The Effect of the Guided Inquiry Learning Model Assisted by PhET Simulations on Students' Learning Outcomes in Static Fluids

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Abstract - *This study aims to examine the effect of the guided inquiry learning model assisted by PhET simulation on students' learning outcomes in static fluid. The study employed a quasi-experimental method using a nonequivalent control group design. The population consisted of 93 Grade XI students at SMAN 1 Kediri, from which 41 students were selected through purposive sampling. Class XI-A1, comprising 21 students, served as the experimental group and received guided inquiry instruction assisted by PhET simulation, while Class XI-A2, comprising 20 students, served as the control group and received conventional instruction. Cognitive learning outcomes were measured using an 18-item multiple-choice test that had been validated in terms of validity, reliability, difficulty level, and discriminating power. Observation sheets were also used to assess students' affective and psychomotor outcomes as supporting data. Data analysis included normality and homogeneity tests, followed by an independent-samples t-test using the pooled-variance formula at a 5% significance level. An N-gain analysis was also conducted to assess the improvement in cognitive learning outcomes. The results showed that the calculated t-value (t = 3.46) exceeded the critical value (t = 2.02), indicating a statistically significant difference between the experimental and control groups. The N-gain results placed the experimental group in the high category and the control group in the low category. The mean affective scores of the experimental and control groups were 84.92 and 82.24, respectively, both of which were categorized as good. The experimental group also obtained a higher mean psychomotor score than the control group (85.71 vs. 80.58). These findings indicate that the guided inquiry learning model assisted by PhET simulation has a significant positive effect on students' learning outcomes in static fluid.*

Keywords*: Guided Inquiry; PhET Simulation; Learning Outcomes; Static Fluid.*

INTRODUCTION

The competency demands faced by students are increasingly growing in line with changes occurring across various aspects of life ('Ardhuha *et al*., 2022). Critical thinking, problem-solving, creativity, innovation, communication, and collaboration are the four core skills that students must master (Makhrus *et al*., 2019). This makes physics one of the subjects responsible for developing these competencies so that students are prepared to face the challenges of real life.

Physics is one of the branches of natural science that directly examines various natural phenomena, as many physics concepts are closely related to everyday life (Zainuri *et al*., 2022). Physics learning requires students to be able to construct their own knowledge through direct experience and active engagement in the learning process (Ariani, 2020). One of the important goals in physics learning is the achievement of optimal learning outcomes (Ardiannisa *et al*., 2020).

Learning outcomes refer to the behavioral changes acquired by students during the learning process, encompassing the cognitive, affective, and psychomotor domains (Ridha *et al*., 2025). However, physics is known as an abstract subject, which often causes students to experience difficulties in learning it, ultimately leading to low learning outcomes (Fitriani *et al*.,

2020). 'Ardhuha *et al*. (2019) further noted that physics learning still contains many abstract concepts, causing some students to perceive physics as a difficult subject (Listyaningrum & Widodo, 2024).

Based on the results of an interview with the Grade XI physics teacher at SMAN 1 Kediri, it was found that the learning models commonly implemented in the classroom include lecturing, question-and-answer sessions, and discussions. The students' average scores remained below the Minimum Competency Achievement Criteria (KKTP), indicating that their learning outcomes still need to be improved. Furthermore, the laboratory facilities have not been utilized optimally, as most of the equipment is no longer in serviceable condition. These problems are further compounded by additional challenges faced by students, namely difficulties in mathematical ability, particularly in calculations and the application of formulas. In addition, students' low learning motivation has become another obstacle in physics learning, highlighting the need for instructional innovations that can more effectively support the improvement of student learning outcomes.

To address these problems, an appropriate and suitable learning model is needed one that actively engages students and guides them in the process of discovering knowledge, such as the inquiry learning model (Ardiannisa *et al*., 2020). The guided inquiry learning model is a learning model that prioritizes the teacher's role as a facilitator, in which students actively strive to understand and find answers to given problems on their own through activities such as observation, measurement, data collection, and drawing conclusions (Yudiafarani *et al*., 2022; Sulistiyono, 2020).

In addition to the learning model, instructional media also plays an important role in the teaching and learning process, as it can enhance students' conceptual understanding (Suhaemi *et al*., 2020). Inquiry-based learning that emphasizes experimentation and discussion in understanding concepts requires the support of interactive media ('Ardhuha *et al*., 2022). One approach that can make students more active in learning physics is the use of the guided inquiry model supported by virtual experimental media based on Physics Education and Technology (PhET) simulation, which is capable of presenting visual displays as well as explanations through computer simulations (Hasanah *et al*., 2025; Makhrus *et al*., 2020).

PhET is a virtual laboratory that is highly suitable for use in physics learning, as it can help students understand abstract physics concepts that are difficult to observe directly (Rizaldi *et al*., 2020). PhET simulations can effectively visualize subject matter concepts that are initially difficult to comprehend, thereby helping students engage in independent exploration (Djola *et al*., 2021).

Hasanah *et al*. (2025) demonstrated that the guided inquiry learning model assisted by PhET simulation had a significant effect on the learning outcomes of Grade XI students at SMAN 1 Lingsar. Consistently with this finding, Nurdini *et al*. (2022) reported that the use of PhET with the guided inquiry model was able to improve student learning outcomes on dynamic fluid material. Purba & Sinulingga (2025) also confirmed that the guided inquiry model assisted by PhET was effective in improving students' physics learning outcomes, with the experimental class achieving a higher post-test average than the control class.

Although previous studies (Hasanah et al., 2025; Nurdini et al., 2022; Purba &

Sinulingga, 2025) have reported positive effects of this model, they were generally conducted on dynamic fluid, optics, or general physics topics and evaluated the cognitive domain in isolation. The novelty of the present study lies in three aspects: (1) it targets static fluid material at SMAN 1 Kediri, where laboratory facilities are largely non-functional, positioning PhET as a substitute for hands-on apparatus rather than mere enrichment, (2) the PhET Under Pressure simulation is applied consistently across three related sub-topics (hydrostatic pressure, Archimedes' Law, and Pascal's Law), allowing its contribution to be traced indicator by indicator through cognitive levels C1–C6, and (3) this study integrates cognitive, affective, and psychomotor data simultaneously, offering a more comprehensive picture than prior research.

Based on the foregoing discussion, it can be understood that the guided inquiry learning model combined with PhET simulation media holds great potential for improving student learning outcomes, including on static fluid material, which has long been considered abstract and difficult to comprehend. Therefore, the researchers intend to conduct a study entitled The Effect of the Guided Inquiry Learning Model Assisted by PhET Simulation on Static Fluid Learning Outcomes.

RESEARCH METHODS

The type of research employed in this study is quasi-experimental with a nonequivalent control-group design (Creswell, 2014). The research design is presented in Table 1.

Table 1. Nonequivalent Control-Group Design

Group	Pretest	Treatment	Posttest
Experimental	O_1	X	O_2
Control	O_3	-	O_4

(Sugiyono, 2013)

The description of Table 1 is as follows. O_1 is the pretest administered to the experimental class. O_2 is the posttest administered to the experimental class. O_3 is the pretest administered to the control class. O_4 is the posttest administered to the control class. X represents the treatment given to the experimental class in the form of the guided inquiry learning model assisted by PhET simulation. The symbol (-) represents conventional learning applied to the control class.

The population of this study consisted of all 93 Grade XI students at SMAN 1 Kediri. The sample was determined using purposive sampling technique, with class XI A1 serving as the experimental class comprising 21 students and class XI A2 serving as the control class comprising 20 students. The learning process in the experimental class was conducted over three meetings: the first meeting covered hydrostatic pressure, the second meeting discussed Archimedes' Law, and the third meeting addressed Pascal's Law, with the PhET Under Pressure simulation utilized as an interactive learning medium in each meeting.

Learning outcomes in this study were measured using a multiple-choice test as the primary data and observation sheets as supporting data. The test instrument consisted of 18 items that had been tested for validity, reliability, difficulty level, and discriminating power (Supriadi, 2021). The item indicators were based on the Revised Bloom's Taxonomy (Anderson & Krathwohl, 2001), covering C1 (remembering), C2 (understanding), C3 (applying), C4 (analyzing), C5 (evaluating), and C6 (creating). The affective domain was assessed using five indicators by Krathwohl *et al*. (1964) in Nafiati (2021), namely receiving (A1), responding (A2), valuing (A3), organizing (A4), and characterizing

(A5). The psychomotor domain was assessed using five indicators by Harrow (1972) in Asrul *et al*. (2014), namely imitation (P1), manipulation (P2), precision (P3), articulation (P4), and naturalization (P5). The category of observation results for the affective and psychomotor domains is presented in Table 2.

Table 2. Guidelines for the Category of Affective and Psychomotor Domain Observation Results

Success Level	Predicate
86-100	Very Good
71-85	Good
56-70	Moderate
41-55	Low
<40	Very Low

(Ropii & Fahrurrozi, 2017).

This study aims to determine the effect of the guided inquiry learning model assisted by PhET simulation on static fluid learning outcomes. The hypotheses in this study are as follows: H_0: there is no effect of the guided inquiry learning model assisted by PhET simulation on static fluid learning outcomes, and H_a: there is an effect of the guided inquiry learning model assisted by PhET simulation on static fluid learning outcomes.

The hypothesis prerequisite tests include the Chi-Square normality test and the homogeneity test using the F-test (Nuryadi *et al*., 2017), with data declared normal if $\chi^2_{calculated} < \chi^2_{table}$ and homogeneous if $F_{calculated} < F_{table}$. Hypothesis testing was conducted using an independent sample t-test with the pooled variance formula at a significance level of 5%, with the criterion that H_0 is rejected if $t_{calculated} > t_{table}$ (Wahyudi *et al*., 2023). As additional data, the N-gain value was also calculated to determine whether there was an improvement in learning outcomes for each indicator, with the criteria of high if N-gain > 0.7, moderate if 0.3 ≤ N-Gain ≤ 0.7, and low if N-Gain < 0.3 (Hake, 1998).

RESULTS AND DISCUSSION

Result

The cognitive learning outcome test instrument used in this study consisted of 18 multiple-choice items that had been declared valid and reliable. Prior to the treatment, both classes took a pretest to assess students' initial abilities. The pretest results are presented in Table 3.

Table 3. Pretest Scores of Static Fluid Learning Outcomes

Class	Lowest Score	Highest Score	Mean	Standard Deviation
Control	5.56	44.44	26.39	11.06
Experimental	11.11	50.00	28.84	11.38

Based on Table 3, the pretest averages of both classes were relatively low and comparable, indicating that the students' initial abilities in both classes were not significantly different prior to the treatment.

The affective domain assessment was conducted through observation across three meetings based on five indicators, namely receiving (A1), responding (A2), valuing (A3), organizing (A4), and characterizing (A5). The recapitulation of affective domain learning outcomes is presented in Figure 1.

Based on Figure 1, it can be seen that the affective domain learning outcomes of both the experimental class and the control class were in the good category. These results indicate that students in both classes demonstrated good learning attitudes throughout the learning process.

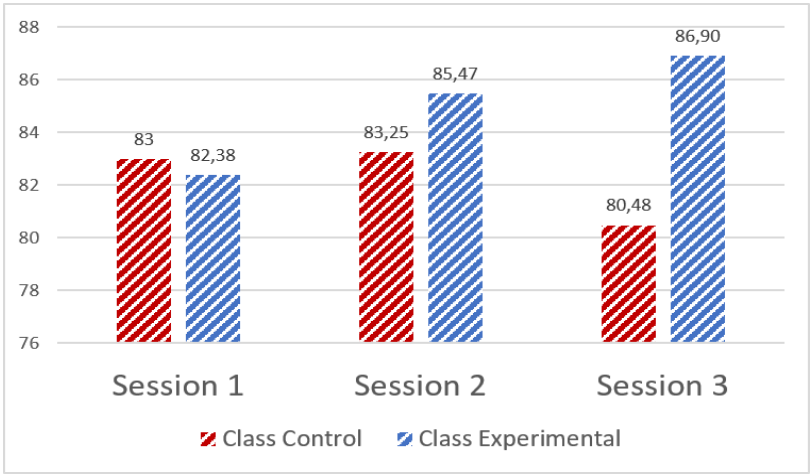


Figure 1. Affective Domain Learning Outcome Data

The psychomotor domain assessment was conducted through observation based on five indicators, namely imitation (P1), manipulation (P2), precision (P3), articulation (P4), and naturalization (P5). The recapitulation of psychomotor domain learning outcomes is presented in Figure 2.

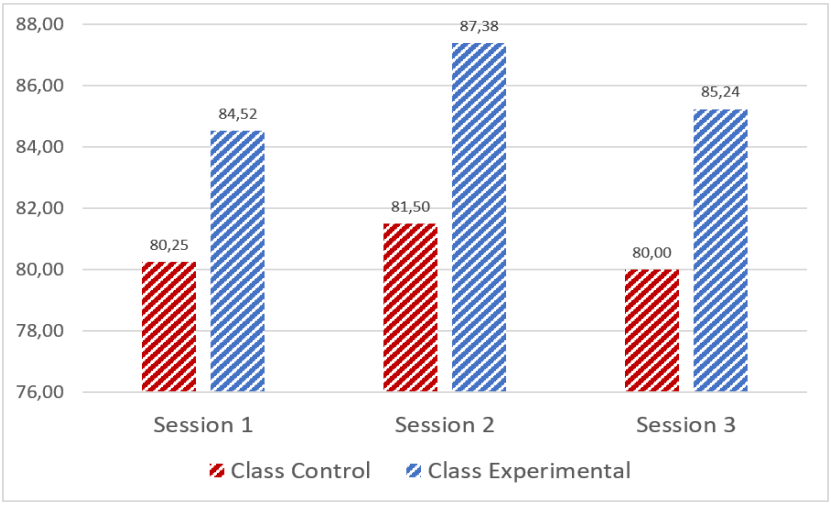


Figure 2. Psychomotor Domain Learning Outcome Data

The psychomotor domain learning outcomes of the experimental class were in the very good category, while the control class was in the good category. This difference occurred because students in the experimental class directly operated the PhET simulation through structured student worksheets (LKPD), in which students were guided to conduct virtual experiments by manipulating variables such as depth, density, and volume of objects, observing their effects on hydrostatic pressure, Pascal's force, and Archimedes' force, as well as recording and analyzing the experimental results systematically, so that students' psychomotor skills were trained progressively through each stage of the investigation.

After the treatment was administered, both classes took a posttest. The posttest data are presented in Table 4.

Table 4. Posttest Score Data of Static Fluid Learning Outcomes

Class	Lowest Score	Highest Score	Mean	Std
Control	61.11	83.33	73.89	7.00
Experimental	66.67	94.44	81.48	8.83

Based on Table 4, after the treatment was administered, the posttest average of the

experimental class increased to 81.48, while the control class increased to 73.89.

The normality test was conducted on the pretest and posttest data of both the experimental and control classes using the Chi-Square (χ^2) test. The normality test results are presented in Table 5 and Table 6.

Table 5. Normality Test Results of Pretest Learning Outcome Data

Class	N	α	$\chi^2_{calculated}$	χ^2_{table}	Desc.
Control	20	0.05	5.213	5.991	Normal
Experimental	21	0.05	2.700	5.991	Normal

Table 6. Normality Test Results of Posttest Learning Outcome Data

Class	N	α	$\chi^2_{calculated}$	χ^2_{table}	Desc.
Control	20	0.05	1.533	5.991	Normal
Experimental	21	0.05	3.096	5.991	Normal

Based on Table 5 and Table 6, the $\chi^2_{calculated}$ values of all groups were smaller than the χ^2table values. The pretest and posttest data of both the experimental and control classes were normally distributed.

The homogeneity test was conducted to determine the equality of variances between the experimental and control classes using the F-test. The homogeneity test results are presented in Table 7.

Based on Table 7, the F calculated value for the pretest data was 1.06, which was smaller than the F_{table} value of 2.14, while the $F_{calculated}$ value for the posttest data was 1.59, which was smaller than the F table value of 2.16. Therefore, the variance of the pretest and posttest data in both groups was declared homogeneous.

Table 7. Homogeneity Test Results of Pretest and Posttest Data

Data	$F_{calculated}$	F_{table}	Description
Pretest	1.06	2.14	Homogenous
Posttest	1.59	2.16	Homogenous

Since the data were normally distributed and homogeneous, hypothesis testing was conducted using an independent sample t-test with the pooled variance formula. The hypothesis test results are presented in Table 8.

Table 8. Research Hypothesis Test Results

Class	N	Mean	$\chi^2_{calculated}$	χ^2_{table}
Control	20	73.89	3.46	2.02
Experimental	21	81.48		

Based on Table 8, the $t_{calculated}$ value exceeded the t table value at a significance level of 5% with df = 39, resulting in the rejection of H_0. This indicates that the guided inquiry learning model assisted by PhET simulation has a significant effect on static fluid learning outcomes. The N-Gain test results for each cognitive indicator of the experimental and control classes are presented in Figure 3.

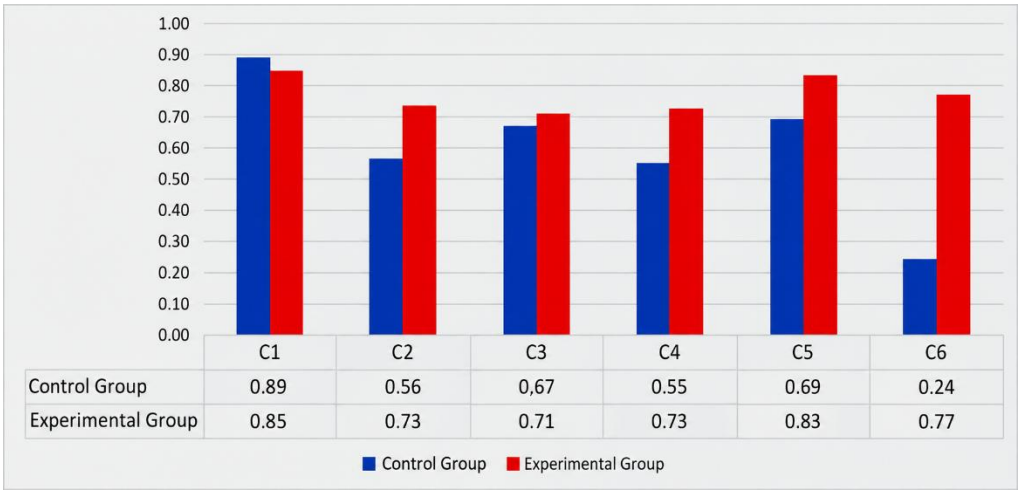


Figure 3. N-gain Test Results for Each Cognitive Indicator.

Discussion

Students in both classes took a pretest prior to the treatment to assess their initial abilities. The pretest averages of both classes were relatively low and comparable, indicating that students in both classes did not yet have adequate understanding of static fluid material before learning began. This condition is consistent with the findings of Fitriani *et al*. (2020), who stated that students generally have low initial understanding of abstract physics material such as static fluids.

The affective domain learning outcomes of both classes were in the good category at every meeting. Based on Figure 1, the affective scores of the experimental class in the first meeting were slightly below those of the control class. This occurred because students were introduced to the PhET simulation for the first time, causing their attention to be largely occupied with understanding how to operate the simulation. As a result, the responding (A2) and characterizing (A5) indicators could not yet be demonstrated optimally, as students still tended to be passive in discussions and were not yet accustomed to working independently using the PhET simulation. This condition is consistent with Rizaldi *et al*. (2020), who stated that students require an adaptation period when using PhET simulation before they can utilize it optimally. Nevertheless, the affective scores of the experimental class continued to improve in the second and third meetings as students became more familiar with the simulation. This affective domain data serves as supporting data to reinforce the research findings in the cognitive domain.

The psychomotor domain learning outcomes showed that the experimental class was in the very good category in the second meeting and the good category in the first and third meetings, while the control class was in the good category across all meetings. This difference occurred because students in the experimental class directly operated the PhET simulation through structured student worksheets, so that their psychomotor skills were trained progressively at each meeting. The imitation indicator (P1) was the easiest indicator to achieve for students in the experimental class, as explained by Harrow (1972) in Asrul *et al*. (2014) that the imitation stage is the initial stage of psychomotor skill development that is easiest to achieve. Meanwhile, the control class, which used discussion sheets without simulation media, had more limited opportunities for psychomotor skill development. These results indicate that the guided inquiry model assisted by PhET simulation not only impacts the cognitive domain but also contributes positively to students' psychomotor skills (Nurjannah *et al*., 2021).

After the treatment was administered, the posttest average of the experimental class was higher than that of the control class. This improvement occurred because the guided inquiry model encourages students to actively construct their own knowledge through a series of systematic investigation stages, ranging from problem orientation, problem formulation, hypothesis formulation, data collection, hypothesis testing, to drawing conclusions (Yudiafarani *et al*., 2022; Sulistiyono, 2020). The hypothesis test results showed that the $t_{calculated}$ value of 3.46 exceeded the t_{table} value of 2.02, indicating a statistically significant effect of the guided inquiry learning model assisted by PhET simulation on static fluid learning outcomes, consistent with the studies of Hasanah *et al*. (2025) and Purba & Sinulingga (2025), which demonstrated that the guided inquiry model assisted by PhET has a significant effect on students' physics learning outcomes.

Taken together, the affective, psychomotor, and cognitive results point to the same mechanism: students in the experimental class were repeatedly required to operate the simulation, manipulate variables, and interpret outcomes, rather than passively receiving information. This active engagement simultaneously built comfort (affective), procedural skill (psychomotor), and conceptual understanding (cognitive), the last of which is reflected in the significant t-test result above. This convergence across the three domains, rather than the cognitive result alone, confirms that the guided inquiry–PhET combination shaped learning as a whole process, consistent with Purwono et al. (2025), who reported that PhET's interactive visualization fosters independent exploration that improves cognitive, affective, and psychomotor outcomes together.The N-Gain test results showed that the experimental class experienced improvement with high criteria across all cognitive indicators C1 through C6. The three static fluid sub-topics hydrostatic pressure in the first meeting, Archimedes' Law in the second meeting, and Pascal's Law in the third meeting were visualized using the PhET Under Pressure simulation with different features and variables at each meeting.

The improvement in the C1 indicator is associated with the problem orientation stage of the guided inquiry syntax, in which the teacher presents phenomena in the form of images or videos related to static fluid material, such as images of a diver at sea depth, a floating ship, or a hydraulic jack, thereby encouraging students to recall previously learned concepts. The improvement in the C2 indicator is associated with the problem formulation stage of the guided inquiry syntax, in which students are guided to construct scientific questions based on the observed phenomena, requiring them to first understand the phenomena before being able to formulate appropriate questions.

For the C3 indicator, the improvement is associated with the data collection stage of the guided inquiry syntax, in which students conducted virtual experiments using PhET simulation by manipulating variables such as sensor depth, fluid type, and cross-sectional area in the context of hydrostatic pressure, Pascal's Law, and Archimedes' Law, so that the ability to apply concepts was directly trained. Nevertheless, the C3 indicator obtained the lowest N-Gain value among other indicators in the experimental class (0.71), due to the characteristics of static fluid material that require the ability to apply concepts quantitatively, meaning students still need further practice despite the assistance of PhET simulation visualization.

The improvements in the C4 and C5 indicators are associated with the hypothesis formulation and hypothesis testing stages of the guided inquiry syntax, in which students modified variables in the PhET simulation such as sensor depth or fluid type, then analyzed and evaluated the conformity of the results with the previously formulated hypothesis. Meanwhile, the improvement in the C6 indicator is associated with the conclusion formulation and result communication stages of the guided inquiry syntax, in which representatives of each group presented their experimental results and conclusions in front of the class so that students could share their findings with one another. This finding is consistent with Listyaningrum & Widodo (2024), who stated that guided inquiry-based learning is effective in comprehensively improving students' understanding of physics concepts.

In contrast, the control class only achieved high criteria on the C1 indicator with an N-Gain score of 0.89, while

indicators C2 (0.56), C3 (0.67), C4 (0.55), and C5 (0.69) were in the moderate criteria. The C6 indicator only obtained an N-Gain score of 0.24, which was categorized as low. The low improvement in the C6 indicator suggests that students in the control class experienced difficulties in constructing or reconstructing investigative procedures without the aid of simulation visualization, as conventional learning tends to be one-directional and provides fewer opportunities for students to practice discovering concepts independently (Salim & Fianti, 2024). Throughout the learning process, Pascal's Law sub-topic was the most difficult material for students in both classes to understand, as it requires the ability to comprehend and apply the relationship between force, cross-sectional area, and pressure in a closed system quantitatively.

On the PhET Under Pressure simulation, this sub-topic is represented by the hydraulic-lift feature, where students only adjust piston area and load while the resulting force and pressure values are generated automatically without displaying the underlying calculation steps. This kept the concept visually concrete but left much of the numerical reasoning behind it untransmitted, explaining why the C3 (applying) indicator remained the weakest cognitive gain in the experimental class despite the visualization support. This finding is consistent with Saudelli et al. (2021), who noted that PhET simulations effectively build students' intuitive, visual understanding, but the accompanying mathematical or quantitative reasoning still requires separate reinforcement.

This study has several limitations, including the scope of material that was limited to three static fluid sub-topics, the relatively small sample size from two classes at SMAN 1 Kediri, the limited time allocation of three meetings which meant that some students had not yet fully adapted to the PhET simulation, and the fact that there were still students in the experimental class who had not yet achieved the learning objective attainment criteria.

Future research is recommended to allocate a separate orientation session for students to familiarize themselves with the PhET interface before the pretest or treatment begins, to apply this model to other physics topics with larger and more varied samples, and to examine additional outcomes such as scientific reasoning or problem-solving skills.

CONCLUSION

Based on the results and discussion, it can be concluded that the guided inquiry learning model assisted by PhET simulation has a significant effect on static fluid learning outcomes. This is evidenced by the higher cognitive learning outcome average of the experimental class compared to the control class $t_{calculated}$ value of 3.46 exceeded the t_{table} value of 2.02, the high-category N-Gain improvement across all cognitive indicators of the experimental class, and the affective and psychomotor learning outcomes of the experimental class that were also superior to those of the control class.

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