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Effectiveness of a Web-Based Guided Inquiry Platform on Dynamic Fluid Material to Improve Students' Critical Thinking Skills

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Abstract

This study investigates the improvement of students' critical thinking skills following the implementation of a web-based learning platform integrated with a guided inquiry model on dynamic fluid topics. The study employed a pre-experimental one-group pretest–posttest design involving 30 Grade XI students at a public senior high school in Banjarmasin, Indonesia. Students' critical thinking skills were measured using an essay-based test developed based on Ennis' critical thinking framework, covering interpretation, analysis, inference, evaluation, and explanation. The maximum possible score was 100, with student responses scored using an analytical rubric and converted to a percentage scale. Data were analyzed using normalized gain (N-Gain) and a paired-sample t-test. The results showed an increase in the mean score from 3.82 on the pretest to 79.69 on the posttest, with an N-Gain of 0.74 (high category). The paired-sample t-test indicated a statistically significant difference between pretest and posttest scores ($p < 0.05$), suggesting a substantial improvement in students' critical thinking skills after the intervention. Improvements were observed across all critical thinking indicators, particularly in analysis and evaluation. Although the findings indicate positive learning gains, the use of a one-group pretest–posttest design limits causal interpretation. Nevertheless, the results suggest that web-based guided inquiry learning has the potential to support the development of students' critical thinking skills in physics learning, especially for abstract topics such as dynamic fluids.

Keywords: Web-based learning media; Guided inquiry; Critical thinking skills, Dynamic fluids

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INTRODUCTION

The development of technology in the 21st century has given rise to the concept of Society 5.0, which integrates the sophistication of technology in various aspects of life, including Education. Learning not only relies on cognitive intelligence, but also needs to foster critical, creative, and adaptive thinking skills so that students are ready to face global challenges (Mardhiyah, 2021). This is in line with national policies through Permendikbud No. 56 of 2021 which encourages the strengthening of 21st century skills. The results of international studies such as PISA also confirm the importance of critical thinking skills in dealing with the complexities of the modern world. Physics subjects have challenges in developing these skills, namely physics, especially dynamic fluid materials that are abstract and require visualization for deep understanding so that it is necessary to develop essential critical thinking skills in the era of Society 5.0 (Suyidno, 2019).

Observations at SMAN 12 Banjarmasin show that the physics learning process is still dominated by a conventional teacher-centered approach. The use of teaching materials is limited to package books and student worksheet without interactive media support, causing

low student participation and less developed critical thinking skills. The results of the daily repetition showed an average score of only 48.13, indicating a weak mastery of concepts as well as analysis and evaluation skills. The lack of digital learning facilities and media that provide real-time evaluation exacerbates this condition. Therefore, a new learning approach is needed that not only improves conceptual understanding, but also trains students' critical thinking skills systematically and contextually, especially in challenging dynamic fluid materials.

One of the solutions to overcome students' low critical thinking skills is the development of a website-based learning media that integrates a guided inquiry model. Website media provides flexible learning access, allows dynamic presentation of materials, and supports interactive and collaborative learning (Baisa, 2019). This characteristic is very suitable for practicing critical thinking skills, because students not only receive information, but are also required to analyze, plan, evaluate, and conclude independently (Tsai, 2022). Web media improves students' understanding and critical thinking skills through engaging and interactive educational content (Baisa, 2019; Sevtia et al., 2022) . The integration of guided inquiry models has also been shown to be effective in encouraging higher-level thinking skills, as shown by Falentina (2021) and Wartini (2021), who emphasize that the application of guided inquiry in technology-based learning can increase students' motivation as well as critical thinking skills. In addition, research by Mahtari et al (2020) found that the integration of PhET simulations with scaffolding question prompts is able to strengthen the understanding of concepts and learning outcomes, which indicates that the incorporation of digital technology with an inquiry approach can enrich students' learning experiences.

In fact, according to , (Sari et al., 2023) the use of web-based media is not optimal if it is not equipped with evaluation features and discussion forums that allow for continuous student interaction and reflection. Evaluation provides students with the opportunity to review their understanding, while discussion forums strengthen argumentation and collaboration skills that are closely related to critical thinking (Teig, 2021). Therefore, this study is important because it presents a website-based learning media with a guided inquiry approach that not only provides interactive materials and simulations, but is also equipped with videos, learning activities, discussion forums, and evaluative quizzes. The integration of these features is designed to accommodate every indicator of students' critical thinking skills on dynamic fluid materials that are known to be complex and require a deep conceptual understanding. Recent international studies also emphasize that web-supported inquiry environments play a significant role in fostering higher-order thinking and scientific reasoning, particularly when combined with structured scaffolding (Teig, 2021; Zhang & Quintana, 2022). This study aims to evaluate the effectiveness of a web-based learning medium integrated with the guided inquiry learning model in improving students' critical thinking skills on the topic of dynamic fluids.

METHOD

Research Design

This study employed a quantitative pre-experimental design using a one-group pretest–posttest model (O_1–X–O_2) to examine changes in students' critical thinking skills after the implementation of a web-based guided inquiry learning platform. In this design, students' critical thinking skills were measured before (pretest) and after (posttest) the intervention. Although this design allows for the identification of learning improvements, it does not permit strong causal inference due to the absence of a control group.

Participant, Sample, or Subject

The participants consisted of 30 Grade XI science-track students from a public senior high school in Banjarmasin, Indonesia, selected using purposive sampling. The selection criteria included students who had completed prerequisite physics topics and had not

previously received instruction on dynamic fluid concepts through web-based inquiry learning. The learning activities were conducted during regular physics lessons.

Prior to data collection, students were informed about the research objectives and procedures, and their participation was voluntary. All collected data were used solely for research purposes and were treated confidentially.

Learning Media and Intervention Procedure

The learning intervention utilized a web-based learning platform integrated with a guided inquiry model, developed using Scirra Construct 2. The platform was designed to support student-centered learning and was structured according to the guided inquiry learning stages: orientation, problem formulation, hypothesis generation, data collection, data analysis, and conclusion drawing.

The learning activities were conducted over three instructional meetings, each lasting approximately 90 minutes. During the implementation, the teacher acted as a facilitator by guiding students through inquiry tasks, monitoring discussion forums, and providing feedback when necessary. Students accessed the platform in a blended learning setting, combining in-class guidance with independent exploration of the learning materials.

The web-based guided inquiry learning platform used in this study was developed by the authors and can be accessed at https://rahman-marker9.github.io/nadia-skripsi/ for research and instructional purposes. The platform included interactive simulations of dynamic fluid phenomena (e.g., continuity equation and Bernoulli's principle), instructional videos, inquiry-based worksheets, discussion forums, and formative evaluation quizzes. These features were designed to support students' engagement in inquiry processes and to stimulate critical thinking through observation, analysis, and reflection.

Instrument for Measuring Critical Thinking Skills

Students' critical thinking skills were measured using an essay-based test developed based on Ennis' critical thinking framework, encompassing five indicators: interpretation, analysis, inference, evaluation, and explanation. The test items were aligned with dynamic fluid subtopics and designed to assess students' ability to reason scientifically and apply physics concepts to problem situations.

The instrument consisted of five essay questions, each scored using an analytical rubric with a maximum score of 20 per item, resulting in a total maximum score of 100. Students' raw scores were converted into percentage scores for analysis. The content validity of the instrument was evaluated by experts in physics education and instructional media, yielding a Content Validity Index (CVI) greater than 0.80, indicating high content validity.

Data Collection and Analysis

Data were collected through pretest and posttest administrations conducted before and after the intervention. To evaluate learning improvement, the data were analyzed using the normalized gain (N-Gain) formula. The effectiveness of the intervention was further examined using a paired-sample t-test with a significance level of 0.05.

Prior to inferential analysis, data distribution was examined to ensure the appropriateness of parametric testing. In addition, Cohen's d effect size was calculated to determine the magnitude of the observed improvement in students' critical thinking skills.

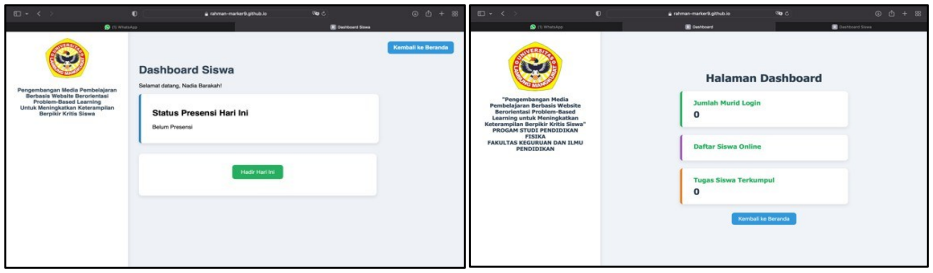

Figure 1. Student dashboard page and teacher dashboard

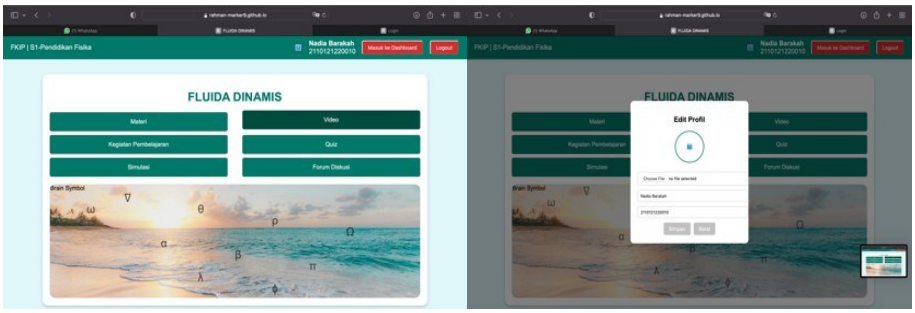

Figure 2. Home page

RESULTS AND DISCUSSION

Overall Improvement of Students' Critical Thinking Skills

The effectiveness of the web-based guided inquiry learning platform was evaluated by comparing students' critical thinking scores before and after the intervention. Students' responses were scored using an analytical rubric with a maximum score of 100.

The descriptive analysis shows a substantial increase in students' mean scores from the pretest to the posttest. As presented in Table 1, the average pretest score was 3.82, indicating very low initial critical thinking performance. After the implementation of the web-based guided inquiry learning platform, the mean posttest score increased to 79.69, categorized as high.

The normalized gain analysis yielded an N-Gain value of 0.74, which falls within the high improvement category, indicating a strong increase in students' critical thinking skills after the learning intervention.

Table 1. Overall Critical Thinking Skills Improvement

Test	Mean Score	Category
Pretest	3,82	Low
Posttest	79,69	High
N-Gain	0,74	High

Improvement Based on Critical Thinking Indicators

To obtain a more detailed picture of students' learning progress, critical thinking skills were further analyzed based on Ennis' five indicators, namely interpretation, analysis, inference, evaluation, and explanation. The results of the indicator-based analysis are presented in Table 2.

Table 2. N-Gain Analysis Based on Critical Thinking Indicators

Indicator	Pretest Mean	Category	Posttest Mean	Category	N-Gain	Category
Interpretation	4.10	Low	78.20	High	0.73	High
Analysis	5.06	Low	72.30	High	0.71	High
Inference	6.12	Low	80.45	High	0.75	High
Evaluation	3.21	Low	86.90	Very High	0.86	High
Explanation	7.27	Low	86.50	Very High	0.85	High
Avarage	5.28	Low	81.90	Very High	0.81	High

The results indicate that all five indicators of critical thinking skills experienced meaningful improvement after the intervention. The highest gains were observed in the evaluation and explanation indicators, suggesting that students became more capable of judging evidence, assessing reasoning, and articulating scientific explanations related to dynamic fluid phenomena. The analysis indicator showed slightly lower gains, although it still reached the high category.

Table 3. Paired Samples Statistics

	Mean	N	Std. Deviation	Std. Error Mean
Pre-test	3.82	30	0.91	0.17

	Mean	N	Std. Deviation	Std. Error Mean
Post-test	79.69	30	6.78	1.24

Inferential Statistical Analysis

To examine whether the observed improvement was statistically significant, a paired-sample t-test was conducted. The results are summarized in Tables 3 and 4.

Table 4. Paired Samples Test

	Mean Diff.	SD	SE	95% CI		t	Df	Sig. (2-tailed)
				Lower	Lower			
Pre – Post test	-75.87	6.85	1.25	-78.45	-73.29	-25.47	29	0.000

The paired-sample t-test results show a statistically significant difference between pretest and posttest scores ($p < 0.05$), indicating that students' critical thinking skills improved significantly after the learning intervention. The magnitude of this improvement was further supported by the large mean difference between the two measurements

Effect Size Analysis

To determine the strength of the observed improvement, Cohen's d was calculated based on the pretest and posttest scores. The analysis yielded a Cohen's d value greater than 2.0, indicating a very large effect size. This result suggests that the web-based guided inquiry learning platform had a strong practical impact on students' critical thinking performance.

DISCUSSION

Improvement of Students' Critical Thinking Skills through Web-Based Guided Inquiry

The results of this study indicate a substantial improvement in students' critical thinking skills following the implementation of the web-based guided inquiry learning platform. The increase in mean scores from the pretest to the posttest, accompanied by a high N-Gain value (0.74), suggests that students demonstrated markedly better performance in interpreting, analyzing, evaluating, and explaining dynamic fluid phenomena after the intervention. These findings align with previous studies reporting that inquiry-oriented digital learning environments can facilitate higher-order thinking skills by actively engaging students in the learning process (Maknun, 2020; Ristanto et al., 2023; Samadun et al., 2023).

The guided inquiry framework embedded within the web-based platform required students to engage with problems, generate hypotheses, analyze data from simulations, and draw conclusions based on evidence. Such learning activities encourage students to move beyond passive content consumption toward active knowledge construction. From a constructivist perspective, this process supports meaningful learning, as students integrate new information with prior knowledge through inquiry and reflection. Consequently, the observed improvement in critical thinking skills may be attributed to the structured inquiry stages that scaffold students' reasoning processes while still allowing independent exploration.

Improvement Across Critical Thinking Indicators

The indicator-based analysis revealed that all five components of critical thinking skills, interpretation, analysis, inference, evaluation, and explanation, showed improvement in the high category. Notably, the evaluation and explanation indicators exhibited the highest gains, indicating that students became more capable of assessing evidence, judging the validity of arguments, and articulating scientific explanations related to dynamic fluid concepts.

These findings suggest that the combination of interactive simulations and guided inquiry prompts particularly supported students' evaluative reasoning. By engaging with simulations of fluid flow and pressure variations, students were encouraged to compare predictions with observed outcomes and to justify their conclusions based on physical principles. This process is consistent with previous research indicating that inquiry-based simulations are effective in

strengthening evaluative and explanatory reasoning, especially in abstract physics topics (Kibirige, 2022; Yulianti & Gunawan, 2019).

Although the analysis indicator showed slightly lower gains compared to other indicators, it still reached the high category. This may reflect the inherent cognitive demands of analytical reasoning in dynamic fluid topics, which require students to integrate multiple variables simultaneously. Nevertheless, the overall improvement across all indicators suggests that the web-based guided inquiry approach provided balanced support for diverse dimensions of critical thinking.

Role of Web-Based Features in Supporting Inquiry Processes

The positive learning outcomes observed in this study may also be associated with the specific affordances of the web-based platform. Interactive simulations allowed students to visualize abstract fluid dynamics concepts, such as velocity changes and pressure distribution, which are often difficult to comprehend through static representations. Visualization and manipulation of variables have been shown to enhance conceptual understanding and analytical reasoning in physics learning (Fathurohman et al., 2018; Mahtari et al., 2020).

In addition, the discussion forum facilitated peer interaction and collaborative reasoning, enabling students to exchange ideas, challenge assumptions, and refine their understanding through dialogue. Such social interaction supports the development of critical thinking by exposing students to alternative perspectives and encouraging justification of reasoning(Krisnan et al., 2022; Sari et al., 2023). The inclusion of formative evaluation quizzes with immediate feedback further supported metacognitive awareness, allowing students to monitor their own learning progress and identify misconceptions.

Together, these features suggest that the web-based guided inquiry platform functioned not merely as a content delivery tool but as an integrated learning environment that supported inquiry, reflection, and self-regulated learning.

Limitations and Threats to Validity

Despite the positive findings, several limitations must be acknowledged. First, this study employed a one-group pretest–posttest design, which is inherently vulnerable to threats to internal validity, such as testing effects, maturation, and the Hawthorne effect. Consequently, the observed improvements cannot be attributed solely to the web-based guided inquiry platform with absolute certainty.

Second, the sample size was relatively small and limited to a single school, which may restrict the generalizability of the findings. Additionally, the study did not include long-term follow-up measurements; therefore, it remains unclear whether the observed gains in critical thinking skills were sustained over time.

These limitations suggest that the results should be interpreted as evidence of learning improvement following the intervention, rather than definitive proof of causal effectiveness. Future studies employing quasi-experimental or experimental designs with control groups, larger samples, and longitudinal measurements are necessary to strengthen causal claims and to further examine the robustness of the findings.

CONCLUSION

The study concludes that integrating the guided inquiry model into a web-based learning environment effectively enhances students' critical thinking and understanding of dynamic fluid concepts. Statistical results show a significant improvement from pre-test to post-test (N-Gain = 0.74; $p < 0.05$), confirming the media's effectiveness. The combination of inquiry-based learning stages with interactive simulations, discussion forums, and immediate feedback fosters analytical reasoning, self-regulation, and engagement. Therefore, the developed web-based guided inquiry platform serves not only as an instructional tool but also as a transformative approach to developing higher-order thinking and independent learning in 21st-century science education.

RECOMMENDATION

Recommendations describe things that will be done related to the next idea of the research. Barriers or problems that can influence the results of the research are also presented in this section.

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AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Nadia Barakah	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	
Suyidno	✓	✓		✓			✓			✓	✓	✓	✓	✓
Saiyidah Mahtari	✓	✓		✓			✓			✓	✓	✓	✓	✓

CONFLICT OF INTEREST STATEMENT

The authors state that they have no conflict of interest related to the research, authorship, or publication of this article

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, [NB, S, SM], upon reasonable request.

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