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Natural Science Mini-Project Practicum E-Module to Enhance Higher-Order Thinking, Science Process Skills, and Scientific Attitudes

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Abstract

Science learning in schools still rarely uses natural science mini-project practicums packaged in the form of e-Modules. This study aims to 1) develop a Natural Science Mini-Project Practicum E-Module that is suitable for improving critical thinking skills (HOTS), science process skills (SPS), and scientific attitudes (SA). 2) determine the effect of the E-Module on the dependent variable. This study uses a 4D model with a trial involving 115 students (37 students in a limited trial and 78 students in a large-scale trial) at SMP Negeri 17 Mataram. The instruments consisted of multiple-choice questions, observation sheets, and questionnaires. Data were analyzed using the percentage of validity and practicality, N-Gain, prerequisite tests, and hypothesis testing. The results showed that the E-Module was valid (3.69), practical (3.37), and effective in improving HOTS (70.87), SPS (72.27), and SA (70.54) with high criteria. The results of the HOTS (0.000), SPS (0.001), and SA (0.003) hypothesis tests obtained significance values below 0.05. Thus, this e-module is feasible and effective for science learning.

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INTRODUCTION

21st Century Education demands student for control think critically, creatively, collaborate, and communicate (Asrizal et al., 2022). Education must prepare students to fulfil demands, in particular through the development of high-order thinking skills (HOTS), science process skills (SPS), and scientific attitudes (SA) (Osborne et al., 2003). 21st century education emphasizes organization education, namely, strengthening character and attitude, scientific, ICT literacy, spiritual values, and 4C skills (Afandi et al., 2019).

Based on findings from studies latest show ability student weak in integrating science with problem-solving in daily life (Sari et al., 2024). (Agnafia, 2019; Ramdani et al., 2021; Sarwanto et al., 2021) stated that the ability of weak students, especially in the dimension of "explaining ideas and presenting". A student expressing ideas is also problematic (Suherman & Vidákovich, 2024). Students still have low ability in analysis and decision-making (Salimi et al., 2024). These conditions influence the involvement and readiness student for face future demands (Blegur et al., 2024).

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Lack of student involvement in Study contribute to the SPS of students who are still not yet adequate (Darmaji et al., 2022). Apart from that said, SA students like openness to evidence, desire know, and perseverance are still low (Darmaji et al., 2022; Hilala et al., 2023). SA students do not develop optimally (Suryawati & Osman, 2017). The gap is what triggers the main difficulties.

Difficulty caused by learning more memorization-oriented drafts than understanding and apply it in real-life contexts (Novalia et al., 2025; Susilawati et al., 2024). Learning is still providing minimal experience exploratory (Ramdani et al., 2021). Learning limit development of students' SPS, making it difficult for them to recognize science through a systematic investigation process (Gizaw & Sota, 2023). These skills are important For develop understanding and strengthening students' science literacy (Azari et al., 2023). Teachers are also limited in developing learning (Bagiani & Agustini, 2025). Management time, environment learning, and management plan achievement learning make things difficult implementation learning (Heong et al., 2011). Lack of adequate learning and opportunities for students to solve problems in an independent manner (Rakesh et al., 2024). Activities such as practicals are often nature procedural and not flexible (Kelley & Knowles, 2016).

To overcome the matter mentioned, learning direct learning and learning project used to support conceptual learning (Mills, 2016). The combination between learning direct learning with learning models and tools learning interactive learning that focuses on HOTS, SPS, and SA. The HOTS concept is rooted in the cognitive level high that is analysis, evaluation, and creation (Liu et al., 2024). SPS is a set of skills used in observation, grouping or classifying, interpreting data, predicting, asking questions, making hypotheses, planning experiments/research, using tools/materials, and communicating through activity investigation or experiments. SPS consists of basic SPS and integrated SPS (Santos & David, 2017). SPS emphasizes How student learn science through interaction with the environment (Piaget, 1970; Vygotsky, 1978). SA is the ability think, act, and behave as a feeling of desire, know the phenomenon, honesty in data reporting, transparency towards new ideas, respect for evidence and facts, thinking critically and objectively, as well as awareness of limitations in knowledge (Bloom, 1971).

Model and device innovation is expected, and learning is very much needed to improve HOTS, SPS, and SA. One of the innovations ever done through an activity experiment laboratory (Poo et al., 2023). Practicum allows student to strengthen their understanding of theory in real-world situations, even practical work need simplified to still reach the desired goal, which is essential solutions (Heradio et al., 2016). When the activity is practical work supported with a module practicum, then the ability to analyze and reason scientifically can be increased (Nurhasanah et al., 2023). Modules are available in various formats, including print and electronic (Netriwati et al., 2023). Utilization of technology in aligned learning with the demands learning 21st century, then matters the need to optimize (Wati & Syafriani, 2023). One of the form utilization technology is through the existence of e-modules practicum.

E-module has good practicum own characteristic features, practical, simple, and economical time, and still effective in reach objective of appropriate learning with the level of education of its students (Herditiya et al., 2023). The digital format offer mechanism Study independent, multimedia integration that is simultaneous strengthen mastery of concepts and skills (Kurniansyah et al., 2022). An e-module is a source of powerful education in the form of photos, videos, animations, and simulations (Aulia & Yuliani, 2023). However, for the following development technology, the world of education must adapt (Netriwati et al., 2023). Several studies show the development of e-learning products (Shieh & Hsieh, 2021). Therefore, the creation of e-modules becomes right. Many e-module developments for measuring critical and creative (Desnita et al., 2022), e-module to enable critical (Makhrus et al., 2025), and e-module for measuring trust, self, motivation, and results of study students (Delita et al., 2022). However, the Natural Science Mini-Project Practicum E-Module for measuring students' HOTS, SPS, and SA has not developed yet. Approach known practice as mini project practicum, has supported by research previously (Hakim et al., 2016).

Novelty of this study lies in the design of his/her practice, which empowers student for play a role in contextually solving scientific problems, as in the following figure 1.

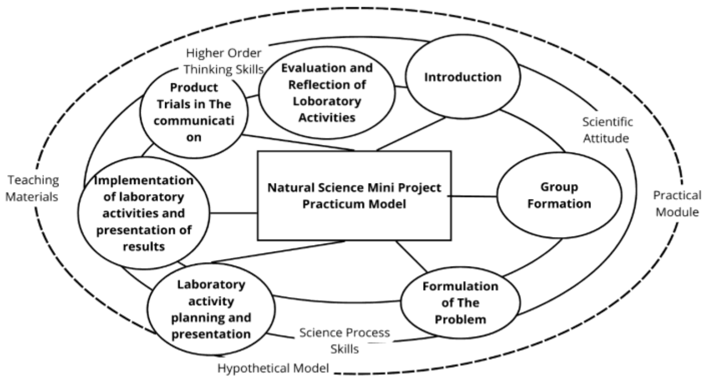

Figure 1: Framework Conceptual Model of Natural Science Mini Project Practical

Based on the Figure 1 framework conceptual model, this describes the mini project natural science practicum model, implemented through 7 stages and facilitated with each indicator of HOTS, SPS, and SA. Research has previously which has been done by experts, not yet developing e-modules practical work with 7 stages and measuring HOTS, SPS, and SA. This can answer the challenge in science education and contribute significantly to forming the next generation of creative individuals. Besides that, through this model student become more innovative and adaptive to changing times.

This study aims to create easy e-modules understandable and interesting for reading, as well as help students learn independently, and the learning process is carried out more simply. Students can utilise the environment around them and support the achievement of learning. This study aims to describe the validity and practicality of the e-module. This study also evaluates the effectiveness of the e-module in improving HOTS, SPS, and SA.

METHOD

This study is Research and Development (R&D) with the 4D model (Thiagarajan, 1947). This Research consists of four stages: Definition, Design, Development, and Dissemination. This model was chosen to produce e-modules, science mini-projects, and natural. The development carried out is related to a mini-project science practicum model, inspired by a learning project. Form an approach 4D procedural to solve the problem presented in Figure 2.

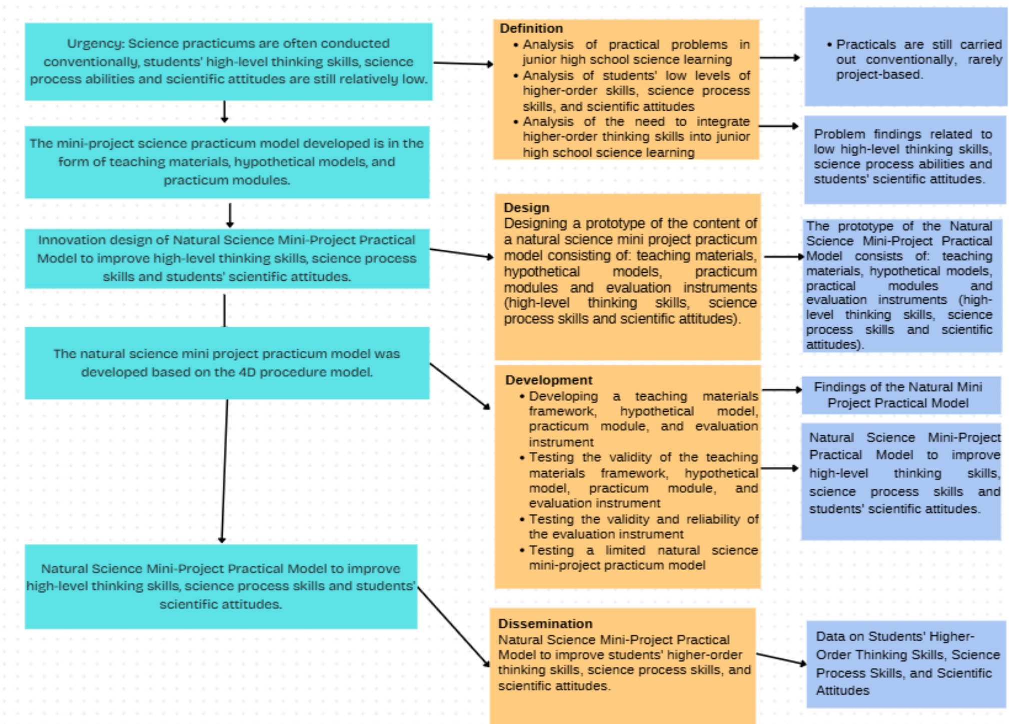

Figure 2: Approach Procedural Solution of the Problem

Approach the problem procedurally and conceptually, this study served in Figure 3.

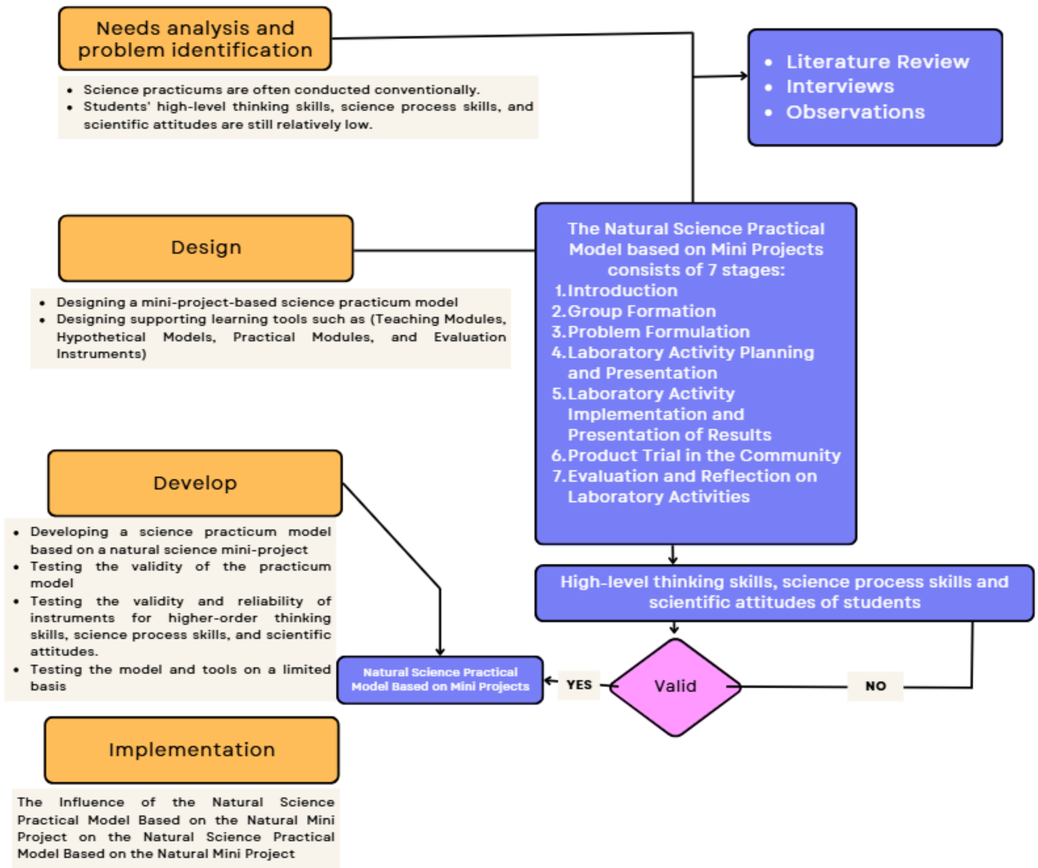

Figure 3: Approach Solution Problem Procedural and Conceptual

Products produced, then assessed validity and practicality, continued with the trial product to evaluate its effectiveness in improving HOTS, SPS, and SA. At the stage end, done. The thing that is disseminated is related to e-modules mini project science practicum natural through the national reputable Sinta and reputable international journals Scopus, and not reputable. In addition, dissemination through Zoom meeting facilities for science teachers in the NTB province. Figure 4 illustrates the stages of this study.

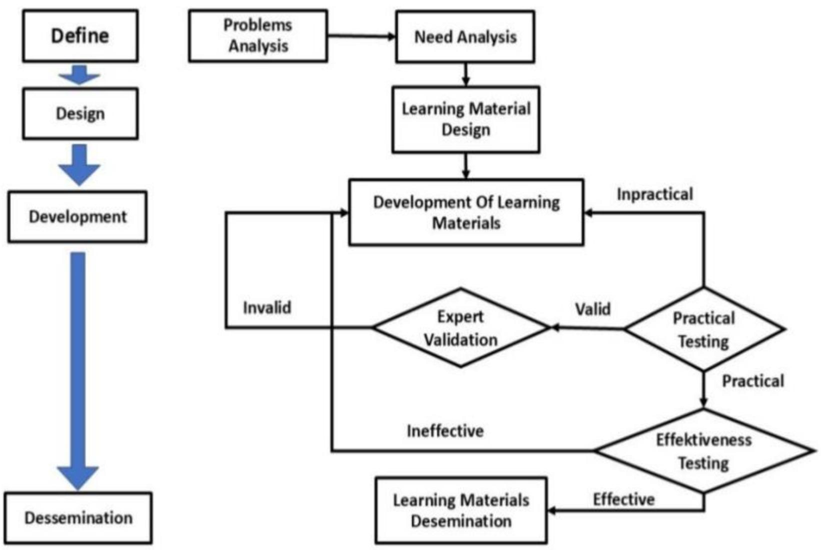

Figure 4. Research Flow of the Natural Science Mini-Project Practicum E-Module (modified from Thiagarajan et al. (1974))

This study was held at Mataram State Middle School 17, involving 115 students, consisting of 37 people in class VII B (trial scale small), 39 people in class VII A, and 39 people in class VII C (trial scale area), one teaching teacher, and three teachers as observers. Trial scale-wide implemented in class VIIA as class experiments and class VIIC as class control. Products developed are E-module Mini Science Lab-Natural Project and Equipment supporters, others, namely: flow objective learning (ATP), teaching modules /RPP, books for students' science reading, HOTS instruments, SPS instruments, and SA instruments. The sub-focus studied is: testing the validity, practicality, and effectiveness of e-modules and devices to support others for improving HOTS, SPS, and SA.

Analysis of the E-module validity and supporting device of the mini model project natural science practicum, analyzed the use technique, and the descriptive qualitative technique (Pamungkas et al., 2022). The number of validators performing evaluation e-module and device validation supporters is as many as 6 people. The validator is an expert in the field of science. Each validator does an evaluation related to validated documents, creates notes related to improvements and suggestions for content, construction, and language writing on validated documents. Score validation results evaluation validator grouped into 4 category like served in Table 1. Final score results validation for every aspect is determined based on the average score of the validator. Follow-up results validation is do a revision document in accordance with information/suggestions/revisions as well as directions given by the validator.

Table 1. Level Validity Model and Device Learning Criteria

Interval Score	Criteria	Information
3.25 < P ≤ 4.00	Very Valid	Can be used without revision
2.5 < P ≤ 3.25	Valid	Can be used with slight revision
1.75 < P ≤ 2.5	Quite Valid	Can be used with Lots revision
1.0 < P ≤ 1.75	Less Valid	Can be used and still need consultation

Calculation reliability results e-module and device validation supporters based on the interobserver agreement obtained from the analysis statistics *percentage of agreement* (Borich, 1988).

$$Percentage\ of\ agreement = \left[1 - \frac{A - B}{A + B}\right] x100\%$$

A: Frequency aspect activity Which observed by the observer, who provides high frequency
B: Frequency aspect activity Which observed by the observer, who provides low frequency

Assessment results e-module and device validation mini project science practicum learning model natural, it is said to be reliable If have percentage ≥ 75% (Borich, 1988). The main from interobserver agreement is to ensure that the data collected from observation is reliable and does not depend on bias or subjectivity from the observer's individuality. Practicality of the Natural Science Mini-Project Practicum E-Module and device supporters, which is implemented and evaluated use the criteria outlined in Table 2 to determine the level of practicality. The analysis process questionnaire teacher and student responses started from the process of tabulating the results of the data collected from students. Tabulated data is converted to form a percentage with the formula:

$$P = \frac{\sum score\ per\ item}{maximum\ score}\ x\ 100$$

Percentage each results calculation then categorized in Table 2.

Table 2. Result Practicality Criteria

Interval	Criteria
0% – 20%	Very impractical
21% - 40%	Less practical
41% - 60%	Quite practical
61% - 80%	Practical
81% - 100%	Very practical

The size increase in HOTS, SPS, and SA that occurred can be counted with the use of the normalized gain formula (N-gain) with formula (Hake, 1998):

$$g = \frac{S_{Post} - S_{Pre}}{S_{max} - S_{pre}}$$

Information:
⟨ *g* ⟩ : Normalized gain value
Post : Mark *posttest*
Spread : *Mark pretest*
Smax : Mark maximum

Normalized N-Gain interpreted for the effectiveness of the Natural Science Mini-Project Practicum E-Module. To improve HOTS, SPS, and SA with criteria N-gain is shown previously in Table 3.

Table 3. N-Gain Criteria

Score N-Gain	Criteria
N-gain ≥ 0.7	High
0.3 ≤ N-gain < 0.7	Currently
N-gain < 0.3	Low

Apart from that determine criteria N-Gain, Achievement value N-Gain Index, if converted to a function percentage, allows an average percentage of N-Gain aligned with criteria effectiveness. Furthermore, the average N-Gain achievement, when associated with level effectiveness, is presented in the table previously in Table 4 Conversion. This gives interpretation results more learning clear, so that makes it easier to classify the effectiveness of the applied model. With compare N-Gain value obtained with the gauge measure that has been set, the level of improvement for learning students can be determined more accurately.

Table 4. Effectiveness Criteria

Average % N-Gain	Criteria
85.1% to 100%	Very Effective
70.1% to 85%	Effective
50.1% to 70%	Enough effective
0% to 50%	Less effective

In the following table 5 is a summary related to various types, methods, and instruments for data collection to get results validation, practicality, and effectiveness.

Table 5. Data Types, Data Collection Techniques, Instruments, and Data Analysis Techniques

Data type	Data collection technique	Instrument data collection	Data analysis techniques
Validity device	Questionnaire Validation Content, construction and language	Validation sheet	Descriptive
Ability Higher-Order Thinking	*Test (22 questions)*	HOTS Question Sheet	Analysis Question Items
Science Process Skills	*Test (10 questions)*	Dimensions Question Sheet Knowledge	Analysis Question Items
Attitude Scientific	Observation *Sheet* with 28 statements	SA assessment sheet	Descriptive
Implementation Learning	Observation Sheet	Assessment Sheet implementation learning	Descriptive

Effectiveness of the the Natural Science Mini-Project Practicum model can statistical tests were also carried out for inferential. Application of trial scale mini project natural practicum E-module and documented supports other stated effective if: (a) the student's N-Gain score for HOTS, SPS and SA are in category moderate (normalized gain ≈ 0.3–0.7); and (b) inferential test show significance at $p < 0.05$ (two-sided), conventional threshold for state significance statistics in study education experimental (Gligorea et al., 2023; Dewi & Kuswanto, 2023; Wasserstein & Lazar, 2016).

Draft classification of creature life and change form object become focus of materials used in the Natural Science Mini Project Lab. Utilization of Electronic Natural Science Mini Project Lab Modules and devices supports for topic classification creature life and change form object formulated into 6 (six) mini projects, namely: 1) Making a mini aquarium; 2) Naming the creatures life with Google Lens help; 3) Create extract dry from leaf plant medicine; 4) Making drink Healthy from leaf greetings; 5) Make chemical test solution in naturally; 6)Make simple water purification.

Ethics Approval and Consent to Participate

The researchers meticulously followed ethical protocols throughout the research process. They met with seventh-grade students and junior high school teachers from Mataram City who served as the sample for data collection. In the consent form, participants were informed of their right to withdraw from the study at any time. Participants were students who independently decided to participate. To protect privacy, identification numbers, not names, were used to secure the data, thus maintaining the anonymity and confidentiality of participants and their responses.

RESULTS AND DISCUSSION

The Mini Science Lab-Natural Project and Equipment supports other implementations, including the development of Electronic Modules, Learning Objective Flow, Teaching Modules /RPP, Student Science Reading Materials, HOTS Instruments, SPS Instruments, and SA Instruments, as well as Questionnaire Response Students (related to SPS and SA). E-module for Science Practical Mini-Natural Projects and devices supporters other used in learning, because it is very relevant with purposeful activities for improving HOTS, SPS, and SA. The e-module can be accessed through the link following: https://online.fliphtml5.com/rwbkrj/mqzm/.

E-Modules Validation and Instruments Supports

The validation process focuses on content, construction, and language, all components. Six experts validate e-modules and instrument support. The six validators implemented the same validation. Table 6 presents the results evaluation of validity.

Table 6. Validity Test Results Device E-Module Learning of Science Mini Project Practicals and Equipment Supporters Other

No	Validated Documents	Validation	Validation Score	Criteria Validation	PA Score	Criteria Reliability
1	E-Module	Contents	3.38	Very Valid	85.71	Reliable
		Construction	3.50	Very Valid	85.71	Reliable
		Language	3.67	Very Valid	85.71	Reliable
2	ATP	Contents	3.38	Very Valid	85.71	Reliable
		Construction	3.56	Very Valid	85.71	Reliable
		Language	3.67	Very Valid	85.71	Reliable
3	Teaching Module/Lesson Plan	Contents	3.50	Very Valid	85.71	Reliable
		Construction	3.42	Very Valid	85.71	Reliable
		Language	3.28	Very Valid	85.71	Reliable
4	Book Student Science Reading	Contents	3.29	Very Valid	85.71	Reliable
		Construction	3.28	Very Valid	85.71	Reliable
		Language	3.67	Very Valid	85.71	Reliable
5	HOTS Instrument	Contents	3.33	Very Valid	81.90	Reliable
		Construction	3.39	Very Valid	79.37	Reliable
		Language	3.63	Very Valid	85.71	Reliable
6	SPS Instrument	Contents	3.40	Very Valid	85.71	Reliable
		Construction	3.44	Very Valid	85.71	Reliable
		Language	3.58	Very Valid	85.71	Reliable
7	SA Instrument	Contents	3.50	Very Valid	85.71	Reliable
		Construction	3.50	Very Valid	85.71	Reliable
		Language	3.67	Very Valid	85.71	Reliable

Evaluation validity shows that all the learning is very valid and reliable. The validators concluded that e-modules and devices are supportive and worthy of use, but only need a little revision. Statement things to do revised by the validator and statement. Already revised/form improvements by researchers are presented in Table 7.

Table 7. Suggestions and Input from the Validator Expert to Draft 1 (Mini Project Science Practical Model, Natural and Device Supporters)

No.	Validator Suggestion	Repair
1	There are too many stages in the syntax of the practical model in the e-module (9 stages)	The syntax stages of the practical model have been adjusted to 7 stages in the e-module.
2	In the reading book, it is necessary to add reading material that is appropriate to the mini practical activities.	Improvements have been made with Adding material related to natural mini project practical activities
3	The practicum e-module still contains tools, materials and procedures	Improvements have been made by giving students space to think at a high level by mentioning the tools and materials needed and available at their respective homes and asking students to re-arrange the mini project procedures.
4	For the final evaluation of the practicum, students need to be encouraged to carry out routine mini project activities at their respective homes.	Has done repair with add further student assignments by carrying out mini project activities at their respective homes
5	Instructions for practical activities should be arranged more clearly so that they are easy for students to understand.	Has done repair with replace some instruction sentences in the practical module to make them easier to understand
6	It is necessary to pay attention to the	Improvements have been made regarding

No.	Validator Suggestion	Repair
	proportion of each indicator to ensure it fits the model. There are indicators of learning objective achievement that do not match the substance.	indicators of achievement of learning objectives.
7	Please note that meetings 1-2 seem to have insufficient time.	Has done repair by adjusting the time of each stage of implementation
8	There needs to be synchronization between teacher activities and student activities.	Improvements have been made according to suggestions and input for stage activity natural mini projects
9	For HOTS instruments, the knowledge dimension is so that the cognitive level of the questions is more in line with the substance of the material.	Has done repair in the form of improving the form of questions at the cognitive level of analysis, creation and evaluation
10	The scientific attitude instrument has fulfilled the criteria, but it is necessary to improve the statements for each scientific attitude indicator.	Improvements have been made with repair statement as suggested

After e-modules and devices were declared valid, a trial was conducted to evaluate their effectiveness in improving HOTS, SPS, and SA. The validators provide assessment and feedback to e-modules and device supporters based on the minor revision. E-module format and devices, his supporters validated especially from the aspect of content, with an objective to increase understanding of students, while ensuring e-module and device readiness. To implement practical and effective testing. Targeted clarification and improvement were done for perfect material and to ensure optimal effectiveness of e-modules in supporting learning students. Limitations revision shows that core content and design are already strong, placing material in an advantageous position for success. Implementation of the Science Mini-Project Practical e-Module. A comprehensive validation process will strengthen the belief in the potential of the module to give meaningful and sustainable improvement in science education.

Practicality of the Natural Science Mini-Project Practicum E-Module

E-module trial involving one model teacher and three observer teachers. Table 8 presents the results e-module assessment. Implementation of the Natural Science Mini-Project Practical e-Module achieved an average score of 88.10 with very practical criteria. Observation data show that its implementation is in harmony with the syntax of the practical model. These findings show that the e-module fulfills the criteria of practicality and reliability, which shows that it can be implemented in class effectively.

Table 8. Results of the Implementation Test of the Natural Science Mini Project Practical E-Module

Syntax	Score	Criteria	PA	Criteria
Introduction	61.11	Practical	80	Reliable
Orientation problem	77.78	Practical	80.00	Reliable
Arrangement Formation group	100.00	Very Practical	100.00	Reliable
Designing project proposals and presentations	100.00	Very Practical	100.00	Reliable
Implementation projects and presentations product	100.00	Very Practical	100.00	Reliable
Submit product to public school	77.78	Practical	80.00	Reliable
Evaluation	100.00	Very Practical	100.00	Reliable
Average	88.10	Very Practical	91.43	Reliable

Practical test based on implementation learning with the use of e-modules and mini-project natural science practicum models, then done analysis of practicality e-module implementation to HOTS, SPS, and SA achievements with results in succession, also 83.21%, 87.97%, and 82.67% with very practical criteria. Results of the practicality test analysis are presented in Table 9.

Table 9. Practicality Test Results of E-Modules to HOTS, SPS, and SA Achievements based on Student

Test Practicality	% Response	Criteria	PA	Criteria
HOTS	83.21	Very Practical	84.74	Reliable
SPS	87.95	Very Practical	83.76	Reliable
SA	82.67	Very Practical	81.32	Reliable

Validity and practicality test results E-Module Science Practical Mini-Natural Project are in line with the findings of several previous studies. This is in line with research conducted by Yusuf (2022) states that mini project practicum can increase critical thinking skills in critical students, and get a positive response from the implementer of the practicum.

HOTS Effectiveness

Simultaneously with practicality tests, effectiveness tests are also carried out. This test aims to evaluate the impact of the e-module for Natural Science Mini-Project Practicals on the thinking skill. Effectiveness is measured use N-Gain value, which is calculated from the score at the test start and the test end for students. N-Gain results for variables HOTS dependents are presented in Table 10.

Table 10. Results of the Effectiveness Test of the Natural Project Mini Science Practical E-Module on HOTS

Class	Initial Test	Final Test	Score N-Gain	N-Gain Score (%)	Criteria	Effectiveness
Experiment	55.48	87.18	0.71	70.87	High	Effective
Control	53.38	78.67	0.53	53.43	Currently	Enough Effective

If the N-Gain score achieved is > 0.7, then the effectiveness of e-modules towards HOTS in the class experiment criteria is higher than the class control. Achievement criteria high the due to increase results test start and test the end that experienced improvement. On the indicator questions about analyzing characteristic features of creature life with others, indicators question. This is the highest ability achieved by students. On the indicators question, analyze how change can influence diversity in various kingdoms, which is the lowest ability achieved by students.

SPS Effectiveness

Simultaneously with practicality tests, effectiveness tests are also carried out in a way. This test aims to evaluate the impact of the E-module for Science Practical Mini-Natural Projects on science process skills of students. Effectiveness is measured use N-Gain value, which is calculated from the score at the test start and the test end for students. N-Gain results for the SPS dependent variables are presented in Table 11.

Table 11. Results of the Effectiveness Test of the Natural Science Mini Project E-Practical Module on SPS

Class	Initial Test	Final Test	Score N-Gain	N-Gain Score (%)	Criteria	Effectiveness
Experiment	48.42	86.04	0.72	72.27	High	Effective
Control	47.75	85.59	0.52	52.12	Currently	Enough Effective

If the N-Gain score achieved is > 0.7, then the effectiveness of e-modules towards SPS in the class experiment criteria is higher compared to the class control. Achievement criteria have increased due to an increase in results at the start and the end that experienced improvement. On the indicator question observation by using as many indicators as well as indicator submission formulation problem related projects, which will be implemented based on the orientation problems that have been delivered, the indicators that have the highest achievements. On the indicator compile and deliver report results systematically, the indicator questions that have the lowest achievements.

SA Effectiveness

Simultaneously with practicality tests, effectiveness tests are also carried out in a way. This test aims to evaluate the impact of the E-module for Science Practical Mini-Natural Projects on attitude scientific students. Effectiveness is measured use N-Gain value, which is calculated from the score of the questionnaire and the questionnaire's end students. N-Gain results for variables SA dependents are presented in Table 12.

Table 12. Results of the Effectiveness Test of the Natural Science Mini Project E-Practical Module on SA

Class	Initial Test	Final Test	Score N-Gain	N-Gain Score (%)	Criteria	Effectiveness
Experiment	37.45	81.66	0.71	70.54	High	Effective
Control	43.75	82.14	0.68	67.93	Currently	Enough Effective

If the N-Gain score achieved is > 0.7, then the effectiveness of e-modules towards SA in the class experiment criteria is higher compared to the class control. Achievement criteria high due to increase results test start and test the end that experienced improvement. Indicator questionnaire filled out by students with the highest in the aspect attitude value, specifically attitude Respecting friends in the work group. The questionnaire indicator with the lowest score was the aspect of responsible attitude, especially regarding the attitude of completing tasks according to the agreed time.

Statistical Test Inferential E-Module, Effectiveness Mini Project, Natural Science Practicum

E-module mini project natural science practicum is based on understanding intuitions about concepts, meanings, and relationships. This Approach allows student understand science concepts through application, with more laboratories, simple and easily accessible, so that push greater understanding deep about principles involved. E-module push student to identify and explore concepts through thinking, which allows them to develop ideas and principles independently. Normality test done using the SPSS program, with the Kolmogorov-Smirnov test. The criteria for normality are: If Z_{count} >0.05 (α), then the null - hypothesis (H_0) is accepted. The results of this test are presented in Table 13-15.

Table 13. Results of the Normality Test of Pretest and Posttest Data on Ability: Higher-order Thinking (HOTS)

Group	Test	Test Statistics	Df	p-value	Decision
Experiment	Pretest	Kolmogorov-Smirnov	39	0.200*	Normal
	Posttest	Kolmogorov-Smirnov	39	0.157	Normal
Control	Pretest	Kolmogorov-Smirnov	39	0.200*	Normal
	Posttest	Kolmogorov-Smirnov	39	0.091	Normal

Information:
*) The p-value is rounded from the maximum available in the Table.
α = 0.05. Data is normally distributed if p-value > 0.05.

Table 14. Results of the Normality Test for Pretest and Posttest Data on Science Process Skills (SPS)

Group	Test	Test Statistics	Df	p-value	Decision
Experiment	Pretest	Kolmogorov-Smirnov	39	0.103	Normal
	Posttest	Kolmogorov-Smirnov	39	0.062	Normal
Control	Pretest	Kolmogorov-Smirnov	39	0.215	Normal
	Posttest	Kolmogorov-Smirnov	39	0.180	Normal

Information:
*) The p-value is rounded from the maximum available in the table.
α = 0.05. Data is normally distributed if **p-value > 0.05.**

Table 15. Results of the Normality Test for Scientific Attitude Scale Data (SA)

Group	Measurement Time	Test Statistics	Df	p-value	Decision
Experiment	Before E-Module	Kolmogorov-Smirnov	39	0.200*	Normal
	After E-Module	Kolmogorov-Smirnov	39	0.120	Normal
Control	Before E-Module	Kolmogorov-Smirnov	39	0.200*	Normal
	After E-Module	Kolmogorov-Smirnov	39	0.087	Normal

Information:
*) The p-value is rounded from the maximum available in the table.
α = 0.05. Data is normally distributed if p-value > 0.05.

Table 13-15 shows that HOTS, SPS, and SA data for every class show a level of significance of 0.05 (α). Based on normality test criteria, p. This shows that HOTS, SPS, and SA data are normally distributed. After that, the data is tested for its homogeneity using MANOVA. Criteria For determine homogeneity is level of Levene's test significance must exceed α (0.05). The results of the analysis are shown in Table 16.

Table 16. Results of the Homogeneity Test, Pretest, and Posttest Variance on HOTS, SPS, and SA

Variables	Test Types	Test Statistics	df1	df2	p-value	Decision
HOTS	Pretest	Levene's Test	39	39	0.427	Homogeneous
	Posttest	Levene's Test	39	39	0.218	Homogeneous
SPS	Pretest	Levene's Test	39	39	0.310	Homogeneous
	Posttest	Levene's Test	39	39	0.145	Homogeneous
SA	Pretest	Levene's Test	39	39	0.502	Homogeneous
	Posttest	Levene's Test	39	39	0.389	Homogeneous

Information:
- Statistics: Levene's Test is used to test similarities variance (homogeneity) between groups.
- Criteria: If p-value > 0.05, then the variance is stated as homogeneous. If the p-value ≤ 0.05, then the variance is not homogeneous.
- Gain Homogeneity Test: This test is important to ensure that the score gain between group experiments and controls also comes from the population with the same variance before an independent t-test was performed on the gain score (if using gain analysis). The p-value in the example is this all > 0.05, so assumptions homogeneity is fulfilled.

Based on Table 16, the results of the homogeneity test show mark significance of 0.05 (α value). This means that HOTS, SPS, and SA data of students in various class study distributed homogeneously. To test the influence of combination variables, the MANOVA statistical test was conducted. The criteria used for this test are as follows: if the mark probability (sig.) is less than α=0.05, then hypothesis H_0 is rejected; if (sig.) is more than α=0.05, then Hypothesis H_0 is accepted.

The results of the Univariate Significance Test (Test of Between-Subjects Effects) are shown in Table 17.

Table 17. Results of the Univariate Significance Test (Test of Between-Subjects Effects)

Source	Variables Bound	Amount Square Type III	df	Mean Square	F	Sig.
Corrected Model	HOTS	14520.500	1	14520.500	128,340	.000
	SPS	950,250	1	950,250	7,120	.001
	SA	650,800	1	650,800	4,950	.003
Intercept	HOTS	385200.500	1	385200.500	9.850E3	.000
	SPS	298500.200	1	298500.200	2.150E3	.000
	SA	185000.600	1	185000.600	1.450E3	.000
Class	HOTS	19850.600	1	19850.600	480,220	.000
	SPS	950,750	1	950,750	9,120	.004
	SA	620,900	1	620,900	5,280	.025
Error	HOTS	2401.633	74	41,407		
	SPS	7706.167	74	132,865		
	SA	6800.300	74	91,900		
Total	HOTS	421973.233	78			
	SPS	307107.367	78			
	SA	193072.600	78			
Corrected Total	HOTS	25568.983	77			
	SPS	8876.583	77			
	SA	6687.275	77			

Description:
a. R Squared =.906 (Adjusted R Squared =.904) b. R Squared =.132 (Adjusted R Squared =.117)
c. R Squared =.121 (Adjusted R Squared =.103)

The output results of the hypothesis test in Table 17, Test of Between-subject effects, consist of six rows. For the first row, namely the corrected model for known validity, the influence of e-mini project modules towards HOTS, SPS, and SA of students in class experiments and learning conventional in-class control. Second line, namely intercept for known mark changes to HOTS, SPS, and SA without influenced by the e-mini project modules naturally. While the third line class aims to know the influence of e-mini project modules, natural Good to activities and results study students, so that it is used in discussion, this is more on the next line three. Based on Table 17 shows that: a) The influence of the mini project e-module model is natural to the activity, Study student own level significance 0.000, where Sig. 0.000 < 0.05, p. This shows that there is a natural influence of HOTS on e-mini project modules. b) The influence of e-mini project modules is natural towards students' SPS own level significance 0.001, where Sig. 0.001 < 0.05, p. This shows that there is an influence of SPS on using e-mini project modules naturally. C) There is an influence on the use of e-mini project modules, natural towards student SA, with a mark significance of 0.000, where Sig. 0.000 < 0.05. MANOVA test results are presented in Table 18.

Table 18 MANOVA Test Results

Variables	Class	Mean	Standard Deviation	N
HOTS	Class Experiment	105.87	5,095	39
	Class Control	58.82	6,865	39
	Total	**85.47**	**21,643**	**78**

Variables	Class	Mean	Standard Deviation	N
SPS	Class Experiment	77.84	10,655	39
	Class Control	72.53	15,617	39
	Total	**78,324**	**15,423**	**78**
SA	Class Experiment	74.43	15,453	39
	Class Control	69.00	10,617	39
	Total	**76.56**	**16,534**	**78**

Based on Table 18, the results of the hypothesis test calculation show that there are HOTS, SPS, and SA students, namely, class experiment using e-mini project modules and class control using a learning model. Class experiment with 39 students has an average HOTS of 105.87, SPS of 77.84, and SA of 74.43, while the class control with 39 students has an average HOTS of 58.82, SPS of 72.53, and SA of 69.00. It can be concluded that classes that use e-mini project modules produce more scientific results than classes that use learning models conventional for HOTS, SPS, and SA students. 2) Significance Test Multivariate (Multivariate test) Multivariate significance test is used to measure the influence variables free (variable independent) against variables bound (variable bound) in a simultaneous or at the same time. As provision 0.05 (5%) with H_1 and H_0 as follows: Hypothesis 3 was tested with variables bound activities and results study H_0: There is a significant influence on the influence of e-mini project modules scientific against HOTS, SPS, and SA. H_1: There is unintended influence significance to the influence of e-mini project modules on scientific against HOTS, SPS, and SA. Condition Retrieval something conclusion, namely: a) If the value significance < 0.05, then H_1 is accepted and H_0 is rejected, b) If the value significance > 0.05, then H_1 is rejected and H_0 is accepted. Multivariate Sig. The test can be seen from the results of the multivariate test, which are presented in Table 19.

Table 19. Results of Multivariate Significance Tests

Effect	Test Statistics	Mark	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.986	7.546E3	3,000	74,000	.000
	Wilks' Lambda	.004	7.546E3	3,000	74,000	.000
	Hotelling's Trace	264,782	7.546E3	3,000	74,000	.000
	Roy's Largest Root	264,782	7.546E3	3,000	74,000	.000
Class	Pillai's Trace	.915	3.063E2	3,000	74,000	.000
	Wilks' Lambda	.085	3.063E2	3,000	74,000	.000
	Hotelling's Trace	10,747	3.063E2	3,000	74,000	.000
	Roy's Largest Root	10,747	3.063E2	3,000	74,000	.000

Description:
a. Statistics exact
b. Design: Intercept + Class

The SPSS output results in Table 19, Multivariate Tests, contain two rows. First line shows the intercept, namely to know mark changes in HOTS, SPS, and SA students without using e-mini project modules, or using a conventional learning model, and second row show class namely to know the influence of e-mini project modules towards HOTS, SPS and SA students, so that in the discussion this is what is used is the second line. Based on the table above, shows that F value has Sig. value 0.000 where Sig. value 0.000 < 0.05 means price F can be considered significant, then H_1 is accepted, and H_0 is rejected, which means that there is an average difference between HOTS, SPS, and SA together in science learning using E-mini project modules, Class VII of SMPN 17 Mataram.

After the validation process, data collection continues. with evaluation practicality material. Three observers, who were science teachers who were currently teaching classes VII-C, VII-D, and VIII-A, monitoring implementation of learning in accordance with the plan learning (RPP) that has been arranged. The task is evaluate the suitability of implementing learning with planned content during the Use of the Science Mini-Project Practical E-Module. Observers evaluate overall series learning, from beginning to end, to ensure consistency with design-planned learning. Observation results were noted systematically on the sheet of observations provided.

Mini Science Practicum Project is strongly supported by a validation expert for material learning related to. The experts' material lesson evaluates the components of the Natural Science Mini-Project Practical E-module as highly valid and reliable. Validation comprehensive highlight quality and harmony of materials with the objective of expected education, especially in increasing science education. Reliable material ensures that the material is presented in a way consistent and accurate measure the desired learning, so that give strong foundation to apply concepts in practice. Validation process designed with care to evaluate the content, construction, and language of every component material learning. With focus on key aspects, the experts ensure that material is not only accurate and up to date, but also presented with a clear, logical, and engaging manner. Content is reviewed in a comprehensive manner to ensure its relevance to the curriculum and its alignment with the scientific standards that have been established. Structure material evaluated to ensure its coherence and organization, ensuring material is easy navigate and supports the learning process effectively. Language is assessed to ensure clarity, accuracy, and appropriateness with the target audience. Approach strict validation ensure that material learning fulfil standard quality, highest, and most suitable to reach the objective of education.

E-module Natural Science Mini-Project Practical Work fulfills the criteria of practicality, showing that the e-module can be implemented effectively and consistently in the environment class. Practicality refers to the convenient implementation of e-modules in environmental teaching, while reliability refers to the consistency of e-module results from time to time and in various contexts. E-module education that shows practicality is more likely to be adopted and used with success by teachers (Wulandari et al., 2025). This e-module has designed with careful for fulfil second criteria said, making it a valuable and adaptive tool to increase quality science education. High scores in various stage implementation, starting from pre-test up to evaluation, shows reliability and convenience of use of e-modules. These results show that the e-module is not only easy to implement but also effective in increasing results for students. Consistent performance across all stage shows that the e-module is device designed education with good and tough, and capable of being implemented with success in various context classes.

The practicality of e-modules has a general significant increase in power pull for educators looking for effective teaching strategies. However, easy managed, although the teachers continue to explore innovative ways to increase learning for students, they often face constraints like limited time, limited resources, and training. E-modules offer a practical and feasible approach to overcoming challenges and provide a high-quality approach for science education. Ease in use, its suitability with the existing curriculum, and its effectiveness that has been proven, make it an interesting choice for educators who want to enrich science learning in class.

An e-module has developed at the level of students to increase critical thinking skills (Phandini et al., 2023). Further research has done on practical work laboratory (Widayana & Malik, 2024), which supports the development of science process skills from a science teacher perspective. According to the theory, Cone Edgar Dale's experience results in the most effective learning achieved through experience directly (concretely) in the real-world environment, participant education. These experiences develop from interaction with concrete objects in the real world, through the use of artificial, and finally to representation, abstract like verbal symbols (Manishimwe et al., 2023).

The effectiveness of e-modules in increasing skills has been proven by significant improvement observed in HOTS, SPS, and SI of students. The third realm is crucial for science success and discipline-related knowledge, and e-module capabilities for improving its potential in transforming science education. Observed improvements reflect the designed model activities, with well, the emphasis on learning based experience, and its deliberate focus on development skills think critical and problem-solving skills.

Implementation of e-modules has classified as effective (Joyce & Weil, 1972). Learning based laboratory follows a series of stages, modified from Joyce & Weil, (1972) which include: orientation problem, formulation problem, investigation, finding a solution to the problem, and connecting laboratory results with the draft or theory. Findings show that all stages in a way effectively increase the critical thinking skills students. E-module laboratory has its own potential for a significant increase in scientific attitude, science process skills, and skills (Saregar, 2016).

This improvement originates from understanding that concepts, meanings, and relationships are cultivated through practical work. E-modules are designed to support student develop greater understanding, deep and intuitive about science, involving them in direct and real-world problem-solving. This approach allows student for connect the draft abstract with concrete, so that learning becomes more meaningful and impressive. Furthermore, the E-module also encourages exploration connection between concepts, so that a better understanding of science is holistic and integrated.

E-module can be used by students from various backgrounds and level skills Because emphasis on simplicity and usability. Students can develop foundation strong knowledge and skills through an approach that breaks down complex ideas become more components small and more easy managed. Emphasis on application and practical increase understanding student about relevance of science in everyday life, making learning more interesting and motivating.

The e-module has proven to be very effective in improving students' HOTS, SPS, and SA. HOTS includes thinking analytically, evaluatively, and creatively, which are fundamental for successful academic and professional students (Heong et al., 2011; Liu et al., 2024). Design and implementation of this model in actively develop competencies through interesting and stimulating intellectual activities. With the offer student chance to apply knowledge in context, practical and real world, modules are electronic in a way significant strengthen capacity to think critically and problem solving problem. Effectiveness measured through N-Gain score indicates the level of improvement in skills and reflects the difference between pre-test and post-test (Hake, 1998). High N-Gain scores recorded give strong proof about the effectiveness of e-modules in improving students' HOTS, SPS, and SA.

This E-module develops skills think analytically, evaluatively, and creatively. Thinking analytically covers the ability to describe a complex become more parts, smaller and more easy managed. Thinking evaluative involving ability to evaluate the credibility and reliability of information. Thinking creatively refers to the ability to generate new ideas and innovative For problem. 4C skills, namely critical thinking, creativity, collaboration, and communication, can be developed effectively through an E-module for the Science Practical Mini-Natural Project. These skills are important for success in the 21st century (Kelley & Knowles, 2016; Blegur et al., 2024). E-module design intentionally integrates the chance to develop every skill, so that prepare student become adaptive learners, capable workers, and responsible citizens.

E-module support student in developing components important thinking level: analyze, evaluate, and create. Analyze refers to the ability to break down complex elements into smaller and more easily understood parts. Evaluate by taking the right decision about the credibility and reliability of information. Creating involving creation of ideas and solutions original For problem. E-module on purpose arranged for developing third cognitive skills cognitive this, so that they increase their thinking skills and prepare them for academic success and professional in future (Vidergor, 2018). E-module push high level thinking, problem-solving, and innovation among students, encouraging student to study material scientifically in a critical way, and design creative solutions for complex problems. This module offer chance for student to innovate and develop new solutions for real-world problems, equip student to become competent problem solvers, and minded innovators proceed in academic and professional activities in the future.

This E-module, in a way, significant increase students' science process skills (SPS), including observing, measuring, classifying, analyzing data, and drawing conclusions. These skills are important for study scientific and grow deep and understanding continuously of scientific concepts. Effectiveness proven from high N-Gain scores achieved related to SPS, giving proof of the quantitative impact of the model on SPS development. High gains show ability student in observing, measuring, classifying, analyzing data, and drawing conclusions based on proof.

The main advantage of the e-module lies in its emphasis on the application of theoretical knowledge through practical. Approach pedagogical This allows student for bridge the concepts from scientific abstract to concrete experience in the real world, so that learning becomes more meaningful and effective. E-module overcome lack of practical experience in traditional science education, which often prioritizes theoretical over practical (Hofstein & Lunetta, 2004). E-module give student lots chance for participate in activity practice, solve real-world problems, and investigate phenomena, so that they push for greater understanding, deep and intuitive about science.

Students get experience directly in design and carry out experiments, formulate hypotheses, collect and analyze data, and draw interesting conclusions based on evidence. Experience is very valuable to develop their science process skills and grow a greater understanding of science, preparing them to become scientists and problem solvers, effective problem solvers in their future.

This e-module, in a way, effective grow positive scientific attitude (SA), such as a feeling of desire to know, openness to evidence, critical thinking, and perseverance in finding solutions. Attitudes are important for students to be involved with science in general, a meaningful and growing interest in investigation (Osborne et al., 2003; Suryawati & Osman, 2017). Through interesting activities, real problem solving, and environmental learning supportively, the e-module equip student to become effective learners, problem solvers, and innovators. The module also encourages a thinking development pattern, pushing student for questioning knowledge critically, instead of accepting it passively.

E-module help student view science as something relevant and interesting in everyday life. With connect concepts with real-world problems and applications, electronic modules electronic this make learning meaningful and effective. This module also overcome problem of low attitude scientific students and negative perceptions that science is difficult or not relevant by provide environment learning interesting, practical, and meaningful. Through direct activities and opportunities for invention, module electronic instill curiosity, openness to proof, and a sense of wonder towards science (Ramdani et al., 2021; Hakim et al., 2016), positioning science as a valuable tool for understanding and improving the world around us.

LIMITATIONS

This e-module functions as a source of digital learning to facilitate the implementation of the Mini-Natural Project Science Practical Model. The main module electronic features its limited electronics. For serve stages activity, practical work, and mini project, temporary response student still recorded and displayed manually. Activities and mini projects provided in the module electronically are limited to junior high school science topics, namely classification of creature life and change of material. Moreover, the module electronics are not equipped with a system to come back or correct automatically. To determine the accuracy of student responses, a learning approach that require student produce concrete results, such as posters and exteriors project end.

CONCLUSION

This study successfully developed a Natural Science Mini-Project Practicum E-Module designed to improve students' higher-order thinking skills (HOTS), science process skills (SPS), and scientific attitudes (SA). The development process followed the 4D model, and the resulting product demonstrated strong feasibility from the perspectives of validity and practicality. Expert validation obtained a score of 3.69 (very valid), while teacher and student response data showed high levels of practicality (3.37), indicating that the e-module is easy to understand, engaging, and aligns well with the learning objectives. The implementation of the e-module in limited and large-scale trials yielded significant improvements in students' competencies. The average N-Gain values for HOTS (70.87), SPS (72.27), and SA (70.54) fell within the high category, and the hypothesis test results (< 0.05) confirmed that the improvements were statistically significant. These findings show that the integration of a mini-project practicum approach within a digital learning module effectively supports students' conceptual understanding, investigative abilities, and scientific dispositions.

Overall, the mini-project e-module developed in this study is feasible and effective to be used in science learning. It offers opportunities for students to engage in contextual investigation, apply scientific procedures independently, and connect theory to real-world problems. Future research may explore wider implementation across grade levels, adaptation across subject matter, or integration with hybrid and fully online learning environments to maximize its impact.

AUTHOR CONTRIBUTIONS

This journal article received support from the contributions of each author. BA initiated the idea and initial concept of the research, including the preparation of research instruments and investigations into the research activity location. AR, as the promoter, is responsible for all correspondence related to the paper, verification of the concept of thinking, research methodology, verification of the instruments and research data results, and data processing. AH and MM are responsible for the study of the model development design document, research instruments, and research data. SK and NJ are responsible for verifying the theory used in the development of the model and editing the writing in accordance with the rules.

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REFERENCES

Afandi, A., Sajidan, S., Akhyar, M., & Suryani, N. (2019). Development frameworks of the Indonesian partnership 21st-century skills standards for prospective science teachers: A Delphi study. *Jurnal Pendidikan IPA Indonesia, 8*(1), 1–8. https://doi.org/10.15294/jpii.v8i1.11647

Agnafia, D. N. (2019). Analisis kemampuan berpikir kritis siswa dalam pembelajaran biologi. *Florea: Jurnal Biologi dan Pembelajarannya, 6*(1), 45–53. https://doi.org/10.25273/florea.v6i1.4369

Asrizal, A., Yurnetti, Y., & Usman, E. A. (2022). ICT thematic science teaching material with 5E learning cycle model to develop students' 21st-century skills. *Jurnal Pendidikan IPA Indonesia, 11*(1), 61–72. https://doi.org/10.15294/jpii.v11i1.33764

Aulia, M., & Yuliani, H. (2023). POE-based E-module (predict, observe, and explain): Improving students' critical thinking skills on kinetic theory of gases. *Online Learning in Educational Research, 2*(2), 57–66. https://doi.org/10.58524/oler.v2i2.128

Azari, A. M., Wilujeng, I., & Nurohman, S. (2023). Development of web-based science learning in living things interaction materials to improve ICT literacy and conceptual understanding skills. *Journal of Science Education Research, 7*(1), 21–26. https://doi.org/10.21831/jser.v7i1.54840

Bagiani, N. L. P., & Agustini, K. (2025). Optimalisasi kemampuan berpikir kritis melalui kombinasi model problem-based learning dengan flipped learning. *Ideguru: Jurnal Karya Ilmiah Guru, 10*(3), 1944–1952. https://doi.org/10.51169/ideguru.v10i3.1929

Blegur, J., Ma'mun, A., Berliana, B., Mahendra, A., Bakhri, R. S., & Calunsag, B. D. (2024). Enhancing teaching competence of prospective physical education teachers with integrated learning model. *Jurnal Cakrawala Pendidikan, 43*(3), 586–606. https://doi.org/10.21831/cp.v43i3.57858

Bloom, B. S. (1971). *Handbook on formative and summative evaluation of student learning*. McGraw-Hill.

Borich, G. D. (1988). *Effective teaching methods*. Pearson Education India.

Darmaji, D., Astalini, A., Kurniawan, D. A., & Triani, E. (2022). The effect of science process skills on students' argumentation skills. *Jurnal Inovasi Pendidikan IPA, 8*(1), 78–88. https://doi.org/10.21831/jipi.v8i1.49224

Delita, F., Berutu, N., & Nofrion, N. (2022). Online learning: The effects of using e-modules on self-efficacy, motivation and learning outcomes. *Turkish Online Journal of Distance Education, 23*(4), 93–107. https://doi.org/10.17718/tojde.1182760

Desnita, D., Festiyed, F., Novitra, F., Ardiva, A., & Navis, M. Y. (2022). The effectiveness of CTL-based physics E-module on the improvement of the creative and critical thinking skills of senior high school students. *TEM Journal, 11*(2), 802–810. https://doi.org/10.18421/TEM112-38

Dewi, P. S., & Kuswanto, H. (2023). The effectiveness of the use of augmented reality-assisted physics e-module based on pedicab to improve mathematical communication and critical thinking abilities. *Journal of Technology and Science Education, 13*(1), 53–63. https://doi.org/10.3926/jotse.1714

Gizaw, G., & Sota, S. S. (2023). Improving science process skills of students: A review of literature. *Science Education International, 34*(3), 216–224. https://doi.org/10.33828/sei.v34.i3.5

Gligorea, I., Cioca, M., Oancea, R., Gorski, A.-T., Gorski, H., & Tudorache, P. (2023). Adaptive learning using artificial intelligence in e-learning: A literature review. *Education Sciences, 13*(12), 1216. https://doi.org/10.3390/educsci13121216

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

Hakim, A., Liliasari, L., Kadarohman, A., & Syah, Y. M. (2016). Effects of the natural product mini project laboratory on students' conceptual understanding. *Journal of Turkish Science Education, 13*(2), 27–36.

Heong, Y. M., Othman, W. B., Yunos, J. B. M., Kiong, T. T., Hassan, R. B., & Mohamad, M. M. B. (2011). The level of Marzano higher order thinking skills among technical education students. *International Journal of Social Science and Humanity, 1*(2), 121–125. https://doi.org/10.7763/IJSSH.2011.V1.20

Heradio, R., De La Torre, L., Galan, D., Cabrerizo, F. J., Herrera-Viedma, E., & Dormido, S. (2016). Virtual and remote labs in education: A bibliometric analysis. *Computers & Education, 98*, 14–38. https://doi.org/10.1016/j.compedu.2016.03.010

Herditiya, H., Sari, M., & Koriaty, S. (2023). Development of an e-module based on virtual practicum integrated with local potential in invertebrate material. *Bio-Inoved: Jurnal Biologi-Inovasi Pendidikan, 5*(2), 155–164. https://doi.org/10.20527/bino.v5i2.15620

Hilala, R., Laliyo, L. A. R., Kilo, J. L., Tangio, J. S., Mohamad, E., & Sihaloho, M. (2023). Measuring students' scientific argumentation skills in explaining phenomena related to acid-base concepts. *Jurnal Pendidikan Sains Indonesia, 11*(2), 360–378. https://doi.org/10.24815/jpsi.v11i2.27822

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science Education, 88*(1), 28–54. https://doi.org/10.1002/sce.10106

Joyce, B., & Weil, M. (1972). *Conceptual complexity, teaching style and models of teaching.*

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education, 3*(1), 1–11. https://doi.org/10.1186/s40594-016-0046-z

Kurniansyah, M. Y., Hidayat, W., & Rohaeti, E. E. (2022). Development of combined module using contextual scientific approach to enhance students' cognitive and affective. *Infinity Journal, 11*(2), 349–366. https://doi.org/10.22460/infinity.v11i2.p349-366

Liu, J., Liu, Z., Wang, C., Xu, Y., Chen, J., & Cheng, Y. (2024). K-12 students' higher-order thinking skills: Conceptualization, components, and evaluation indicators. *Thinking Skills and Creativity, 52*, 101551. https://doi.org/10.1016/j.tsc.2024.101551

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*(1), 1–14. https://doi.org/10.22521/edupij.2025.17.399

Manishimwe, H., Shivoga, W. A., & Nsengimana, V. (2023). Enhancing students' achievement in biology using inquiry-based learning in Rwanda. *International Journal of Evaluation and Research in Education, 12*(2), 809–818. https://doi.org/10.11591/ijere.v12i2.23375

Mills, S. (2016). Conceptual understanding: A concept analysis. *The Qualitative Report, 21*(3), 1–12. https://doi.org/10.46743/2160-3715/2016.2308

Netriwati, N., Tricia, A., Gunawan, W., & Nendra, F. (2023). E-module in learning mathematics: An effort to stimulate learning independence. *Online Learning in Educational Research, 2*(2), 67–74. https://doi.org/10.58524/oler.v2i2.149

Novalia, R., Marini, A., Bintoro, T., & Muawanah, U. (2025). Project-based learning: For higher education students' learning independence. *Social Sciences & Humanities Open, 11*, 101530. https://doi.org/10.1016/j.ssaho.2025.101530

Nurhasanah, D., Iswanto, B. H., & Nasbey, H. (2023). E-modul project-based learning untuk pembelajaran fisika SMA pada materi pemanasan global. *Lontar Physics Today, 2*(1), 1–8. https://doi.org/10.26877/lpt.v2i1.14349

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049–1079. https://doi.org/10.1080/0950069032000032199

Pamungkas, A. R., Wijayanti, N. P. N., Vai, A., & Ittaqwa, I. (2022). Development of smartphone-based athlete physical fitness applications during work from home. *Journal of Coaching and Sports Science, 1*(1), 18–27. https://doi.org/10.58524/jcss.v1i1.107

Phandini, I., Miharja, F. J., Husamah, H., Fauzi, A., & Nuryady, M. M. (2023). STEM-PBL integrative electronic module: Is that effective in improving students' critical thinking skills? *Jurnal Inovasi Pendidikan IPA, 9*(2), 118–126. https://doi.org/10.21831/jipi.v9i2.60871

Piaget, J. (1970). *Science of education and the psychology of the child*. Orion Press.

Poo, M. C.-P., Lau, Y., & Chen, Q. (2023). Are virtual laboratories and remote laboratories enhancing the quality of sustainability education? *Education Sciences, 13*(11), 1110. https://doi.org/10.3390/educsci13111110

Rakesh, D., McLaughlin, K. A., Sheridan, M., Humphreys, K. L., & Rosen, M. L. (2024). Environmental contributions to cognitive development: The role of cognitive stimulation. *Developmental Review, 73*, 101135. https://doi.org/10.1016/j.dr.2024.101135

Ramdani, A., Jufri, A. W., Gunawan, G., Fahrurrozi, M., & Yustiqvar, M. (2021). Analysis of students' critical thinking skills in terms of gender using science teaching materials based on the 5E learning cycle integrated with local wisdom. *Jurnal Pendidikan IPA Indonesia, 10*(2), 187–199. https://doi.org/10.15294/jpii.v10i2.29956

Salimi, M., Hidayah, R., Suhartono, Susiani, T. S., Wahyono, Wahyudi, A. B. E., & Fajari, L. E. W. (2024). Evaluating the impact of the DECIDE model on decision-making skills in elementary teacher education students in Indonesia. *Journal for Lesson and Learning Studies, 7*(3), 449–460. https://doi.org/10.23887/jlls.v7i3.84231

Santos, M. D., & David, A. P. (2017). Self- and teacher-assessment of science process skills. *The Normal Lights, 11*(1), 1–20. https://doi.org/10.56278/tnl.v11i1.377

Saregar, A. (2016). Pembelajaran pengantar fisika kuantum dengan memanfaatkan media PhET simulation dan LKM melalui pendekatan saintifik: Dampak pada minat dan penguasaan konsep mahasiswa. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni, 5*(1), 53–63. https://doi.org/10.24042/jipfalbiruni.v5i1.105

Sari, I. N., Mahanal, S., & Prabaningtyas, S. (2024). The complexity science problem-based learning: Correlation of science literacy and concept mastery to problem-solving skills. *JPBI: Jurnal Pendidikan Biologi Indonesia, 10*(3), 920–927. https://doi.org/10.22219/jpbi.v10i3.35793

Sarwanto, S., Fajari, L. E. W., & Chumdari, C. (2021). Open-ended questions to assess critical-thinking skills in Indonesian elementary school. *International Journal of Instruction, 14*(1), 615–630. https://doi.org/10.29333/iji.2021.14137a

Shieh, M.-D., & Hsieh, H.-Y. (2021). Study of influence of different models of e-learning content product design on students' learning motivation and effectiveness. *Frontiers in Psychology, 12*, 753458. https://doi.org/10.3389/fpsyg.2021.753458

Suherman, S., & Vidákovich, T. (2024). Relationship between ethnic identity, attitude, and mathematical creative thinking among secondary school students. *Thinking Skills and Creativity, 51*, 101448. https://doi.org/10.1016/j.tsc.2023.101448

Suryawati, E., & Osman, K. (2017). Contextual learning: Innovative approach towards the development of students' scientific attitude and natural science performance. *Eurasia Journal of Mathematics, Science and Technology Education, 14*(1), 361–379. https://doi.org/10.12973/ejmste/79329

Susilawati, E., Hamidah, I., Rustaman, N., & Liliawati, W. (2024). Problem-solving learning in science education: A systematic literature review. *Jurnal Penelitian Pendidikan IPA, 10*(8), 548–558. https://doi.org/10.29303/jppipa.v10i8.5033

Thiagarajan, S. (1947). *Instructional development for training teachers of exceptional children: A sourcebook.*

Vidergor, H. E. (2018). Effectiveness of the multidimensional curriculum model in developing higher-order thinking skills in elementary and secondary students. *The Curriculum Journal, 29*(1), 95–115. https://doi.org/10.1080/09585176.2017.1318771

Vygotsky, L. S. (1978). *Mind in society* (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Eds.). Harvard University Press.

Wasserstein, R. L., & Lazar, N. A. (2016). The ASA statement on p-values: Context, process, and purpose. *The American Statistician, 70*(2), 129–133. https://doi.org/10.1080/00031305.2016.1154108

Wati, W. W., & Syafriani, S. (2023). Effectiveness of e-modules based on inquiry model integrated with SETS approach on 21st century skills. *Journal of Innovation in Educational and Cultural Research, 4*(4), 673–681. https://doi.org/10.46843/jiecr.v4i4.941

Widayana, S. P., & Malik, A. (2024). Analisis efektivitas praktikum cookbook laboratorium dan inquiry laboratory dalam meningkatkan keterampilan siswa abad 21. *Jurnal Pendidikan dan Ilmu Fisika, 4*(2), 111–118. https://doi.org/10.52434/jpif.v4i2

Wulandari, S., Kurniasih, S., Permana, I., & Ardianto, D. (2025). Teachers' strategies in implementing e-modules in biology learning: A systematic literature review. *Journal of Innovative Science Education, 14*(2), 158–170. https://doi.org/10.15294/jise.v14i2.30060

Yusuf, Y. (2022). Improving students' critical thinking skills against environmental problems: Practicum mini project "Understanding public perceptions of environmental problems." *Jurnal Penelitian Pendidikan IPA, 8*(1), 209–215. https://doi.org/10.29303/jppipa.v8i1.1224