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Guided Inquiry with STEAM: Fostering Critical Thinking on Fluid Statics Concepts

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Abstract: Critical thinking is one of the higher levels of thinking. This study aims to determine the level of critical thinking of students using the STEAM-integrated guided inquiry learning model on static fluid material. The research method used is mixed methods that focuses on the design of embedded experimental models. The subjects in this study consisted of 11th grade high school students in Salatiga. Data from this study were analyzed quantitatively and qualitatively. The conclusion of this study is that there is an increase before and after being taught using STEAM-integrated guided inquiry learning. This is evidenced by the results of the analysis of students' critical thinking levels which were previously in the good category of 3.12%, moderate 31.25%, poor 28.12%, and very poor 37.5% and after learning using STEAM-integrated guided inquiry learning are in the very good, good, and moderate categories. The percentages are very good 6.25%, good 53.12%, and moderate 40.62%.

Keywords: Critical thinking; Guided inquiry learning; STEAM

Introduction

Physics is a subject that is considered difficult by students because it is abstract. Physics itself is not only related to, but students are also required to understand the concept and calculate well (Jaya et al., 2018). One of the physics subjects that is considered difficult is static fluid. Static fluid is a fluid that is at rest or moving but there is no difference in speed. The materials contained in static fluid are Pascal's Law, Hydrostatic Pressure, and Archimedes' Law. The misconception that occurs in static fluid material is the concept of Pascal's Law (Iljannah et al., 2025; Indahwati et al., 2023). According to students, the pressure on the piston is influenced by its cross-sectional area, the smaller the cross-sectional area of the piston, the smaller the pressure. The correct concept is that the pressure applied to the piston will be transmitted to all points and the piston wall is the same (Rafiah & Taufiq, 2017). In addition to Pascal's Law, misconceptions also occur in Archimedes' Law. According to students, the buoyant force is influenced by the mass of the object and the volume of the liquid. The position of the object floating, floating, and sinking is influenced by the amount of liquid. In addition, students also do not understand that the position of objects in fluids is influenced by density (Rohmayanti et al., 2020; Wahdah et al., 2023). In other studies, it can be seen that conceptual understanding in static fluid material is relatively low. Factors that influence low conceptual understanding include: a. internal factors, namely interest and motivation, b. external factors, namely family, facilities and infrastructure, and the community environment (Husain et al., 2018; Mubarokah, 2019). Misconceptions can affect the level of student understanding, where each student has a different understanding. This misconception itself can affect the level of student critical thinking.

Critical thinking is a higher level of thinking. To improve learning outcomes, students need to develop critical thinking skills (Susilawati et al., 2020; Sumarni &

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Kadarwati, 2020). According to Ennis (2011), critical thinking is the ability to think logically that focuses on making accountable decisions. According to Ennis (2011), there are 12 indicators, but only five were used in this study: 1) focusing on questions, 2) asking and answering questions, 3) analyzing arguments, 4) evaluating observational results, and 5) conducting induction. Based on the results of initial observations conducted in high schools, it was found that students had never been taught about critical thinking, especially in physics learning on static fluid material. This makes it a little difficult for students to adapt to questions that require higher-level thinking (Hake, 1998). Critical thinking skills that tend to be low in elementary school graduates up to college are still often complained about (Reta & No, 2012)

According to the results of the PISA in 2016, Indonesia ranked 62nd out of 70 countries. The PISA results explained that students in Indonesia are less capable in problems that require critical thinking skills, creative thinking, and also Higher-Order Thinking Skills (HOTS) (Primayana, 2019; Haritzah et al., 2024). HOTS (High Order Thinking Skills) is a student's thinking process at a higher cognitive level. HOTS includes the ability to solve problems, think creatively, think critically, argue, and make decisions (Dinni, 2018). HOTS questions developed from Bloom's taxonomy are questions that measure abilities in the domains of analyzing (C4), evaluating (C5), and creating (C6) (Ismayani et al., 2020). The HOTS that will be used in this study is critical thinking. Critical thinking is the ability to think logically that focuses on making decisions that can be accounted for. When someone is used to practicing critical thinking questions that must be solved, it is not difficult to solve these questions. A person who thinks critically will be able to solve problems well and can think rationally about what to do (Susilawati et al., 2020).

Based on these issues, learning is needed that can provide opportunities for students to conduct investigations to form and refine physics concepts. One learning model that is appropriate for this problem is the guided inquiry learning model, often referred to as the guided inquiry model. This learning model emphasizes critical thinking skills, scientific investigation, and science process skills. Research results show that this method is considered effective because it significantly improves students' critical thinking skills (Nurhudayah et al., 2016; Herlita et al., 2023; Nor & Sihes, 2021).

Guided inquiry learning is a learning model that uses a method for problem solving, planning and conducting experiments, collecting and analyzing data, and drawing conclusions. With this model, students are mentally and physically involved in solving problems given by the teacher. The characteristics of the guided inquiry model are that students learn creatively and reflect on their experiences, learning from what they know (Guo et al., 2022). Through guidance, students can develop a series of thoughts in the learning process. Student development occurs gradually. The process of this model consists of identifying and resolving contradictions, generalizing, concluding, and solving problems (Lumentut et al., 2017; Belbase et al., 2022)

One approach that aligns with the guided inquiry model in the 4.0 era is STEAM (science, technology, engineering, art, and mathematics), which is a skill development tool needed in the 21st century (Suryani et al., 2025; Aguilera et al., 2021; Arisoy & Aybek, 2021; Paminto et al., 2023). STEAM is an approach to learning that provides opportunities to expand knowledge and science. STEAM is intended to develop skills in the form of communication, critical thinking, creativity, teamwork, and other skills. However, the ability required is critical thinking. The STEAM used in this study is art in the form of design art. The use of design art aims to increase student creativity (Mu'minah, 2020; Oner et al., 2016).

The purpose of this study was to determine the critical thinking skills of high school students after being taught using STEAM-integrated guided inquiry learning on the concept of static fluids.

Method

In this study, the method used is mixed methods that focus on the design of embedded experimental models. This method aims to collect quantitative and qualitative data (J. Creswell & J. Creswell, 2018). This study focuses on the level of critical thinking of students with static fluid material (Pascal's Law and Archimedes' Law) on hydraulic bridges with the subjects of this study amounting to 32 high school students. The researcher also conducted interviews with several students with the aim of qualitative data purposes to confirm answers and to find out more deeply about students' knowledge regarding Static Fluid material. The learning steps using the STEAM integrated guided inquiry learning method can be seen in Table 1.

The data obtained were analyzed quantitatively and qualitatively. The quantitative data were the results of the pre-test and post-test critical thinking tests, where the data were analyzed using statistical description tests, normalization tests, difference tests, n-gain scores, and effect sizes (Ellis, 2010). Qualitative data were obtained from interviews after the pre-test and post-test. The interview results were then analyzed using the categories of students' critical thinking levels according to Yati et al. (2015), which can be seen in Table 2.

Figure 1. Guided Inquiry Learning Syntax

Guided Inquiry Learning Syntax	Activity	STEAM
Submitting a Problem	The teacher guides students to identify problems and divides students into groups.	Science Technology
Formulating a Hypothesis	The teacher asks students to submit temporary answers and guides students in determining hypotheses.	Science
Designing Problem Solving	The teacher guides students in determining the steps of the experiment.	Science Technology
Conducting an Experiment	Teachers guide students to obtain data through experiments and direct observation.	Science Technology Engineering Art Mathematics
Collecting and Testing Data	The teacher gives each group the opportunity to write down the experiment in a learning medium and convey the results of managing the collected data.	Science Technology Mathematics
Making Conclusions	The teacher guides students in making conclusions based on the data that has been obtained.	Science

Table 2. Categories of Critical Thinking Levels

Interpretation (%)	Category
81–100	Very good
61–80	Good
41–60	Medium
21–40	Bad
0–20	Very bad

Result and Discussion

This study aims to determine the level of critical thinking of high school students through STEAM-integrated guided inquiry learning on the concept of Static Fluids. The results of the study were obtained through pre-tests, post-tests, and interviews. The data were then analyzed quantitatively and qualitatively to determine the level of critical thinking of students after being taught using the STEAM-integrated guided inquiry learning method. The average student scores can be seen in Figure 1.

As seen in Figure 1, the average pre-test score for students was 33.28 and the average post-test score was 67.03. This indicates that students' thinking skills improved after being taught using the STEAM-integrated guided inquiry learning method. The results of the pre-test and post-test were then analyzed quantitatively. Data were analyzed using N-gain, effect size, and paired samples tests. This aims to determine the category of students' critical thinking skills. The results of the pre-test and post-test analysis can be seen in Table 3 (Mutakinati et al., 2018).

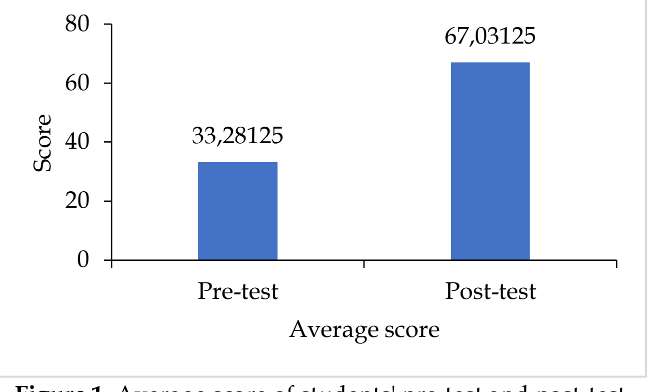

Figure 1. Average score of students' pre-test and post-test results

Based on Table 3, it can be seen that the results of the N-gain analysis are 0.492, where these results indicate that there is an increase in students' critical thinking abilities towards STEAM-integrated guided inquiry learning. The category of increasing students' critical thinking abilities is in the moderate category. According to research, using the STEAM-integrated guided inquiry learning model can improve students' critical thinking levels (Triandini et al., 2021; Tuada & Suparno, 2021).

Table 3. Results of Pre-test and Post-Test Analysis

Analysis of Students' Critical Thinking Levels	Description
N – Gain	0.492 (medium category)
Effect Size	0.823 (medium category)
Paired Sample Test	sig (2-tailed) 0.00 -> students' critical thinking scores increased after being taught using the guided inquiry learning model

The next analysis was the effect size. The result of this analysis was 0.823, which indicates the effectiveness of learning using the STEAM-integrated guided inquiry learning model. The level of effectiveness of learning using the STEAM-integrated guided inquiry learning model was in the moderate category. The paired samples test analysis obtained a sig (2-tailed) of 0.00, indicating a difference between the pre-test and post-test.

The model used in this study is guided inquiry learning integrated with STEAM, where the syntax of the guided inquiry itself consists of posing a problem, formulating a hypothesis, designing a solution, conducting an experiment, collecting and testing data, and drawing conclusions. The process for each syntax can be seen in Table 4.

Table 4. Learning Process Using the STEAM Integrated Guided Inquiry Learning Model

Syntax	STEAM
Submitting a problem	The first learning process involves problem-posing. In Pascal's Law, students are presented with a problem related to static fluids. STEAM is not yet taught in this section, as the problem is newly presented. Critical thinking indicators taught in this section include focusing questions, identifying and formulating questions, and considering possible answers.
Formulating a hypothesis	The next learning syntax is formulating a hypothesis. After students are presented with a problem, they are asked to express their opinions based on it. The STEAM topic taught in this section is science, where students are asked to answer problems based on the learning material being discussed, namely static fluids and Pascal's law. Critical thinking indicators taught in this syntax include answering questions such as what, why, and how.
Designing problem solving	The next learning syntax is designing problem-solving. After students express their opinions, they are asked to design a solution to the problem, guided by the teacher. This includes preparing the tools and materials to be used and what will be done in the experiment. The STEAM taught in this section is science and technology, where students are asked to answer questions posed by the teacher according to the material discussed. The technology used in this section is using the internet to search for references related to the design of the experiment. Critical thinking indicators taught in this syntax include deciding on a course of action, determining a solution, and selecting possible alternative solutions.
Conducting an experiment	The next learning syntax is conducting experiments. After students design a solution to the problem, they are asked to conduct an experiment directed by the teacher. The STEAM taught in this section is science and technology, where students are asked to conduct experiments related to problems related to static fluids and Pascal's law. The technology used in this section is the use of the internet to search for references related to the experiment. The critical thinking indicators taught in this syntax include assessing observation results and identifying corroborating evidence.
Collecting and testing data	The next learning syntax is collecting and testing data. After students conduct an experiment, they are asked to collect and test the data obtained from the experiment. The STEAM topics taught in this section include science, technology, and mathematics. Students are asked to collect and test data based on the experiment. The technology used in this section is the internet to search for references related to data testing. Mathematics in this section is from tests that use calculations. The critical thinking indicators taught in this syntax are assessing observation results and reporting observation results.
Making conclusions	The final learning syntax is drawing conclusions. After students examine the data, they are asked to draw conclusions based on the problem presented at the beginning. The STEAM component taught in this section is science, where students are asked to answer questions to draw conclusions based on problems related to static fluids and Pascal's law. The critical thinking indicator taught in this syntax is analyzing arguments: constructing arguments according to needs.

After the data was analyzed using descriptive analysis, it was then analyzed using crosstabulation. Based on the table below, students' critical thinking levels are divided into five categories: very good, good, moderate, poor, and very poor. Judging from the pre-test results, students are in the good, moderate, poor, and very poor categories. After students were taught using the STEAM-integrated guided inquiry learning method, the post-test results showed that the students' critical thinking levels were in the very good, good, and moderate categories. This indicates that students' critical thinking levels have increased.

The percentage of students' critical thinking levels can be seen in Figure 2. Before being taught using the guided inquiry learning method or pre-test, students were categorized as good, moderate, poor, and very poor. The percentage of each category was: good at 3.12%, moderate at 31.25%, poor at 28.12%, and very poor at 37.5%. After being taught using the guided inquiry learning method, the student categories were very good, good, and moderate. The percentages were: very good at 6.25%, good at 53.12%, and moderate at 40.62%.

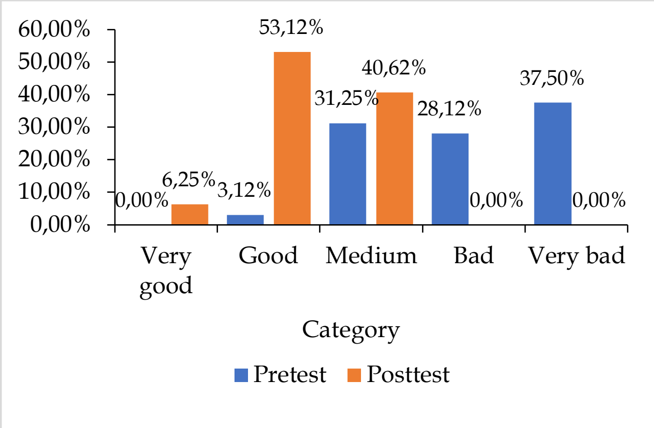

Figure 2. Categories of students' critical thinking levels

According to research Rahayu et al. (2018), students have not written down their complete answers to the steps in solving the problem. Although some students have written complete and correct answers. Furthermore, research Rahayu et al. (2019) revealed that if student results improve, student learning outcomes also improve. Where previously students started from the low category and increased to the high category (Bertrand & Namukasa, 2020).

This aligns with research Suryaningsih et al. (2021) which states that the STEAM approach can improve students' critical thinking. This is because critical thinking supports STEAM skills. Student involvement in project-based learning can improve students' critical thinking skills.

The following are questions and answers from students. Based on figure 3, students in the excellent category correctly answered questions according to the concept. Students answered questions in terms of the particles in each soda and the density that affects the position of objects.

Students in the good category answered that density affects the position of an object. Students did not answer using particles. Students in the moderate category are already moving towards the concept, but they only write down mass. According to research Rohmayanti et al. (2020), according to students, what influences the position of an object is the amount of liquid. What should influence the position of an object is the density. Students are able to identify the problem, but have not yet provided a precise analysis of the answer (Rosdiana et al., 2019).

This is also in accordance with research Prani et al. (2017), where low understanding of students makes it difficult for students to work on questions and the lack of practical work in learning causes students' critical thinking skills to be low.

Soal Perhatikan gambar berikut!  Bu Rini melakukan percobaan menggunakan dua buah kaleng berisi soda. Soda yang digunakan yaitu soda biasa dan soda diet. Kaleng soda biasa memiliki berat total 364 g karena memiliki gula sebesar 39 g. Sekaleng soda diet memiliki berat 355 g dan 0.3 g aspartame (pemanis buatan). Ternyata saat kedua kaleng dimasukkan ke dalam air, soda diet terapung dan soda biasa tenggelam. Menurutmu mengapa hal ini bisa terjadi?
Sangat baik "partikel dalam soda biasa lebih rapat dibandingan dengan partikel soda diet, sehingga soda diet mengapung dan soda biasa tenggelam. Massa jenis soda diet lebih kecil dari pada massa jenis biasa.
Baik "karena massa jenis soda diet lebih kecil dari massa jenis air sehingga terapung. Sedangkan, massa jenis soda biasa lebih besar dari massa jenis air sehingga tenggelam"
Sedang "karena berat soda biasa lebih besar dari soda diet, sehingga massa air lebih besar dari massa soda diet (soda diet terapung)"

Figure 3. Questions and answers from students

Based on observations made during the lesson, it was shown that students were very enthusiastic and responded very well to the instruction provided. This was evident in the large number of students who answered the questions posed by the researcher during the lesson.

Conclusion

The conclusion of this study is that there was an increase before and after being taught using STEAM-integrated guided inquiry learning. This is evidenced by the results of the analysis of students' critical thinking levels which were previously in the good category of 3.12%, moderate 31.25%, poor, 28.12%, and very poor 37.5% and after learning using STEAM-integrated guided inquiry learning were in the very good, good, and moderate categories. The percentages are, very good 6.25%, good 53.12%, and moderate 40.62%. Therefore, the research conducted is considered successful because there was an increase after being taught using the STEAM-integrated guided inquiry learning method. Suggestions for further research, it is hoped to explore the improvement of critical thinking in students on other materials using the STEAM-integrated guided inquiry learning method.

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Author Contributions
Designed the research, collected and analyzed the data, wrote the initial draft of the article manuscript, wrote the article manuscript and conducted editing, P.W.S.; reviewed the research results, reviewed the research results, D.N.

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Conflicts of Interest
The authors declare that they have no conflict of interest related to this research.

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