Facilitating students' analytical thinking skill and scientific attitude in distance learning using local wisdom-based physics PBL E-module

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The cultivation of 21st-century competencies can be facilitated through the study of physics, particularly focusing on the concept of elasticity. Elasticity, a fundamental concept in physics, demands analytical thinking and a scientific mindset for problem-solving within its domain. Employing a problem-based learning approach tailored to elasticity material, students are guided to engage with real-life issues intertwined with local knowledge. This pedagogical strategy aims to enhance students' comprehension of elasticity principles by contextualizing them within familiar scenarios. This experimental study aims to assess: 1) the effectiveness of the Local Wisdom-based Physics PBL E-module to improve the student's analytical thinking skills, 2) the effectiveness of using the Local Wisdom-based Physics PBL E-module in improving student's attitudes toward science. This experimental research used pretest-posttest control group design. The selection of the research sample used the cluster random sampling method in 11th-grade students from the Natural Science program at MAN (Islamic Senior High School) 1 Yogyakarta, Indonesia. The data collection instruments used were pretests-posttets questions, and a scientific attitude questionnaire, yielding quantitative data. Analysis of data was carried out by descriptive statistical analysis using normalized gain. Inferential statistical analysis used normality, homogeneity, correlation, MANOVA, effect size, and Post Hoc tests. Findings indicated the effectiveness of the Local Wisdom-based Physics PBL E-module in enhancing both analytical thinking skills and scientific attitudes among students.

Keywords: E-module; elasticity; analytical thinking; scientific attitude.

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1. Introduction

The advancements in science and technology in the 21st century present formidable challenges within the realm of education. Both students and educators must possess 21st-century skills to equip Indonesia's upcoming generation for the integration of information and communication technology into social dynamics [1]. The cultivation of these skills can be facilitated through the study of physics [2], which serves as a platform for enhancing analytical thinking abilities and nurturing scientific dispositions among students, thus fostering their capacity for 21st-century competencies.

The ability to think analytically is needed in learning physics. This is because in learning physics, students are faced with problems in everyday life that require analysis to solve these problems [3]. The ability to think analytically is something that must be possessed in the 21^{st} century, where students are required to be able to analyze, solve problems, and provide appropriate solutions [4]. Based on Bloom's taxonomy, analytical skills are included in the C4 cognitive domain at the Higher Order Thinking Skill (HOTS) level [5]. Unfortunately, learning physics at school tends to train students accustomed to learning by memorizing mathematical equations [6]. Therefore, the ability to think analytically needs to be improved by educators in learning physics. In addition, one of the important attitudes that students have in learning physics is scientific attitudes such as curiosity, honesty, and conscientiousness. Scientific attitude is a form of intelligence possessed by each individual. The scientific attitude is important to note especially since physics is a process. Physics is a series of scientific processes carried out to discover knowledge about physics. This, of course, requires a scientific attitude in studying physics [7]. Hence, fostering a scientific mindset is paramount in enhancing teaching practices. Moreover, this endeavor is influenced by various factors, including student attitudes. When students perceive physics as challenging, they may disengage from the learning process, leading to apathy and reduced participation. Consequently, this lack of engagement adversely affects students' academic performance in physics.

The findings from observations conducted at Islamic Senior High School 1 Yogyakarta, wich is called MAN (Madrasah Aliyah Negeri) 1 Yogyakarta reveal that students exhibit limited proficiency in analytical thinking skills and scientific attitudes. This is evidenced by consistently low scores in physics assessments and a lack of curiosity, honesty, and precision, particularly during practical sessions. Enhancing students' analytical thinking skills and fostering scientific attitudes is imperative to meet educational objectives and improve learning outcomes. Thus, the adoption of instructional models designed to enhance these competencies becomes indispensable.

Physics is a subject that is considered difficult and avoided by some students. Based on interviews with 11^{th} grade students in the Natural Science program of MAN 1 Yogyakarta they get bored quickly studying physics. This is due to the ignorance of students about the use of physics in everyday life. Moreover, the learning media used are still limited to textbooks and student worksheets at school and PowerPoint only. These kinds of media are not enough to increase the motivation of students to learn physics. Limited learning resources and an unattractive display are obstacle for students in understanding physics learning. This makes it difficult for students to build their knowledge and apply the theories or concepts obtained in solving physics problems in everyday life [8]. Therefore, it is necessary to apply learning media that can attract the attention of students to study physics.

The study of material elasticity in solids offers a rich opportunity to develop students' analytical thinking skills. This subject holds practical relevance in daily life, presenting challenges of a considerable level and involving mathematical complexities. Given its ubiquitous presence in real-world scenarios, a profound understanding of solid elasticity is paramount. However, mastering this concept poses significant difficulties for many students, often leading to misconceptions.

Students encounter challenges when solving physics problems related to elasticity for several reasons [9]: (1) misunderstanding the problem, leading to incorrect application of formulas, (2) struggling to utilize formulas appropriately as per the question's requirements, (3) difficulty discerning known and unknown variables in narrative-style questions, (4) familiarity with the formula but encountering difficulties in its mathematical application. Hence, the development of engaging learning resources becomes imperative to capture students' interest in studying elasticity within physics. This initiative aims to facilitate students' comprehension of physics concepts, particularly those pertaining to elasticity.

In the realm of physics education, effective learning necessitates the use of appropriate educational resources like learning media. Among these resources, electronic modules, commonly referred to as e-modules, serve as valuable tools. An e-module comprises a compilation of digital learning materials, meticulously crafted to enhance learning efficiency. By harnessing the power of technology, e-modules empower students to engage in learning exercises tailored to their individual learning styles, thereby facilitating problem-solving in physics education [10]. E-modules can be accessed using electronic devices such as computers, laptops, tablets, and smartphones. Indeed, the versatility of e-modules allows for accessibility and convenience, enabling students to engage with the material through electronic media at their own pace and convenience, anytime and anywhere [11].

E-modules can be used to improve analytical thinking skills by presenting questions based on indicators of analytical thinking according to [5]. First, students will pass elemental analysis when they can solve the elements contained in the problems presented. Second, students will pass relationship analysis when they can explain the relationship between existing theoretical concepts and everyday life, and solutions to the problems presented. Third, students will pass the analysis of organizing principles when they can make solutions to solve problems and communicate them. If students can pass these 3 levels, they can use analytical thinking skills. Based on research [12], they state that e-modules can improve students' analytical thinking in physics subjects. So it can be concluded that e-modules can improve students' analytical thinking skills.

Certainly, the utilization of e-modules extends beyond just facilitating academic understanding; it can also serve as a catalyst for nurturing students' scientific attitudes. By incorporating real-life scenarios and practical problems within the e-module, students are prompted to actively engage in problem-solving exercises. This hands-on approach fosters attributes like curiosity, honesty, and thoroughness, essential components of a robust scientific mindset. As students grapple with challenges presented in their daily practice, they are encouraged to approach problems with inquisitiveness, integrity, and attention to detail, thereby enhancing their overall scientific disposition.

According to [13] indicators of curiosity are paying attention, compiling notes, asking questions, and comparing. Indicators of honest attitude [14] are not cheating, not plagiarizing, expressing feelings as they are, stating right or wrong attitudes towards material, being brave and confident in answering questions' teacher, and being calm and understanding doing the task. Indicators of a conscientious attitude are carrying out experimental activities according to procedures independently writing down the measurement results [15], and being careful and carefully following activities according to instructions [16]. E-modules can increase scientific attitudes of curiosity [17], honesty [18], and conscientiousness [19]. Based on this research, it can be concluded that e-modules can increase the scientific attitudes of learners.

Indeed, alongside learning media, the adoption of effective learning models is paramount in imparting physics education to students. One of the learning models that can be used is the problem-based learning model. This learning model aims to train students to work on authentic problems and enabling them to consolidate their knowledge, enhance analytical thinking skills, and cultivate independence and scientific attitudes [20].

The syntax of the problem-based learning model according to [20] is 1) orienting students to problems, in this e-module, presented problems related to local wisdom around students. 2) Organizing students to learn, in this e-module, students are asked questions and make hypotheses on the problems presented. 3) Guiding investigations, students carry out individual investigations to solve problems. 4) presenting and presenting the results, students write the results of the investigation in the form of a practical report. 5) Analyzing and evaluating the problem-solving process, students analyze, provide questions, and provide conclusions related to solving the problem.

TABLE I. Research design.

Class	Group	Test Type	Treatment	Test Type
11^{th} Natural Science 2 Grade	Experiment 1	Pretest	X_1	Posttest
11^{th} Natural Science 3 Grade	Experiment 2		X_2	
11^{th} Natural Science 4 Grade	Control		X_3	

Information: X_1: Learning Physics used the elasticity e-module of the Problem-Based Learning model integrated with local wisdom. X_2: Learning Physics used the Problem-Based Learning (PBL) model X_3: Physics learning used conventional learning models

Based on research [21], Problem-Based Learning can improve students' analytical thinking skills. Learning using the Problem-Based Learning model can improve the scientific attitude of students [22]. So it can be concluded that the Problem-Based Learning model can be used to improve students' analytical thinking skills and scientific attitudes.

Improving students' analytical thinking skills and scientific attitudes can be done by presenting problems that are contextual and found around students. This can be done by introducing local wisdom to students. Where local wisdom is the result of cultural heritage from its ancestors, local wisdom and culture are very closely related. Morales' findings show that the use of local culture, traditions, practices, beliefs, and indigenous languages can help improve students' attitudes toward science [23]. The questions presented are integrated with local culture and local wisdom and can be developed into questions that function to measure students' high-level abilities, one of which is analytical ability. By solving questions related to culture in the area around students, students will be more challenged and will increase students knowledge about regional culture in the area [24]. The local wisdom used in this e-module is the game of jumping rubber, catapult, and carriage. Therefore, it is necessary to create a Problem-Based Learning (PBL) e-module model integrated with Local Wisdom that can improve students' analytical thinking skills and scientific attitudes.

Seeing the gap between expectations and reality in the field as described above, the formulation of this research can be conveyed as follows: 1) Is the Local Wisdom Integrated Elasticity PBL E-module effective in increasing students' analytical thinking skills?, 2) Is the PBL Elasticity E-module integrated with local wisdom effective in increasing the student's scientific attitudes?

2. Methodology

After undergoing limited testing and subsequent revisions, the e-module is then subjected to field trials on large cohorts, known as operational field trials. These field tests serve the dual purpose of evaluating the efficacy of the developed e-module in enhancing students' analytical thinking skills and scientific attitudes, as well as refining the product for optimal integration into physics education. During this phase, the developed e-module and research instruments are deployed within the context of physics learning, facilitating comprehensive assessment and refinement of the instructional materials.

During the implementation of the field test, three classes were selected and divided into two groups: two classes formed the experimental group, while one class served as the control group. The experimental group comprised 11th-grade students from Natural Science 2 and Natural Science 3, whereas the control group consisted of 11th-grade students from Natural Science 4. The selection of classes was conducted using the cluster random sampling method.

Experimental Class 1 received treatment involving the utilization of the e-module "Elasticity" within the Problem-Based Learning model, integrated with local wisdom. Experimental Class 2, on the other hand, underwent treatment with the Problem-Based Learning model but did not utilize the developed e-module. Meanwhile, the control class was subjected to conventional learning practices, following the standard educational approach typically employed by educators at the school. The research design is outlined in Table I.

2.1. Research Instruments

This study employed two data collection instruments: a pretest-posttest assessment to gauge the enhancement of analytical thinking skills and a scientific attitude questionnaire to measure the improvement in students' scientific disposition. Both the pretest and posttest instruments comprised four questions, each containing indicators of analytical thinking, as detailed in Table II.

The scientific attitude questionnaire was administered twice: once before the commencement of physics instruction and again after completion of the learning activities, utilizing various treatments in both the experimental and control classes. The indicators assessed through the scientific attitude questionnaire are detailed in Table III.

TABLE II. Indicators of pretest and posttest questions.

Analytical Thinking Indicator	Question Number
Element Analysis	1
Relationship Analysis	2
Analysis of Organizing Principles	3, 4

TABLE III. Indicators of scientific attitude questionnaire.

No.	Aspects of Scientific Attitude	Item Number
1	Curiosity	1,2,3,4,5
2	Honest	6,7,8,9,10
3	Conscientious	11,12,13,14,15
	Total item statement	15

2.2. Data analysis technique

The analysis of the implementation of the lesson plan in learning can be seen from the score of filling out the observation sheet and then analyzed by calculating the Interjudge Agreement (IJA) in the following way:

$$IJA = \frac{A_Y}{A_Y + A_N} \times 100,$$

where A_Y is a learning activity that was carried out, while is a learning activity that was not carried out. A lesson plan's suitability can be determined by its implementation, which is deemed feasible if the learning activities are executed to a percentage exceeding 75% [25]. Additionally, the smooth execution of the Problem-Based Learning (PBL) model throughout the instructional process further validates its efficacy.

The increase in analytical thinking skills and students' scientific attitudes is analyzed using descriptive statistics, the n-gain equation (g), using the following equation:

$$g = \frac{\bar{X}_{\text{final score}} - \bar{X}_{\text{initial score}}}{\text{maxsimum score} - \bar{X}_{\text{initial score}}}.$$

The results of the normalized gain analysis are then interpreted into categories as in Table IV.

To address the research aims comprehensively, inferential statistical analysis, specifically the Multivariate Analysis of Variance (MANOVA) test, was conducted. This analysis aimed to determine the effectiveness of the developed e-module. Effectiveness was evaluated by examining the significant differences between the experimental class utilizing the e-module and the control class not utilizing the e-module. Given the presence of two dependent variables (analytical thinking and scientific attitudes), MANOVA was selected to test the hypotheses. Prior to conducting the MANOVA test, homogeneity and normality tests were performed to ensure that the data in this study were normally distributed and homogeneous. The hypotheses tested in this study were as follows:

1. H_0: This means that there is no difference in the increase in analytical thinking skills and scientific attitude between experimental class 1, experimental class 2, and the control class.
2. H_a: This means that there is a difference in the increase in analytical thinking skills and scientific attitude among students in experimental class 1, experimental class 2, and control class.
3. H_0: rejected if the value of Sig. < 0.05.

The subsequent inferential statistical analysis, namely effect size analysis, seeks to ascertain the magnitude of influence or effect that a variable exerts on other variables. Effect size analysis can be conducted using the following equation:

$$d = \frac{\bar{x}_{\max} - \bar{x}_{\min}}{\sigma}.$$

Information: $\bar{x}_{\max}$: the largest mean value between the two populations, $\bar{x}_{\min}$: the smallest mean value between the two populations, σ : the combined standard deviation of the two populations.

Cohen's effect size criteria regarding the size of the effect size can be seen in Table V.

The final inferential statistical analysis, known as the Post Hoc test, is conducted when the results of the hypothesis test indicate rejection of the null hypothesis, signifying differences in the enhancement of analytical thinking skills and scientific attitudes among students in experimental class 1, experimental class 2, and the control class. The purpose of the Post Hoc test is to identify which class exhibits more pronounced differences in improvement. Inferential statistical analysis is employed because the data concerning the increase in analytical thinking skills and scientific attitudes demonstrate homogeneous variances and normal distribution, as illustrated in Table VI. The primary decision-making criteria in the Bonferroni test are:

1. If the significance value (Sig.) > 0.05, there is no difference in increase between the 2 treatment groups.
2. If the significance value (Sig.) < 0.05, there is a difference in the increase between the 2 treatment groups.

TABLE IV. N-Gain Criterion by [26].

Score (g)	Category
$g \geq 0,7$	High
$0.7 > g \geq 0,3$	Medium
$g < 0,3$	Low

TABLE V. The effect size criterion by [27].

Effect size	Category
$0,7 - \infty$	Big
$0,3 - 0,6$	Medium
$0 - 0,2$	Small

TABLE VI. The Result of homogenity and normality test.

Variables	Aspect	Homogenity test				Normality test		
		Levene Statistic	df 1	df 2	Sig	Class	Sig	Normality
Analytical Thinking Skill	Mean	2.302	2	72	0.107	Experiment 1	0.223	Normal
	Median	1.859	2	72	0.163	Experiment 2	0.632	Normal
	Trimmed mean	2.244	2	72	0.113	Control	0.151	Normal
Scientific Attitude	Mean	2.122	2	72	0.127	Experiment 1	0.204	Normal
	Median	2.122	2	72	0.127	Experiment 2	0.442	Normal
	Trimmed mean	2.201	2	72	0.118	Control	0.164	Normal

3. Results and discussion

3.1. Analysis of the learning process

During the data collection phase, learning sessions were observed and documented by a physics educator from MAN 1 Yogyakarta. The researcher-prepared lesson plan was exclusively utilized in Experiment 1 and Experiment 2 classes, differing only in the learning resources employed. Meanwhile, the control group used the lesson plan prepared by the school teacher. Learning activities spanned across five sessions in all three classes. Variations in the implementation of lesson plans between Experiment 1 and Experiment 2 classes are depicted in Fig. 1.

Based on Fig. 1, Experiment 1 consistently followed all planned activities throughout the initial five meetings. Conversely, Experiment 2 encountered discrepancies, particularly in the second, third, and fourth sessions, where certain learning activities were omitted. Notably, the core activities outlined in the lesson plan involved a learning stage facilitated by the developed e-module. Since Experiment 2 did not utilize this e-module, these stages were consequently excluded. The analysis indicates that both Experiment 1 and Experiment 2 demonstrated commendable adherence to the lesson plan, with an Interjudge Agreement exceeding 75%. This observation is consistent with prior research, which suggests that a percentage above 75% denotes excellent implementation of learning activities [25].

To conclude the effectiveness of the use of the developed e-module, an inferential statistical test was carried out. The results of the MANOVA test analysis can be seen in Table VII.

Based on the MANOVA test results presented in Table VII, all four tests-Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root-yielded significance values below the alpha threshold (sig. < 0.05). Consequently, it can be inferred from this analysis that there exist significant differences in the enhancement of analytical thinking skills and scientific attitudes among students in Experiment 1, Experiment 2, and the control class. These disparities are attributed to the utilization of distinct learning resources, media, and instructional models across the three classes. Specifically, Experiment 1 employed the e-module "Elasticity" within a problem-based learning model integrated with local wisdom.

The influence of the developed e-module on learning in improving the two research variables in each class was analyzed using the effect size. The results of the effect size analysis can be seen in Tables VIII and IX.

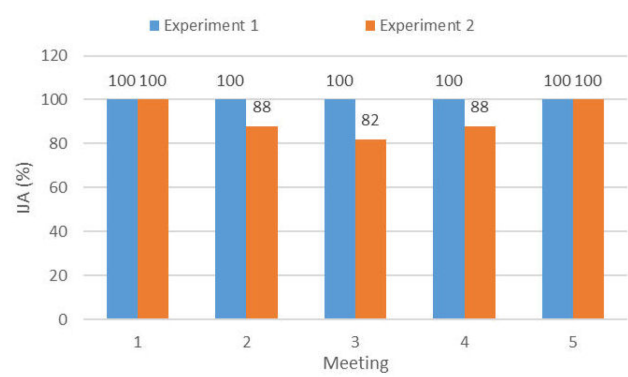

FIGURE 1. Lesson plan implementation diagram.

TABLE VII. MANOVA test result.

Effect	Tes Significance	Value	F	Hypothesis df	Error df	Sig.
Class	Pillai's Trace	0.932	490.070^b	2.000	71.000	0.000
	Wilk' Lambda	0.068	490.070^b	2.000	71.000	0.000
	Hotelling's Trace	0.767	490.070^b	2.000	71.000	0.000
	Roy's Largest Root	0.749	490.070^b	2.000	71.000	0.000

TABLE VIII. Effect size analysis of experimental class 1 and control class.

	Experiment 1		Control			
Dependent Variable	Mean	Std. Deviation	Mean	Std. Deviation	Effect Size	Category
Improved Analytical Thinking	0.66	0.18	0.32	0.19	1.83	High
Improvement of Scientific Attitudes	0.72	0.21	0.49	0.13	1.34	High

TABLE IX. Effect size analysis of experimental class 2 and control class.

	Experiment 1		Control			
Dependent Variable	Mean	Std. Deviation	Mean	Std. Deviation	Effect Size	Category
Improved Analytical Thinking	0.47	0.28	0.32	0.19	0.63	Medium
Improvement of Scientific Attitudes	0.60	0.19	0.49	0.13	0.68	Medium

TABLE X. Results of post hoc analysis bonferroni test.

Dependent Variable	(I) class	(J) class	Mean Difference (I-J)	Std. Error	Sig.
Improved Analytical Thinking	Experiment 1	Experiment 2	0.1928*	0.06218	0.008
		Control	0.3412*	0.06218	0.000
	Experiment 2	Experiment 1	-0.1928*	0.06218	0.008
		Control	0.1484*	0.06218	0,059
	Control	Experiment 1	-0.3412*	0.06218	0.000
		Experiment 2	-0.1484*	0.06218	0,059
Improvement of Scientific Attitudes	Experiment 1	Experiment 2	0.1271	0.05171	0.049
		Control	0.2396	0.05171	0.000
	Experiment 2	Experiment 1	-0.1271	0.05171	0.049
		Control	0.1125	0.05171	0.099
	Control	Experiment 1	-0.2396	0.05171	0.000
		Experiment 2	-0.1125	0,05171	0.099

Tables VIII and IX exhibit significant enhancements in analytical thinking skills and scientific attitudes as a result of the effect size analysis conducted across Experiment 1, Experiment 2, and the control class. Table VIII showcases considerable improvements, while Table IX illustrates moderate gains in these areas.

Additionally, to determine the class ranking with the most significant increase in analytical thinking skills and scientific attitude, a Post Hoc test was executed. The gain data in this study indicates homogeneity. Subsequently, the Post Hoc analysis was conducted utilizing the Bonferroni test, as illustrated in Table X.

Based on the data obtained from the Post Hoc analysis utilizing the Bonferroni test presented in Table X, it is evident that the sequence of classes demonstrating the highest increase in both analytical thinking skills and scientific attitudes is as follows: Experiment 1 class, Experiment 2 class, and control class. Significant differences in the enhancement of analytical thinking skills are observed between the Experiment 1 class and Experiment 2 class, as well as between the Experiment 1 class and the control class, as indicated by sig. < 0.05. Conversely, although an improvement in analytical thinking skills is noted in the Experiment 2 class and the control class, it is not deemed significant, as the sig value > 0.05. This trend is similarly observed in the variable of scientific attitude.

3.2. The effectiveness of E-Module results to improve analytical thinking skill

The effectiveness of the e-module "Elasticity" within the problem-based learning model integrated with local wisdom in enhancing analytical thinking skills can be evaluated through trials of the e-module in the learning process. Analytical thinking ability is assessed using a pretest-posttest test, which comprises indicators of analytical thinking. The increase in analytical thinking indicators for each indicator in Experiment 1 class (11th Grade Natural Science 2) is depicted in Fig. 2.

Based on Fig. 2, it is evident that there has been a notable increase in each indicator of analytical thinking ability on

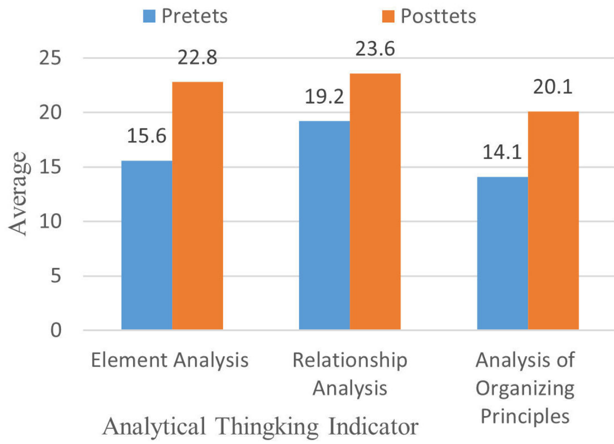

FIGURE 2. Result of analytical thinking per indicator in experiment 1.

average. The most significant enhancement in analytical thinking indicators is observed in the element analysis category, reaching a high magnitude of 0.88. This notable improvement can be attributed to the e-module's utilization of a problem-based learning model, which presents problems grounded in local wisdom surrounding students. Consequently, students find it easier to grasp the material presented, aligning with Bloom's taxonomy.

Moreover, indicators related to relationship analysis and organizational principles analysis show moderate increases, with magnitudes of 0.77 and 0.58 respectively. This is attributed to the e-module's incorporation of problem-based learning, where students engage with problems embedded in local wisdom. Consequently, students can readily connect these presented problems with the theoretical framework of elasticity in solids and propose solutions accordingly.

The increase in analytical thinking skills of students in experimental class 1 can be seen in Fig. 3.

Based on Fig. 3, it can be seen that each student experienced an increase in analytical thinking skills in the medium to high category. This is because the learning media used is

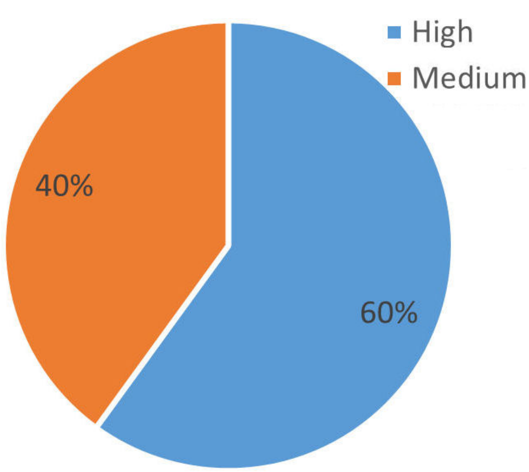

FIGURE 3. Percentage of the enhancing analytical thinking in experiment 1.

in the form of e-modules. Where the developed e-module provides opportunities for students to use information and communication technology via computers or smartphones in the physics learning process. Thus, learning becomes more interesting and flexible.

The use of e-modules in physics learning has the goal that students can learn independently, the teacher is not dominant in learning, students can measure their level of mastery of the material, and accommodate various levels or student learning speeds. This is in line with research [28], which states that e-modules make it easier for students to understand the material by visualizing something abstract in a more real way. So that the use of e-modules in learning physics on elasticity material can improve students' analytical thinking skills. The following research [12] states that e-modules can improve students' analytical thinking skills in physics subjects.

The e-module was developed utilizing a Problem-Based Learning (PBL) model, supported by research findings from [29,30], which assert that Problem-Based Learning enhances analytical thinking skills. This is attributed to the nature of the PBL model, which presents authentic problems as contexts for students to cultivate analytical thinking [31]. Moreover, research from [32] suggests that when students engage in reflective learning within everyday life contexts, their cognitive, affective, and psychomotor learning outcomes are elevated. This is further reinforced by active student involvement in discussions, fostering the development of analytical thinking skills as students grapple with problem-solving [33].

The integration of local culture and wisdom within the problems presented in the e-module. The problems are designed to resonate with the cultural context and heritage of the students' local area. This integration serves a dual purpose: first, it provides students with a deeper connection to the material by making it relevant to their own lived experiences and surroundings. Second, it elevates the cognitive demand of the questions, effectively measuring students' higher-order thinking abilities, particularly their analytical skills.

By incorporating questions that draw upon local culture, students are not only challenged to think critically and analytically but also gain a deeper understanding of their cultural heritage. This approach aligns with research findings [24], which suggest that problem-solving tasks rooted in local culture can enhance students' knowledge about their community's traditions and customs. In essence, the integration of local culture into problem-solving tasks within the e-module not only fosters analytical thinking but also promotes cultural awareness and appreciation among students [24].

3.3. The Effectiveness of E-Module Results to Improve Scientific Attitudes

The evaluation of the e-module's efficacy extended to assessing its impact on enhancing students' scientific attitudes. Figure 4 illustrates the average values derived from the analysis

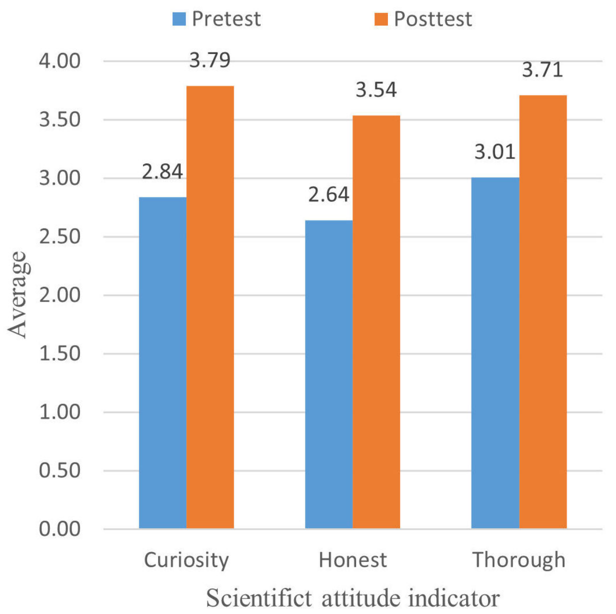

FIGURE 4. Result of scientific attitudes per indicator in experiment 1.

of students' scientific attitudes in Experiment 1 class (11th Grade Natural Science 2).

According to Fig. 4, a noticeable increase is observed in each aspect of students' scientific attitudes. Particularly, the Curiosity indicator exhibits a substantial increase, reaching 0.82 in the high category. This indicator portrays the highest enhancement among the three indicators. This surge can be attributed to the e-module's incorporation of Problem-Based Learning (PBL) methodology, notably in the problem orientation segment, which is seamlessly integrated with local wisdom. This approach aims to stimulate students' curiosity towards learning physics, particularly in understanding elasticity concepts. This finding is corroborated by previous research [17], which suggests that e-modules have the potential to bolster scientific curiosity. Additionally, studies by [34] assert that presenting problems can heighten students' curiosity, a notion supported by [30,35], who further emphasize the efficacy of problem-based learning models in fostering curiosity among students.

Students' honest scientific attitudes similarly demonstrated a noteworthy increase, achieving a magnitude of 0.66 in the moderate category. This finding resonates with previous research [18], which highlights the efficacy of e-modules in fostering honest attitudes. Moreover, studies [22] affirm that problem-based learning models can also contribute to the enhancement of honest attitudes. The e-module under consideration further enriches the learning experience by incorporating practical exercises aimed at resolving presented problems. Students are tasked with presenting data derived from practical experiments and correlating it with established theoretical frameworks. Additionally, fostering honest attitudes in physics education is facilitated by the analysis of real-world problems, contextualized within local wisdom [36].

Students' conscientious attitudes also saw a notable increase, registering at 0.7 in the moderate category. Within this e-book, practical experiments and practice questions are included, encouraging students to approach calculations with care and to consistently note down physics units. This emphasis on precision contributes to the development of conscientiousness among students. These findings are supported by research conducted by [19], which highlights the capacity of e-modules to bolster conscientiousness. Additionally, the problem-based learning model has been shown to have a positive impact on conscientious attitudes [37]. Integrating local wisdom into learning experiences is another avenue for nurturing conscientiousness, as evidenced by research findings [38].

The increase in the scientific attitude of students in experimental class 1 can be seen in Fig. 5.

Based on Fig. 5, it is evident that each student experienced a notable increase in scientific attitude, ranging from moderate to high categories. This enhancement can be attributed to the utilization of e-modules as the learning medium. From the outset of learning, students engaged in independent study and information exploration. The developed e-module integrates various features such as YouTube, Google Forms, and Quizzes, fostering scientific attitudes, particularly curiosity. This finding aligns with research [39], which underscores the e-module's capacity to cultivate students' scientific attitudes.

Moreover, the problems embedded within the e-module are intricately intertwined with local wisdom, enriching students' scientific attitude. This aligns with findings from research [40,41], which suggest that incorporating local wisdom into e-modules can enhance students' scientific attitudes, especially curiosity. Additionally, according to [42],

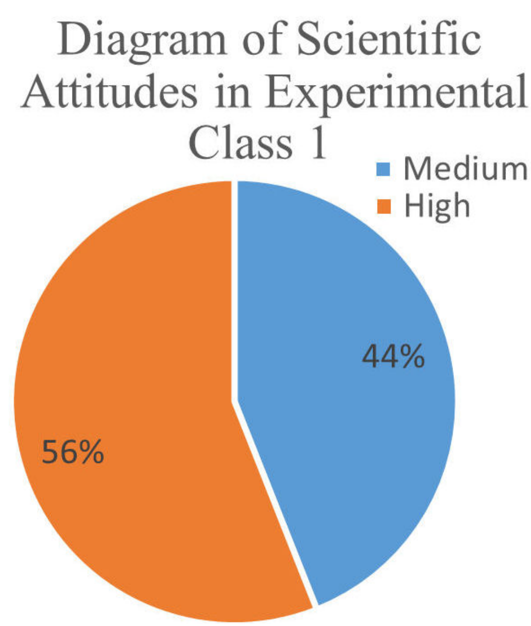

FIGURE 5. Percentage of the enhancing scientific attitudes in experiment 1.

the utilization of learning media that presents contextual problems through discussion can positively contribute to the formation of students' scientific attitudes.

4. Conclusions and recommendations

The e-module on Elasticity, incorporating the Problem-Based Learning (PBL) model and local wisdom, was developed with the aim of enhancing analytical thinking skills and scientific attitudes among 11th-grade students at MAN 1 Yogyakarta. It underwent rigorous validation to ensure its suitability for teaching physics concepts related to elasticity. By integrating problems imbued with local wisdom, the e-module elucidates the intricacies of elasticity, thereby fostering improvements in both analytical thinking and scientific attitude indicators among students. This is substantiated by the observed enhancements in these variables following the implementation of the e-module.

Accessible online, the e-module enables students to engage in independent learning at their convenience. Integrated with platforms such as YouTube, Quisis, and Google Forms, it serves as a comprehensive resource for remote learning, allowing educators to remotely assess students' analytical thinking abilities and scientific attitudes.

For future inquiries in this domain, the developed e-module could be juxtaposed with alternative learning mediums, including offline physics learning activities. Moreover, integrating an online chat platform into this medium would enable students to seek assistance from educators in real-time, enhancing the learning experience. The utilization of this e-module in physics education lays the groundwork for the development of additional online learning resources.

This study provides valuable insights for educators, demonstrating the efficacy of delivering physics education even in the absence of face-to-face interaction. However, a pertinent question arises: will distance learning practices endure as part of instructional methods post-pandemic? Addressing this query presents new challenges in exploring instructional media that can be effectively utilized in the future.

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1. Z. Hidayatullah *et al*., Synthesis of the 21st Century Skills (4C) Based Physics Education Research In Indonesia, *JIPF (Jurnal Ilmu Pendidikan Fisika)* **6** (2021) 1889, `https://doi.org/10.26737/jipf.v6i1.1889`.
2. A. Fahlevi and A. Asrizal, Efektivitas E-modul Getaran dalam Kehidupan Sehari-Hari pada Pembelajaran Daring Untuk Meningkatkan Keterampilan Proses Sains Siswa, *Jurnal Pendidikan Fisika dan Teknologi* **7** (2021) 2997, `https://doi.org/10.29303/jpft.v7i2.2997`.
3. F. Hannum, S. Sukarmin, and C. Cari, Pengembangan Modul Fisika Berbasis Learning Cycle 5e Untuk Meningkatkan Kemampuan Berpikir Analitis Siswa, *Inkuiri: Jurnal Pendidikan IPA* **8** (2019), `https://doi.org/10.20961/inkuiri.v8i1.31824`.
4. S. M. Z. Putri, C. Cari, and W. Sunarno, Analysis of Analytical Thinking and Misconceptions on the Concepts of Heat and Temperature on Physics Students, *J. Phys.: Conf. Ser.* **1233** (2019) 012031, `https://doi.org/10.1088/1742-6596/1233/1/012031`.
5. L. W. Anderson and D. R. Kratwohl, Kerangka Landasan untuk Pembelajaran, Pengajaran, dan Asesmen Revisi Taksonomi Pendidikan Bloom, (Pustaka Pelajar 2015).
6. D. Riwanto, A. Azis, and K. Arafah, Analisis Pemahaman Konsep Peserta Didik Dalam Menyelesaikan Soal-Soal Fisika Kelas X Mia Sma Negeri 3 Soppeng, *Jurnal Sains dan Pendidikan Fisika* **15** (2019) 11033, `https://doi.org/10.35580/jspf.v15i2.11033`.
7. M. K. Azmi, S. Rahayu, and H. Hikmawati, Pengaruh Model Problem Based Learning dengan Metode Eksperimen dan Diskusi Terhadap Hasil Belajar Fisika Ditinjau dari Sikap Ilmiah Siswa Kelas X MIPA SMA N 1 Mataram, *Jurnal Pendidikan Fisika dan Teknologi* **2** (2017) 86, `https://doi.org/10.29303/jpft.v2i2.294`.
8. S. Maiyena and M. Imamora, Pengembangan Modul Elektronik Fisika Berbasis Konstruktivisme untuk Kelas X SMA, *Journal of Teaching and Learning Physics* **5** (2020) 5739, `https://doi.org/10.15575/jotalp.v5i1.5739`.
9. A. Hidayatulloh, Analisis Kesulitan Belajar Fisika Materi Elastisitas Dan Hukum Hooke Dalam Penyelesaian *Soal-Soal Fisika* **4** (2020) 69, `https://doi.org/10.29408/kpj.v4i1.1636`.
10. A. Mishra, S. Rani, and U. D. Bhardwaj, Effectiveness of Elearning Module on First Aid: A Study on Student Nurses, *Int. J. Nurs. Educ.* **9** (2017) 5, `https://doi.org/10.5958/0974-9357.2017.00060.5`
11. T. R. Padwa and P. N. Erdi, Penggunaan E-Modul Dengan Sistem Project Based Learning, JAVIT : *Jurnal Vokasi Informatika* **1** (2021) 23, `https://doi.org/10.24036/javit.v1i1`.
12. M. Maisaroh, T. Mayasari, and M. Sasono, Pengembangan Modul Elektronik Berbasis Real Life Learning Untuk Meningkatkan Kemampuan Analisis Siswa SMK, *Jurnal Ilmiah Pendidikan Fisika* **4** (2020) 33, `https://doi.org/10.20527/jipf.v4i1.1776`
13. S. Novelyya, Pengaruh Karakter Rasa Ingin Tahu Siswa Terhadap Hasil Belajar Mata Pelajaran Ipa Fisika Di Smp Negeri 08 Muaro Jambi, Briliant: *Jurnal Riset dan Konseptual* **4** (2019) 291, `https://doi.org/10.28926/briliant.v4i2.291`.
14. M. Sari, M. Habibi, and R. Putri, Pengaruh Model Pembelajaran Kooperatif Tipe Think-Pairs-Share Dalam Pembela-

jaran Matematika Terhadap Kemampuan Pemahaman Konsep Matematis dan Pengembangan Karakter Siswa SMA Kota Sungai Penuh, Edumatika: *Jurnal Riset Pendidikan Matematika* **1** (2018) 221, https://doi.org/10.32939/ejrpm.v1i1.221

15. L. Anggraini and R. Perdana, Deskripsi Sikap Siswa Pada Mata Pelajaran Fisika di Sekolah Menengah Pertama, *PSEJ (Pancasakti Science Education Journal)* **4** (2019) 7, https://doi.org/10.24905/psej.v4i2.7.
16. R. Supardi, E. Istiyono, and W. Setialaksana, *Developing Scientific Attitudes Instrument of Students in Chemistry*, **1233** (2019) 012025, https://doi.org/10.1088/1742-6596/1233/1/012025.
17. Y. Yulkifli, Y. Yohandri, and H. Azis, Development of physics e-module based on integrated project-based learning model with Ethno-STEM approach on smartphones for senior high school students, *Momentum Phys. Educ. J.* **6** (2022) 93, https://doi.org/10.21067/mpej.v6i1.6316.
18. P. I. Anwar *et al*., Character Education Oriented Physics EModule Development in the Static Fluid Section, *Berkala Ilmiah Pendidikan Fisika* **9** (2021) 174, https://doi.org/10.20527/bipf.v9i2.10518.
19. D. Chen *et al*., Deskripsi Keterampilan Proses Sains Dasar Siswa Kelas VIII Pada Materi Cermin Cekung, *PENDIPA Journal of Science Education* **5** (2020) 50, https://doi.org/10.33369/pendipa.5.1.50-55.
20. R. I. Arends, Learning to Teach. 9th ed. (McGraw-Hill, 2012).
21. E. Nasution, Pembelajaran Berbasis Masalah sebagai Salah Satu Upaya Meningkatkan Kemampuan Analisis dan Penalaran Peserta Didik, *Instructional Development Journal* **3** (2020) 11788, https://doi.org/10.24014/idj.v3i2.11788.
22. M. D. Prastika, M. Wati, and S. Suyidno, The Effectiveness of Problem-Based Learning in Improving Students Scientific Literacy Skills and Scientific Attitudes, *Berkala Ilmiah Pendidikan Fisika* **7** (2019) 185, https://doi.org/10.20527/bipf.v7i3.7027.
23. M. P. E. Morales, Influence of culture and language sensitive physics on science attitude enhancement, *Cult. Stud. of Sci. Educ.* **10** (2015) 951, https://doi.org/10.1007/s11422-015-9669-5.
24. F. Mulyatna, A. Imswatama, and N. D. Rahmawati, Design Ethnic-Math HOTS: Mathematics Higher Order Thinking Skill Questions Based On Culture and Local Wisdom, Malikussaleh *Journal of Mathematics Learning (MJML)* **4** (2021) 48, https://doi.org/10.29103/mjml.v4i1.3059.
25. Y. Nurmaya *et al*., Pengembangan Perangkat Pembelajaran Model Inkuiri Terbimbing Pada Materi Alat-Alat Optik Untuk Meningkatkan Penguasaan Konsep Fisika, *Orbita: Jurnal Kajian, Inovasi dan Aplikasi Pendidikan Fisika* **7** (2021) 147, https://doi.org/10.31764/orbita.v7i1.3835.
26. D. E. Meltzer, The relationship between mathematics preparation and conceptual learning gains in physics: A possible “hidden variable” in diagnostic pretest scores, *Am. J. Phys.* **70** (2002) 1259, https://doi.org/10.1119/1.1514215.
27. L. A. Becker, Effect Size (ES) (2000), https://web.uccs.edu/lbecker/Psy590/es.htm.
28. R. Seruni *et al*., Implementation of e-module flip PDF professional to improve students’ critical thinking skills through problem based learning, *J. Phys.: Conf. Ser*. **1521** (2020) 042085, https://doi.org/10.1088/1742-6596/1521/4/042085.
29. S. Sucipto, Pengembangan Ketrampilan Berpikir Tingkat Tinggi dengan Menggunakan Strategi Metakognitif Model Pembelajaran Problem Based Learning, *Jurnal Pendidikan (Teori dan Praktik)* **2** (2017) 77, https://doi.org/10.26740/jp.v2n1.p77-85.
30. Y. A. Sujatmiko *et al*., The development of andro-webcomic media based on problem-based learning to improve analytical thinking ability and scientific attitude, *J. Phys.: Conf. Ser*. **1918** (2021) 052023, https://doi.org/10.1088/1742-6596/1918/5/052023.
31. S. Dole, L. Bloom, and K. K. Doss, Engaged learning: Impact of PBL and PjBL with elementary and middle grade students, *Interdiscip. J. Probl.-based Learn.* **11** (2017) 2, https://doi.org/10.7771/1541-5015.1685.
32. Lisdiana,W. Isnaeni, and D. Anggarani, Smoking behavior and learning outcomes in student of senior high school on respiratory system with PjBL, *J. Phys.: Conf. Ser*. **1321** (2019) 032095, https://doi.org/10.1088/1742-6596/1321/3/032095.
33. R. Sari *et al*., The Implementation of Problem-based Learning Model with Online Simulation to Enhance the Student’s Analytical Thinking Skill in Learning Physics, *J. Phys.: Conf. Ser*. **1233** (2019) 012030, https://doi.org/10.1088/1742-6596/1233/1/012030.
34. I. Fadilah and S. Kartini, Identifikasi Sikap Rasa Ingin Tahu Siswa Terhadap Pembelajaran Fisika Di Man 1 Batanghari, Sukma: Jurnal Pendidikan **3** (2019) 217, https://doi.org/10.32533/03205.2019.
35. M. D. Agustin, A. D. Lesmono, and H. M. Widodo, Model Problem Based Learning (Pbl) Dengan Pendekatan Science Technology Engineering Mathematics (Stem) Dalam Pembelajaran Fisika Materi Elastisitas Di Kelas Xi Mipa 4 Sma Negeri 2 Jember, *Jurnal Pembelajaran Fisika* **9** (2020) 17964, https://doi.org/10.19184/jpf.v9i1.17964.
36. E. Maryam, A. Fahrudin, and R. Romadon, Desain Kurikulum Pengajaran Fisika Terintegrasi Etnosain untuk Menumbuhkan Karakter Cinta Tanah Air, *Jurnal Pendidikan MIPA* 12 (2022) 1125, https://doi.org/10.37630/jpm.v12i4.754.
37. E. Zarvianti and D. Sahida, Designing Comics By Using Problem Based Learning (PBL) to Improve Student’s Creative Thinking Skills, *International Journal of Social Learning (IJSL)* **1** (2020) 75, https://doi.org/10.47134/ijsl.v1i1.8.
38. A. N. Rahmatih, M. A. Maulyda, and M. Syazali, Refleksi Nilai Kearifan Lokal (Local Wisdom) dalam Pembelajaran Sains Sekolah Dasar: Literature Review, *Jurnal Pijar Mipa* **15** (2020) 151, https://doi.org/10.29303/jpm.v15i2.1663.

39. D. Darmaji *et al*., Students' perceptions of electronic's module in physics practicum, *Journal of Education and Learning (EduLearn)* **13** (2019) 288, https://doi.org/10.11591/edulearn.v13i2.13005.

40. I. W. Suastra and I. G. Arjana, Scientific Approach-Integrated Local Wisdom Content, In Proceedings of the 5th Asian Education Symposium 2020 (AES 2020) (Atlantis Press, 2021) pp. 463-468, https://doi.org/10.2991/assehr.k.210715.095.

41. L. Fitriah, Efektivitas buku ajar fisika dasar 1 berintegrasi imtak dan kearifan lokal melalui model pengajaran langsung, *Berkala Ilmiah Pendidikan Fisika* **7** (2019)82, https://doi.org/10.20527/bipf.v7i2.5909.

42. A. Dwianto *et al*., The development of science domain based learning tool which is integrated with local wisdom to improve science process skill and scientific attitude, *J. Pendidikan IPA Indonesia* **6** (2017) 23, https://doi.org/10.15294/jpii.v6i1.7205.