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Enhancing Students' Scientific Attitudes through STEM-Integrated POE Learning Supported by the Web S.id Platform

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Abstract *- The development of students' scientific attitudes remains a major concern in physics education, as classroom instruction still tends to prioritize cognitive achievement over cultivating attitudes such as curiosity, respect for evidence, critical reflection, flexibility in thinking, and sensitivity to the environment. This study aimed to examine the effect of integrating the STEM approach with the Predict–Observe–Explain (POE) learning model, supported by the Web S.id platform, on senior high school students' scientific attitudes when studying static fluids. The study employed a quantitative quasi-experimental method using a nonequivalent control group pretest–posttest design. The participants were 63 eleventh-grade students selected through purposive sampling and divided into an experimental group (32 students) and a control group (31 students). Students' scientific attitudes were measured using a 12-item questionnaire with acceptable reliability (Cronbach's alpha = 0.72). The data were analyzed for normality and homogeneity, and an independent-samples t-test and N-gain analysis were conducted. The results showed that the experimental group achieved greater improvement than the control group, with posttest means of 49.16 and 46.61, respectively, and a statistically significant difference between groups (p = 0.032). The effect size was moderate (Cohen's d = 0.55). N-gain analysis further indicated that all measured indicators of scientific attitude improved more strongly in the experimental group, with the highest gain found in sensitivity in investigating the environment (g = 0.350). The novelty of this study lies in integrating STEM and POE through the Web S.id digital platform, while positioning scientific attitude as the primary outcome in physics learning, particularly in a simple water-dispenser project on static fluids. In conclusion, the STEM-integrated POE learning model supported by Web S.id was effective in fostering students' scientific attitudes. This study contributes to physics education by providing an empirically supported instructional alternative that integrates project-based STEM learning, inquiry-oriented pedagogy, and digital media to strengthen affective outcomes alongside conceptual learning.*

Keywords: *physics education; scientific attitudes; static fluid learning; STEM-POE learning; Web S.id*

I. INTRODUCTION

Within physics education, scientific attitudes are essential because they reflect the rational, objective, and evidence-based mindset that underpins scientific inquiry. However, classroom practices still tend to emphasize cognitive achievement, while the development of students' character and scientific attitudes often receives less attention (Suryantari et al., 2019). In fact, education should not only support mastery of subject matter but also cultivate attitudes that emerge through engagement in scientific processes. In practice, many students are still not accustomed to conducting experiments or participating independently in scientific activities during science learning (Susilawati et al., 2022). This limited involvement in scientific processes hinders the achievement of optimal learning outcomes. Without well-developed scientific attitudes, the process of acquiring knowledge can be constrained (Raj & Malliga, 2015). Therefore, innovation in physics education is needed not only to strengthen cognitive abilities but also to sustainably foster students' scientific attitudes. This need aligns with the current curriculum orientation, which shifts learning from teacher-centered instruction toward student-centered approaches (Rahman et al., 2021). Such an orientation is expected to help students understand concepts and enhance their ability to analyze problems, generate creative ideas, communicate effectively, and collaborate with others (Novianti et al., 2023).

Evidence from PISA 2022 indicates that Indonesian students' performance in science remains relatively low, particularly in understanding scientific concepts and applying scientific principles (OECD, 2023). This condition is consistent with the findings of Kusherawati et al. (2020), who reported that students' scientific attitudes are generally low. One major challenge in fostering scientific attitudes lies in the limitations of the instructional approaches commonly used by teachers. Lecture-dominated practices, limited classroom interaction, and insufficient opportunities for meaningful scientific activities hinder the development of students' scientific mindsets (Yildirim & Dogru, 2023; Annisa, 2018). This issue becomes more pronounced in physics, which is often perceived as a difficult subject, especially when students have limited opportunities to engage in experiments and inquiry-based activities that can nurture scientific attitudes (Astalini et al., 2020).

To promote the development of scientific attitudes, teachers need to adopt instructional strategies that encourage active student participation. One promising approach is STEM-based project learning, which engages students in solving practical problems encountered in real-life contexts (Kurniati et al., 2022). Such an approach supports the application of theoretical knowledge in authentic situations while strengthening students' scientific process skills and scientific mindsets (Ginting et al., 2022; Nurmayanti & Kristayulita, 2024). In this study, the STEM approach was reinforced by integrating the POE (Predict–Observe–Explain) learning model. POE requires students to predict phenomena, observe processes, and explain outcomes based on scientific concepts. Previous studies have shown that POE can promote critical thinking and support the development of scientific attitudes (Yatmanto et al., 2024; Fitriani et al., 2020), while also providing space for exploration and active participation (Fauziah et al., 2023; Prabawati et al., 2020; Yuenyong & Yuenyong, 2021).

In the twenty-first century, learning is also expected to be integrated with digital technology. Digital platforms such as Web S.id offer an innovative alternative by enabling teachers and students to create interactive learning environments in practical and creative ways (Annisa & Asrizal, 2022). This platform can support STEM–POE integration in digital form, thereby encouraging active engagement and critical thinking. Its ease of use and accessible interface make it suitable for contemporary learners (Nicolaou, 2021). Previous research has also shown that digital media can enhance students' scientific attitudes (Saputri & Wilujeng, 2017; Ribawa et al., 2024). Based on observations and interviews conducted at SMAN 5 Banda Aceh, the implementation of the Merdeka Curriculum has not yet fully supported the development of scientific attitudes, partly due to teachers' limited understanding of innovative instructional approaches.

A number of previous studies have demonstrated the effectiveness of POE in science learning. Hong et al. (2021) reported that POE contributes positively to academic achievement, attitudes toward science, and learning retention. Similarly, Erdem Özcan and Uyanık (2022) found that POE improves academic achievement, attitudes, and retention in science learning. However, a scientific attitude has rarely been positioned as the primary outcome of these studies. In addition, the specific dimensions of scientific attitude, such as curiosity, open-mindedness, and respect for evidence, have not been examined in sufficient depth. Wang and Wang (2023) also showed that integrating POE into STEM education improves learning effectiveness and outcomes, yet explicit assessment of scientific attitude remains limited. Furthermore, none of these studies employed Web S.id as a local web-based platform to facilitate prediction, observation, and explanation activities and to directly support the development and measurement of scientific attitudes in physics learning.

Likewise, Nengsih et al. (2023) found that POE-oriented student worksheets effectively improved science process skills in static fluid pressure material at the junior high school level. However, their study did not examine scientific attitudes or integrate STEM or digital media. Meanwhile, Hikmah et al. (2025) demonstrated, through a meta-analysis, that STEM integration is effective in improving students' scientific attitudes in science and physics learning. Even so, most STEM studies remain general in scope and have not linked STEM with a specific learning model supported by digital technology to examine scientific attitudes more directly. Therefore, a research gap remains in the integration of STEM, POE, and digital media to promote students' scientific attitudes in physics learning.

Based on this gap, the present study investigates the effect of integrating the STEM approach with the POE learning model through the Web S.id platform on students' scientific attitudes in static fluid learning. This study is distinct in emphasizing a scientific attitude as the primary outcome and in implementing the instructional design through a simple water-dispenser project in senior high school physics.

II. METHODS

A. Research design

This study employed a quantitative quasi-experimental method using a nonequivalent control group pretest–posttest design (Sugiyono, 2024). The participants were eleventh-grade students from the science track at a public senior high school. Two classes were selected through purposive sampling. One class, consisting of 32 students, was assigned as the experimental group, while another class, consisting of 31 students, served as the control group.

The experimental group received instruction through a STEM-based approach integrated with the POE model and supported by the Web S.id platform. In contrast, the control group was taught using the POE model with Web S.id support but without integration of the STEM approach.

Table 1. Nonequivalent control group design

Cohort	Pretest	Intervention	Posttest
Experiment	O_1	X	O_2
Control	O_3	-	O_4

In this design, O_1 and O_3 represent the pretest measurements, whereas O_2 and O_4 represent the posttest measurements of students' scientific attitudes.

B. Instrument and data collection

Students' scientific attitudes were measured using a 12-item questionnaire. Responses were rated on a five-point Likert scale ranging from strongly disagree to strongly agree. The instrument covered several dimensions of scientific attitude, including curiosity, respect for evidence, flexibility in ways of thinking, critical reflection, and sensitivity in investigating the environment.

The content validity of the instrument was evaluated by two field experts and one physics teacher, with attention to the relevance and clarity of each item. Based on their suggestions, revisions were made before the instrument underwent empirical validation via item–total correlation analysis. The empirical validation results indicated that all 12 items were valid. The instrument also demonstrated acceptable internal consistency, with a Cronbach's Alpha coefficient of 0.72.

The questionnaire was administered to both the experimental and control groups before and after the intervention in order to identify changes in students' scientific attitudes.

C. Data analysis

The collected data were analyzed using SPSS version 26.0. Prior to hypothesis testing, the data were examined through prerequisite tests, including tests of normality and homogeneity. After these assumptions were met, differences between groups were analyzed using an independent-samples t-test at a significance level of 0.05.

In addition, changes in students' scientific attitudes in both groups were examined using the N-gain test. This analysis was conducted by comparing students' scores before and after the implementation of the learning treatment. The N-gain values were calculated using the formula proposed by Hake (2002) and supported by Sukarelawan et al. (2024).

$$g = \frac{\text{posttest score} - \text{pretest score}}{\text{maximum score} - \text{pretest score}} \quad (1)$$

Table 2. N-gain criteria

N-Gain	Criteria
$g > 0.7$	High
$0.3 < g \leq 0.7$	Medium
$g \leq 0.3$	Low

D. Scientific attitude indicators

The scientific attitude indicators used in this study were compiled by considering several expert perspectives, as presented in Table 3.

Table 3. Scientific attitude indicators

Harlen (2000)	Supardi et al., (2019)	Khan and Siddiqui (2020)
Curiosity	Curiosity	Rationality
Respect for evidence	Honesty	Open mindedness
Flexibility in ways of thinking	Objectify	Confidence in scientific method
Critical reflection	Perseverance	Curiosity
Sensitivity in investigating the environment	Conscientious	Aversion to superstition
	Open-mindedness	
	Being critical	
	Being Responsible	

(Harlen, 2000; Supardi et al., 2019; Khan & Siddiqui, 2020)

Based on these expert perspectives, the indicators proposed by Harlen (2000) were selected for the instrument because they provide a comprehensive framework for representing key affective dimensions in science learning. The five selected indicators capture essential aspects of scientific thinking that are aligned with the goals of contemporary education.

E. Research procedure

The research procedure was carried out in several interrelated stages: preparation of the learning instruments and research tools; administration of the pretest; implementation of the learning treatment in both groups; administration of the posttest; and statistical analysis of the collected data. The overall procedure is illustrated in the flowchart presented in Figure 1.

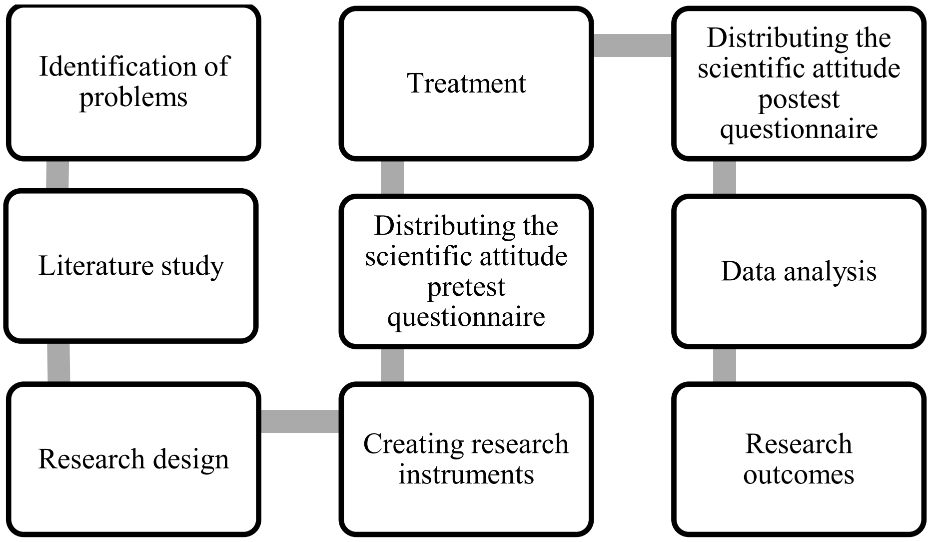

Figure 1. Research phases in this study

III. RESULTS

At the beginning of the study, the experimental group obtained a mean pretest score of 38.69 (SD = 5.20), while the control group obtained a mean pretest score of 40.39 (SD = 4.28). These results indicate that the two groups started the study with relatively comparable levels of scientific attitude.

Table 4. Descriptive statistics of students' scientific attitude scores

Groups	Test	Mean	Standard deviation
Experimental	Pretest	38.69	5.20
	Posttest	49.16	4.04
Control	Pretest	40.39	4.28
	Posttest	46.61	5.14

After the intervention, the experimental group showed a higher posttest mean score (49.16, SD = 4.04) than the control group (46.61, SD = 5.14). This finding suggests that students who participated in learning through the STEM-integrated approach demonstrated greater improvement in scientific attitude than those who received learning without STEM integration. In addition, the effect size, as measured by Cohen's *d*, was 0.55, indicating a medium effect.

Before testing the hypothesis, prerequisite tests were conducted, including tests of normality and homogeneity of variance.

Table 5. Results of the normality test for scientific attitude questionnaire data

Normality assessments							
		Kolmogorov-Smirnov			Shapiro-Wilk		
	Class	Calculated	Df	Sig.	Calculated	df	Sig.
Pretest questionnaire experimental and control classes	1.00	.146	32	.080	.967	32	.414
	2.00	.098	31	.200*	.966	31	.416
Posttest questionnaire experimental and control classes	1.00	.113	32	.200*	.959	32	.258
	2.00	.094	31	.200*	.976	31	.708

The normality test results show that all significance values from both the Kolmogorov–Smirnov and Shapiro–Wilk tests were greater than 0.05. Therefore, the data for both the experimental and control groups were normally distributed and met the assumptions required for further parametric analysis.

Table 6. Results of the homogeneity test

Variance homogeneity assessment					
		Levene's test	df1	df2	Sig.
Pretest questionnaire for the experimental and control classes	Using the mean value	.138	1	61	.712
	Median based	.153	1	61	.697
	Median-based Modifications df	.153	1	54.744	.697
	Based on the trimmed mean	.140	1	61	.710
Posttest of the experimental and control class questionnaire	Using the mean Value	.658	1	61	.421
	Median based	.659	1	61	.420
	Median-based modification df	.659	1	55.199	.420
	Using the trimmed mean	.675	1	61	.414

The homogeneity test results indicate that all significance values were above 0.05. This means that the variances of the data in the two groups were homogeneous, and the data met the assumption of equal variance.

Table 7. Results of the independent samples t-test

Independent t- test for the sample

t-Test for Equality of Means				
		Sig (2 tailed)	Average discrepancy	Std. error of the discrepancy
Questionnaire results	Assuming equal variances	.032	2.54335	1.16229
	Assuming unequal variances	.033	2.54335	1.16671

The results of the independent-samples t-test show a significance value of 0.032 under the assumption of equal variances, which is below the significance level of 0.05. This indicates a statistically significant difference between the mean scores of the experimental and control groups. Thus, the null hypothesis was rejected, and the alternative hypothesis was accepted. These findings confirm that the STEM-integrated POE learning approach, supported by the Web S.id platform, had a significant effect on students' scientific attitudes.

To examine the magnitude of improvement in each scientific attitude indicator, an N-gain analysis was conducted for both groups.

Table 8. Comparison of N-gain scores for scientific attitude indicators

Scientific attitude indicator	**N-Gain experimental class**	**Category**	**N-gain control class**	**Category**
Curiosity	0.324	Medium	0.159	Low
Respect for evidence	0.341	Medium	0.201	Low
Flexibility in ways of thinking	0.319	Medium	0.239	Low
Critical reflection	0.305	Medium	0.282	Low
Sensitivity in investigating the environment	0.35	Medium	0.132	Low

Table 8 shows that the experimental class achieved higher N-gain scores across all scientific attitude indicators than the control class. All indicators in the experimental group were classified as medium, whereas all indicators in the control group remained low. The greatest improvement in the experimental class was observed in sensitivity to the environment ($g = 0.350$), while the control class showed only a small improvement on the same indicator ($g = 0.132$). This result suggests that the STEM approach integrated with the POE model and supported by Web S.id was more effective in improving students' scientific attitudes across all measured dimensions.

Figure 2 presents a visual comparison of the N-gain scores for the five scientific attitude indicators in both groups.

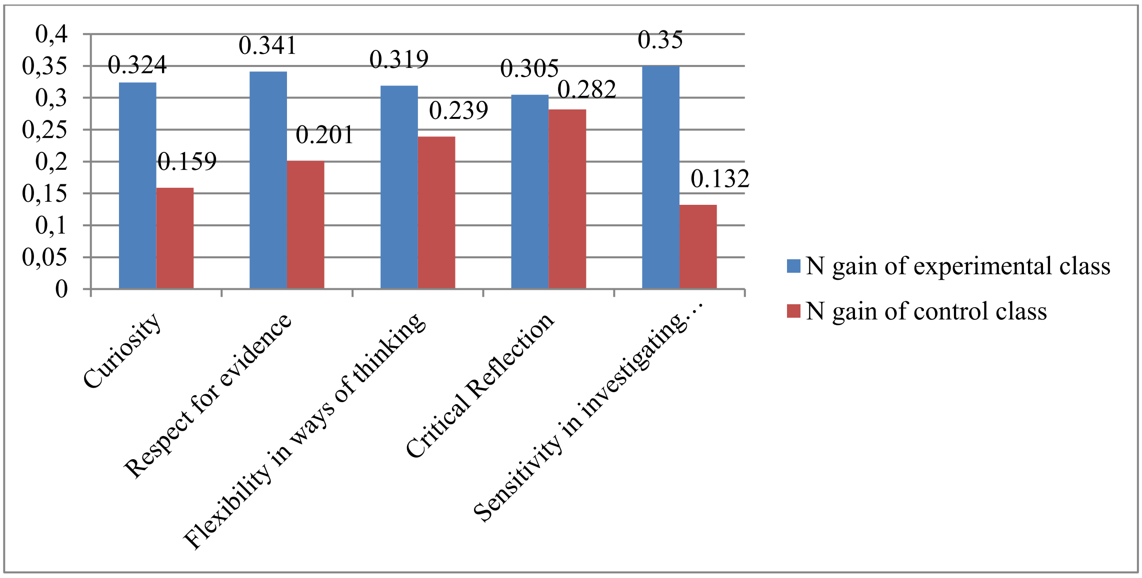

Figure 2. Scientific attitude graph between two classes

IV. DISCUSSION

This study examined the integration of a STEM-based approach with the POE learning model, supported by the Web S.id platform, in fostering students' scientific attitudes in physics learning. The findings showed that the experimental group improved more than the control group, as reflected in both the posttest results and the N-gain scores across all indicators. These results indicate that the combination of STEM activities, the POE model, and Web S.id was more effective in promoting students' scientific attitudes at the senior high school level. This finding is consistent with Lestari and Muhajir (2024), who reported that STEM-based activities in physics learning can increase student engagement and curiosity. Likewise, Annam et al. (2020) found that the POE model contributes positively to students' development of critical thinking.

Compared with previous studies, the present findings also suggest that integrating digital media may strengthen the effectiveness of STEM and POE implementation. Rogayan and Nebrida (2019), for example, reported that although students demonstrated awareness of environmental issues, this did not necessarily translate into greater concern for environmental conservation. In the present study, however, improvement was observed across several scientific attitude indicators, including sensitivity in investigating the environment. This difference may be associated with the use of Web S.id as an interactive digital medium that more systematically supported prediction, observation, and explanation activities. Therefore, although STEM and POE have each been shown to be effective, their integration with digital technology appears to provide additional value in supporting affective learning outcomes. This interpretation is also in line with Yennita et al. (2025), who emphasized that STEM-oriented learning can create meaningful learning experiences while improving both cognitive and affective domains.

Overall, the improvement observed in this study indicates that integrating STEM and POE encouraged students to participate actively in contextual, real-world problem-solving activities. The STEM approach not only develops cognitive and psychomotor skills but also supports affective development, particularly scientific attitudes, which are essential in scientific, technological, and social contexts. A positive scientific attitude helps students investigate phenomena more constructively and interact meaningfully during learning activities such as discussions and group work (Dewi et al., 2020). In addition, the changes observed in students' scientific attitudes reinforce the view that such attitudes are not fixed traits, but can be developed through learning experiences and environmental influences (Ernawati et al., 2022).

1. Sensitivity in investigating the environment

The greatest improvement in the experimental group was found in sensitivity in investigating the environment. This improvement was reflected in students' involvement in designing a simple dispenser project on static fluids using the STEM approach and the POE model. During this process, students were encouraged to consider efficiency and environmental impact at each stage of learning, which helped foster responsibility and awareness toward their surroundings. This approach not only strengthened students' conceptual understanding but also encouraged them to make decisions based on scientific reasoning and environmental considerations. This finding is consistent with Samudera et al. (2017), who emphasized the importance of scientific character, including environmental awareness. It is also supported by Mayangsari et al. (2020) and Suastra and Ristiati (2019), who highlighted the importance of learning models that promote interaction, exploration, reflection, and environmental awareness.

Through the STEM–POE sequence, students first identified contextual problems in the Ask stage, corresponding to the Predict phase in POE, such as considering the use of recycled materials to produce a simple, environmentally friendly dispenser. In the Plan and Create stages, which corresponded to Observe, students designed and constructed the product while considering water efficiency and environmental impact. The Explain stage allowed students to connect scientific concepts with the outcomes of their design, while the Improve stage guided them to revise their products based on feedback. These activities appear to have helped students develop greater sensitivity toward environmental issues and sustainability in problem-solving.

2. Respect for evidence

The indicator of respect for evidence also showed improvement in the experimental group. In STEM-based learning integrated with the POE model and supported by Web S.id, students were required to make predictions, conduct observations, and compare the results with their initial assumptions. When the observed outcomes differed from their expectations, students were encouraged to accept the findings objectively and revise their understanding accordingly. This process cultivated a scientific attitude that values empirical evidence over personal assumptions.

The Predict and Observe stages of the POE model played an important role in this process because they required students to formulate initial ideas and then confront those ideas with evidence obtained through observation and experimentation. Such activities are closely related to the development of conceptual understanding and science process skills, as reported by Fiteriani et al. (2023). In the context of this study, integrating STEM and POE also helped students become more familiar with evidence-based reasoning during the design and testing processes. This finding is in line with Venida and Sigua (2021), who argued that POE-based instruction can foster positive attitudes toward science, including objectivity, respect for evidence, and rational thinking in problem solving.

3. Critical reflection

The improvement in critical reflection was relatively limited compared with the other indicators. This may be because the Explain stage of the POE model was not yet used optimally as a space for in-depth analysis of predictions and observations. Limited time allocation, insufficient reflective prompts, and students' unfamiliarity with reflective learning practices may have constrained the development of this aspect. In addition, limited conceptual understanding and insufficient content mastery may have contributed to the low level of students' critical reflection.

This finding suggests that developing critical reflection requires more explicit instructional support. Strategies such as reflective guiding questions, structured discussion sessions, and opportunities for deeper conceptual evaluation may help strengthen this dimension of scientific attitude. This interpretation is consistent with Larasati et al. (2018), who emphasized the importance of POE in promoting critical thinking when properly facilitated. It is also supported by Indrašienė et al. (2023), who argued that critical reflection is not merely a metacognitive activity, but also a process that encourages individuals to examine assumptions, reconsider beliefs, and make meaningful changes in thought and action.

Within the STEM–POE process, the Ask and Plan stages should provide opportunities for students to evaluate alternative solutions, while the Explain and Improve stages should serve as moments to review conceptual accuracy, product effectiveness, and the reasoning underlying the design process. In this study, however, these reflective opportunities may not yet have been sufficiently developed. Therefore, although the STEM-integrated POE model contributed to the development of scientific attitudes overall, more deliberate strategies are still needed to strengthen students' critical reflection.

4. Flexibility in ways of thinking

Flexibility in ways of thinking also improved in the experimental group. Through the Ask and Imagine activities, which correspond to the Predict stage in POE, students were encouraged to consider multiple possible solutions for the simple dispenser design. During the Plan and Create stages, students tested various ideas and adjusted their approaches as needed. In the Improve stage, they revised their strategies based on feedback and observation results. These experiences helped students become more open to alternative ideas and more adaptive in solving problems.

This finding is consistent with Hebebci and Usta (2022), who found that STEM practices can improve students' problem-solving abilities, scientific creativity, and critical thinking dispositions. It is also supported by Waters and Orange (2022), who argued that a STEM-driven learning culture strengthens collaboration, adaptive thinking, and strategic flexibility. In addition, the meta-analysis conducted by Öndeş (2025) confirmed that STEM practices significantly enhance students' problem-solving skills, especially when learning activities involve iterative design and revision.

The present results suggest that flexibility in thinking can be developed when students are placed in learning situations that require them to generate, test, and refine solutions. The integration of STEM and POE appears to support this process effectively because students are asked not only to understand concepts but also to apply them in designing solutions to contextual problems.

5. Curiosity

Curiosity in the experimental group also increased, although the degree of improvement remained moderate. At the Ask stage, which corresponds to the Predict phase in POE, students were encouraged to ask questions, identify real-world problems, and propose initial solutions. The Plan and Create stages provided opportunities to test these ideas, while the Improve stage allowed students to continue exploring and refining their work. Web S.id also supported this process by facilitating access to information, prediction activities, observation records, and discussion.

Although the experimental group showed greater improvement than the control group, the increase in curiosity was still not optimal. One possible reason is that the projects were relatively structured, which may have limited students' freedom to explore more independently. In addition, students' passive learning habits and limited experience with self-directed inquiry may have also reduced the growth of natural curiosity. These findings suggest that STEM-based learning should be enriched with more exploratory, open-ended activities to more strongly stimulate curiosity.

This result supports the view that the POE model, combined with the STEM approach and digital media such as Web S.id, can provide better outcomes than instruction without STEM integration. It is also in line with Barokah et al. (2024), who argued that the STEM approach is an effective learning method because it integrates multiple domains of knowledge and enhances students' cognitive, psychomotor, and affective abilities. In this context, a scientific attitude can be understood as a student's readiness and inclination to engage in scientific practice during learning (Jamaluddin et al., 2024).

Overall, this study offers further insight into how digitally supported STEM learning through project-based activities can strengthen students' scientific attitudes in physics education. The findings provide practical implications for teachers and policymakers in designing learning environments that integrate STEM, POE, and digital tools to support the development of key twenty-first-century competencies. In addition, the instructional model used in this study can be adapted to other physics topics beyond static fluid material.

V. CONCLUSION AND SUGGESTION

The findings of this study indicate that integrating the STEM approach with the POE learning model, supported by the Web S.id platform, was effective in improving senior high school students' scientific attitudes in the study of static fluids. Students in the experimental group showed greater improvement than those in the control group, as reflected in the posttest results and the N-gain scores across all scientific attitude indicators. Among these indicators, the highest improvement was found in sensitivity in investigating the environment. Overall, the results confirm that STEM-integrated POE learning, supported by digital media, can provide meaningful learning experiences that foster students' scientific attitudes toward physics learning.

This study has several limitations that should be considered. First, the sample was limited to two classes in one senior high school, which may limit the generalizability of the findings to other educational contexts. Second, although the instrument had acceptable validity and reliability, further refinement is needed to more comprehensively measure students' scientific attitudes. Third, the intervention's duration was relatively limited, which may have constrained the development of certain indicators, particularly critical reflection and curiosity. Therefore, future research is recommended to involve larger, more diverse samples, to apply the intervention over a longer period, and to examine its implementation in other physics topics or in relation to other variables, such as science process skills, critical thinking, or learning motivation. Despite these limitations, this study contributes to the field of physics education by providing empirical evidence that integrating STEM, POE, and digital media, such as Web S.id, can serve as an effective instructional alternative to promote scientific attitudes and support the development of twenty-first-century competencies in physics classrooms.

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