the growth of these skills. Curricula that focus on competencies have been shown to improve learning results (Chieng & Tan, 2021). Future assessment systems are also expected to measure a wider set of abilities, so schools need new ways to evaluate students in a more complete and balanced manner (Kyllonen et al., 2024). After the COVID-19 pandemic, many

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educators have turned to approaches such as Project-Based Learning to help students catch up. Research shows that this approach can improve students' abilities in mathematics, language and science, as well as their collaboration and critical thinking, especially when projects use technology as part of the learning process (Arrieta-Cohen et al., 2024).

Critical thinking is an essential competency for dealing with complex information and solving unfamiliar problems, and involves the ability to evaluate, analyze, infer, and reason in a systematic way (Mlambo et al., 2020). However, international assessments such as PISA show that many Indonesian students still struggle with higher order reasoning tasks in science, which suggests that conventional teaching has not yet succeeded in developing these skills (Nuangchalerm et al., 2022). In response, the Indonesian government introduced the Merdeka Curriculum, which emphasizes competency development, learning recovery, and flexible use of digital resources, giving teachers more autonomy to design context relevant learning (Rasmitadila et al., 2025). The curriculum is designed to support twenty first century skills such as critical thinking, creativity, and digital literacy through student centred and project based learning (Langoday et al., 2024). Yet research on digital integration in primary science education indicates that, especially at the upper elementary level, implementation is still uneven. Teachers generally have positive attitudes toward digital resources, but actual use is often limited by lack of training, unequal access to materials, and varying levels of digital competence (Althubyani, 2024; Muhaimin et al., 2020). Teacher professionalism and well designed professional development are therefore crucial for building confidence and skill in using digital tools (Rasmitadila et al., 2025).

At the same time, empirical models and concrete classroom examples for using digital teaching materials in primary science remain scarce. Although electronic learning can enrich instruction, there is still a need for studies that offer clear frameworks for how technology should be implemented to support curriculum goals and critical thinking development (Kazempour & Amirshokoohi, 2020). Continuous professional development and collaborative practices such as peer learning, mentoring, and sharing successful case studies are needed to help teachers interpret the Merdeka Curriculum in practical ways and to integrate technology more effectively (Rasmitadila et al., 2025). Addressing the challenges in students critical thinking therefore requires aligning the vision of the Merdeka Curriculum with concrete teaching strategies that use digital resources in purposeful ways, supported by strong evidence based models and sustained professional learning so that teachers can guide students toward better problem solving and reasoning skills

E-modules are emerging as important digital learning resources in Indonesian schools, especially within the Merdeka Curriculum, because they allow difficult science concepts to be presented through multimedia, interactive tasks, and self-paced activities so teachers can better respond to diverse learning needs (Endaryati et al., 2021; Nurissamawati et al., 2024). A growing body of research shows that such e-modules can improve higher-order outcomes: studies report gains in critical thinking, collaboration, environmental attitudes, scientific literacy, and conceptual understanding when e-modules are designed contextually, based on local wisdom, or oriented to problem-based and inquiry-based learning (Indrasari & Baihaqi, 2023; Nadia et al., 2024; Pudyastuti et al., 2024; Sanders & Scanlon, 2021; Wulandari & Supiah, 2023; Yani et al., 2023; Yersi et al., 2025). Together, these findings strengthen the argument that well-designed PBL- and inquiry-oriented e-modules can systematically foster students' higher-order thinking and collaboration across different science topics and educational levels.

When e-modules are designed with problem based learning and inquiry based learning, they can support the growth of students critical thinking skills. Several studies report that e-modules built on these approaches improve critical thinking outcomes (Akmala, 2025; Rahayu et al., 2022; Triwahyuningtyas et al., 2022). PBL based e-modules, for example, have been shown to help students practise analysis and reasoning in line with the goals of the Merdeka Curriculum (Putri & Dwikoranto, 2022). These e-modules usually combine text, images, video and interactive questions, so they not only make the content more engaging but also guide students to think more deeply about what they learn (Rahayu et al., 2022).

Even so, there is still a clear gap in research on e-modules for upper elementary students under the Merdeka Curriculum. Much of the existing work focuses on secondary or higher education, while quasi experimental studies on Grade VI Integrated Science and Social Studies (IPAS) are still rare (Setiadi et al., 2025). Scholars argue that more systematic studies are needed to show how e-modules can be developed and used to meet the specific competencies in the Merdeka Curriculum and to support critical thinking in Grade VI science (Nurissamawati et al., 2024; Siswanto et al., 2025). Future research therefore needs to provide concrete models and classroom based evidence on e-module implementation at this level. With stronger empirical support and contextually designed e-modules, teachers will be better equipped to use digital resources to build students twenty first century skills in primary science education.

This study addresses that gap by developing and testing the "Exosistem" e-module specifically for Grade VI IPAS at State Primary School 04 Kota Solok within the Merdeka Curriculum framework. The novelty of this research lies in its focus on: (1) a curriculum-aligned e-module targeting concrete ecosystem concepts at the critical transition stage from primary to secondary school; and (2) quasi-experimental evidence on its impact on students' science learning outcomes compared with conventional instruction. By providing empirical data on learning gains and practical insights into classroom implementation, this study is important for informing teachers, curriculum developers and policymakers about how e-modules can be used to strengthen science learning quality and support the development of essential twenty-first century competencies in Indonesian elementary education.

Method

This study used a quantitative approach with a quasi-experimental, non-equivalent pretest-posttest control group design to evaluate the effectiveness of E-modules in improving student learning outcomes. This design is appropriate for comparing an experimental and a control group in authentic classroom settings where random assignment of students is not feasible (Febriyanto & Yanto, 2019). The design can be summarized by Figure 1.

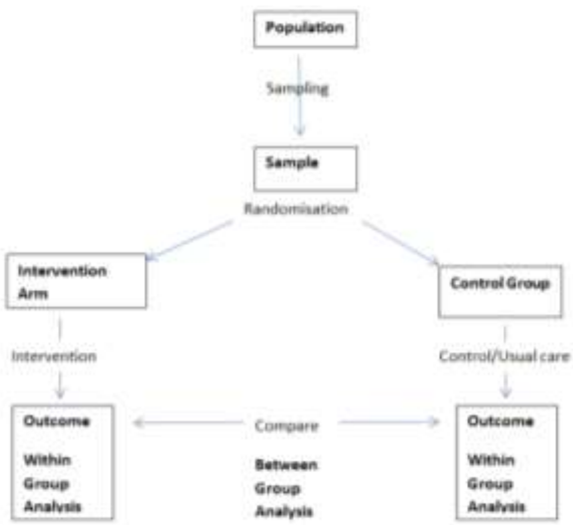

Figure 1. Flow Diagram of Quasi-Experimental

Table 1. Non-equivalent Pretest-Posttest Control Group Design

Group	Pretest	Treatment	Posttest
Experimental	O1	X	O2
Control	O1	–	O2

O1 denotes the pretest, O2 denotes the posttest, and X denotes the treatment using E-modules.

Participants and Sampling

The population of this study consisted of Grade VI students at State Primary School 04 Kota Solok. The sample was selected using purposive sampling based on considerations such as similarity of curriculum, school environment, and accessibility for research. Two intact Grade VI classes that met these criteria were chosen. One class was assigned as the experimental group (20 students) and the other as the control group (20 students). The experimental group received instruction using E-modules, whereas the control group followed conventional learning methods.

Because intact classes were used and students were not randomly assigned to conditions, the study is classified as a quasi-experiment with non-equivalent groups. This situation creates potential threats to internal validity, since pre-existing differences between groups may remain beyond what is captured by the pretest. To reduce these threats, both groups were drawn from the same school, followed the same curriculum, and received a pretest so that initial achievement levels could be compared before the treatment.

Procedure

The research procedure comprised several stages. First, the researcher identified the learning objectives and constructed a learning outcome test aligned with the curriculum and the indicators for the topic under study. Second, the test instrument was submitted for expert review. Two subject-matter experts and one educational evaluation expert examined the items for content relevance, clarity, and alignment with test construction principles. Reliability analysis was then conducted to ensure that the instrument consistently measured student learning outcomes.

After the instrument had been validated and found reliable, it was administered as a pretest (O1) to both the experimental and control groups to measure students' initial learning outcomes. The treatment phase followed. The experimental group received instruction using the developed E-modules, while the control group received conventional instruction without E-modules. Both groups studied the same topic within a comparable time frame and under similar classroom conditions. At the end of the intervention, the same test was administered as a posttest (O2) to both groups in order to measure changes in learning outcomes.

Instrument

Student learning outcomes were measured using a learning outcome test that had undergone expert validation and reliability testing. The test items were constructed to represent the targeted competencies and were administered under standardized conditions during both the pretest and posttest sessions. The use of a validated and reliable test was intended to increase the accuracy and consistency of the data collected.

Data Analysis

Data analysis was carried out in two main stages. First, independent samples t-tests were conducted to compare the learning outcomes of the experimental and control groups. These analyses examined whether the mean posttest scores, and where relevant the gain scores, differed significantly between groups, thereby providing evidence of the impact of the E-module intervention.

Second, normalized gain (N-Gain) was calculated to measure the effectiveness of the E-modules in improving student learning outcomes. N-Gain for each student was computed using the Formula 1.

$$\text{N-Gain} = \frac{\text{Posttest Score} - \text{Pretest Score}}{\text{Ideal Score} - \text{Pretest Score}} \quad (1)$$

This formula provides a proportional measure of learning improvement that takes into account students' initial scores and the maximum possible score (Fakhrurrazi et al., 2019).

The interpretation of N-Gain in this study follows the percentage-based categories proposed by Endaryati et al. (2021), which offer a more detailed distinction within the medium to high improvement range. The categories are shown in Table 2.

Table 2. Interpretation of N-Gain Effectiveness (Sari & Atmojo, 2021)

Percentage (N-Gain)	Interpretation
< 40%	Not effective
40% – 55%	Less effective
56% – 75%	Moderately effective
> 75%	Effective

Many studies use Hake's (1998) classification with a cut-off of 70 percent for high effectiveness. However, this study adopts the more fine-grained categorization by Sari & Atmojo (2021), which sets a slightly higher threshold for the effective category (> 75 percent), in order to apply a stricter criterion and to provide clearer differentiation between moderate and high levels of learning improvement.

Result and Discussion

Assumption Tests

Before testing the main hypothesis, prerequisite tests were conducted, namely normality, homogeneity, and initial ability equivalence tests. These tests ensured that the data met the assumptions required for parametric analysis using the independent samples t-test (Lubis et al., 2020).

Normality Test

The normality test was conducted at a significance level of 0.05. Data are considered normally distributed if the p-value is greater than 0.05 (Usmadi, 2020). The results of the normality test for the pretest and posttest scores in both groups are presented in Table 3.

Table 3. Normality test results

Class	Test	Statistic	p-value	Interpretation
Experimental	Pretest	0.200	0.200	Normal
Experimental	Posttest	0.080	0.080	Normal
Control	Pretest	0.240	0.240	Normal
Control	Posttest	0.440	0.440	Normal

All p-values for both pretest and posttest in the experimental and control classes are above 0.05, indicating that the score distributions do not deviate significantly from normality. Thus, the normality assumption for further parametric analysis is satisfied.

Homogeneity Test

The homogeneity test was conducted to determine whether the variances of the posttest scores in the experimental and control groups were equal. Homogeneous variance is required for the independent samples t-test to be valid (Sianturi, 2022). The result is shown in Table 4.

Table 4. Homogeneity test result

Variable	Significance	Interpretation
Posttest scores	0.51	Homogeneous

The significance value of 0.51 is greater than 0.05, indicating that the variances of the two groups can be considered homogeneous. Therefore, the homogeneity assumption is fulfilled.

Initial Ability Equivalence Test

An equivalence test on the pretest scores was carried out to ensure that the experimental and control groups had comparable initial abilities before the treatment (Ruhama & Erwin, 2021). The result is summarised in Table 5.

Table 5. Pretest equivalence test result

Variable	Significance	Interpretation
Pretest scores	0.78	Equivalent

The p-value of 0.78 is much higher than 0.05, indicating no significant difference in initial ability between the two groups. This result supports the fairness of the comparison and strengthens the internal validity of the study, because subsequent differences in posttest scores are more likely to be caused by the treatment rather than by pre-existing differences.

Hypothesis Testing

After all assumptions were met, the main hypothesis was tested using an independent samples t-test on the posttest scores. This analysis examined whether there was a significant difference in learning outcomes between students who used the E-module and those who followed conventional instruction. The result is presented in Table 6.

Table 6. Independent samples t-test result for posttest scores

Variable	Significance	Interpretation
Posttest scores	0.000	Significantly different

The significance value of 0.000 is smaller than 0.05, which indicates a statistically significant difference in posttest scores between the experimental and control groups. This finding supports the research hypothesis that the use of E-modules has a significant effect on improving science learning outcomes.

The result is consistent with previous studies that reported higher achievement when interactive digital materials and structured E-modules are integrated into science instruction at the primary level, since these media can provide clearer explanations, multimodal representations, and more opportunities for students to revisit and practice key concepts.

Effectiveness Based on N-Gain

To further evaluate the effectiveness of the intervention, normalized gain (N-Gain) was calculated for both classes. N-Gain provides a proportional measure of the improvement in learning outcomes by considering students' initial scores and the maximum possible score. The mean N-Gain values and their interpretations are shown in Table 7.

Table 7. N-Gain effectiveness results

Class	Mean N-Gain	Percentage %	Interpretation
Experimental	0.68	68	Moderately effective
Control	0.29	29	Not effective

The experimental class achieved an N-Gain of 0.68 or 68 percent. Based on the percentage-based classification proposed by Endaryati et al. (2021), this value falls into the "moderately effective" category. Although formally labelled moderate, the value of 0.68 is close to the upper limit of this category, indicating a substantial improvement in students' understanding.

In contrast, the control class obtained an N-Gain of 0.29 or 29 percent, which is categorised as "not effective". This result suggests that conventional teaching in this context was less successful in improving students' conceptual understanding compared to the E-module based instruction.

These findings are in line with studies that show interactive E-modules can support higher conceptual gains than traditional teacher-centred methods by offering structured content, feedback, and visualisation of abstract concepts.

It is important to note that N-Gain measures cognitive gains in terms of test scores, not student engagement directly. While low gains may be associated with lower engagement, N-Gain itself should be interpreted cautiously and not equated with motivation or behavioural participation. In this study, the contrast between N-Gain values indicates that learning with E-modules was more effective in improving understanding, but any claims about engagement must be supported by observational or questionnaire data.

Interpretation in Terms of Cognitive Development

From the perspective of cognitive development, sixth grade students are typically in the late concrete operational stage and are beginning to enter the formal operational stage, around the age of 11 to 12 years. At this transitional stage, students start to develop the ability to think more abstractly, reason hypothetically, and connect concepts across different contexts.

The E-module used in this study provided structured explanations, visual representations, and guided activities that helped to link concrete examples with more abstract scientific ideas. The moderate yet substantial N-Gain of 0.68 in the experimental class suggests that the E-module supported students in reorganising and deepening their understanding, which is consistent with Piagetian views that learning tools should facilitate active exploration and the gradual shift from concrete manipulation to symbolic and abstract reasoning.

Previous research has also shown that digital modules and interactive media can be effective in bridging concrete and abstract thinking by offering simulations, animations, and interactive tasks that help students visualise processes that cannot be directly observed. The present findings strengthen this evidence by showing that, when applied in a real classroom setting with Grade VI students, E-modules can produce significantly higher learning gains compared to conventional methods.

Discussion

The research findings demonstrate that the use of e-modules in Natural and Social Sciences (IPAS) learning effectively enhances student learning outcomes. These findings can be explained through several significantly interrelated aspects. First, e-modules provide an interactive learning method that supports independent learning. Through digital platforms, students can learn at their own pace, review materials they haven't understood, and interact with digital content. This aligns with the characteristics of Grade VI students who are in the concrete operational stage, where they require approaches that allow exploration and independent understanding (Prilliza et al., 2020; Tita Kartika et al., 2020). With easy accessibility through smartphones or laptops, students can learn anytime and anywhere, providing flexibility that cannot be achieved through conventional teaching methods.

Figure 2. E-Module Cover Design

The "Exosistem" e-module is designed to present innovation in digital learning that is easily accessible. The presented material not only contains information but also engages students through interactive elements such as barcode scanning and links that facilitate transitions to learning materials. These advantages facilitate better understanding and reduce students' anxiety about falling behind in lessons, thereby encouraging the achievement of more optimal learning outcomes (Habellia & Suyanta, 2021).

Second, the presence of multimedia elements in e-modules, such as images, animations, and interactive simulations, plays a significant role in helping students understand abstract concepts in IPAS. For example, concepts of photosynthesis processes and ecosystem interactions are presented in visual and engaging ways, helping students form a better understanding of complex materials. Research shows that teaching materials using visual elements enhance students' conceptual understanding (Asriani et al., 2023; Setiawan et al., 2022).

Figure 3. E-Module Content

The "Exosistem" e-module is also structured with systematic material presentation that begins with basic explanations of ecosystem components and continues with various forms of biotic and abiotic interactions. The presentation, consisting of biotic components such as plants, animals, and humans, as well as abiotic components, enables students to deeply understand ecosystem dynamics. To strengthen understanding, this e-module is equipped with real examples and additional explanatory videos that students can easily access, making the delivered material more engaging and easily digestible (Nurhayati Sholihah, 2025).

Figure 4. Student Worksheet

Third, the N-Gain test results showing a value of 68% in the "Moderately Effective" category indicate that the design of learning activities in the e-module significantly contributes to improving student learning outcomes. This e-module not only presents material but also complements it with activities that stimulate active student engagement. With the presence of worksheets, interactive images, and analysis activities, students not only receive information passively but are expected to construct their own understanding (Pebrianti et al., 2023). This contrasts sharply with the control class using conventional methods, which only recorded an N-Gain of 29%, indicating lower student engagement in learning (Purnamasari et al., 2021).

Considering the various aspects above, it is clear that the use of e-modules in IPAS learning has a significant impact on improving student learning outcomes, training critical thinking skills, and creating a broader space for creativity in the teaching-learning process. The integration of technology through e-modules not only makes learning more engaging but also facilitates the development of essential 21st-century skills that students need to face future challenges.

Conclusion

This study shows that the use of E-modules in science learning for sixth grade students has a significant and practically strong impact on learning outcomes. The independent samples t-test indicates a statistically significant difference in posttest scores between the experimental class using E-modules and the control class using conventional methods. The experimental class achieved an N-Gain of 0.68, which, although categorised as moderately effective in the adopted classification, represents a substantial improvement that is very close to the high-effect threshold. In contrast, the control class obtained an N-Gain of only 0.29, categorised as not effective. This large gap between groups demonstrates that the E-module based intervention is clearly more effective than conventional instruction in improving students' conceptual understanding of science. In the context of primary education, these results confirm that the developed E-module is a feasible and promising learning innovation that can be implemented to enhance science learning outcomes in similar classroom settings.

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The authors declare no conflict of interest.

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