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The Influence of the 9E Learning Cycle with A STEM Approach on Students' Science Process Skills in Static Fluid Topics

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Abstract: This study investigated the effectiveness of integrating the 9E Learning Cycle Model with STEM approaches to enhance students' Science Process Skills (SPS) in static fluid concepts. The research employed a mixed-methods embedded experimental design with 32 senior high school students. Quantitative data were collected through pre- and post-tests, while qualitative data were gathered via observations and interviews. Results showed significant improvements across all SPS components, with N-gain values ranging from 0.63 to 0.64, indicating medium gains. Students demonstrated enhanced abilities in observing, classifying, measuring, inferring, predicting, and communicating scientific concepts. The integrated approach facilitated practical application of knowledge, as evidenced by students' work on flood-resistant garage prototypes and wave-powered electricity generators. Qualitative findings revealed increased student engagement and improved problem-solving skills. The study concludes that the integration of the 9E Learning Cycle Model with STEM approaches offers an effective framework for enhancing students' science process skills and their ability to apply these skills to real-world problems. These recommendations aim to provide a more comprehensive understanding of the approach's potential in science education across various domains and student populations

Keywords: 9E Learning Cycle Model; science process skills; STEM

Introduction

Static fluid is a challenging topic in physics that iselated to everyday life phenomena(Dyah et al., 2019; Maison et al., 2019; Suprapto et al., 2020; Zani et al., 2019). In a study ranking the difficulty of topics in basic physics, fluid was ranked first as the most difficult, followed by optics, linear momentum and collisions, rotational motion, dynamics, vibrations and waves, two-dimensional motion, heat, measurement, quantities, units and vectors, sound, equilibrium, gravitation, and work and energy(Yusrizal, 2016). tudents struggle with understanding Archimedes' principle(Diyana et al., 2020) and often focus on mathematical equations while neglecting the underlying concepts(Periyanti et al., 2019). Connecting previous experiences and reflecting them in practice is a characteristic of physics that requires science process skills(Mukaromah & Wusqo, 2020; Zahirah et al., 2024). However, students often have difficulty evaluating data from static fluid experiments due to a lack of skills in analyzing and presenting results(Goszewski et al., 2013). Previous research on science process skills did not evaluate aspects such as integrated skills, including describing relationships between variables(Rophi et al., 2024). Therefore, the problem addressed in this study is how to improve students' science process skills in static fluid material. Although various studies have attempted to improve the teaching and learning of static fluid concepts, many have focused on isolated aspects, such as theoretical understanding or practical skills, without integrating both effectively. For instance, while some approaches emphasize hands-on experimentation, they often lack the necessary theoretical depth, and others focus solely

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on conceptual knowledge, leaving students underprepared for real-world applications(Putri & Meilana, 2023). These gaps suggest a need for a more comprehensive instructional model.

The novelty of this study lies in the application of the 9E Learning Cycle Model, which extends the traditional 5E model by adding phases like elicitation and exchange, thus fostering a deeper engagement with both theoretical and practical elements of science learning(Dyah et al., 2019). Furthermore, integrating the STEM (Science, Technology, Engineering, and Mathematics) approach within this model allows students to engage with real-world problems in a structured, reflective learning environment. The 9E Learning Cycle Model promotes not only a deeper understanding of static fluid principles but also enhances students' science process skills by guiding them through an iterative learning process, from activating prior knowledge to applying new concepts(Maison et al., 2019). This research aims to improve science process skills in static fluid material through the 9E Learning Cycle Model with STEM Approach. The 9E Learning Cycle Model (Engage, Explore, Explain, Elaborate, Evaluate, Extend, Exchange, Express, and Evaluate)(Assi et al., 2023) is to increase student participation and improve their Science Process Skills(Arwizet & Saputra, 2019; Ismalia et al., 2022). The model integrates four learning elements: science, technology, engineering, and mathematics, focusing on solving concrete problems and presenting topics in daily activities(Purba et al., 2019).

This research is crucial because it addresses several interconnected problems in physics education. First, many students struggle with static fluid concepts due to an overemphasis on rote learning and equation solving, which does not encourage conceptual understanding(Handayani & Suharyanto, 2016). The integration of the 9E Learning Cycle with a STEM approach emphasizes solving concrete, real-world problems, making physics more relevant and accessible(Purba et al., 2019). By focusing on science process skills, this study aims to equip students with the ability to critically evaluate data and present scientific findings, skills that are essential for scientific inquiry but often underdeveloped in traditional instruction (Adi et al., 2018). Secondly, previous research on improving students' science process skills has often been fragmented, lacking holistic approaches that bridge theoretical understanding and practical application(Zani et al., 2019). In the context of static fluid, a subject that many students find challenging, this fragmentation becomes more evident as many studies either focus solely on hands-on experiments or theoretical aspects without integrating both effectively(Putri & Meilana, 2023). The 9E Learning Cycle model, when integrated with a STEM approach, addresses these gaps by providing a structured, comprehensive method that enhances both conceptual understanding and practical application. This dual focus is essential in today's educational landscape, where STEM competencies are increasingly in demand(Boyaci & Atalay, 2016). While recent studies have highlighted the difficulties students face with static fluid concepts and their lack of science process skills(Zani et al., 2019), research combining the 9E model and STEM in this specific context remains limited(Adam & Suprapto, 2019; Andaru et al., 2019). Therefore, this study aims to investigate the effectiveness of the 9E Learning Cycle Model integrated with STEM in improving students' science process skills in static fluid material.

Finally, the integration of STEM within the 9E model aligns with current educational trends that emphasize interdisciplinary learning and problem-solving skills. By incorporating technology, engineering, and mathematics into physics education, this study addresses the growing need for students to connect scientific concepts to technological innovations and practical engineering challenges(R. Kelley et al., 2019). Therefore, this research has the potential to significantly improve both the content knowledge and the scientific thinking skills of students, preparing them for future challenges in academic and professional fields

Method

This study employs a mixed methods approach with an embedded experimental design (Méndez-Aguado et al., 2020; Dhillon & Murray, 2021), as presented in Figure 1.

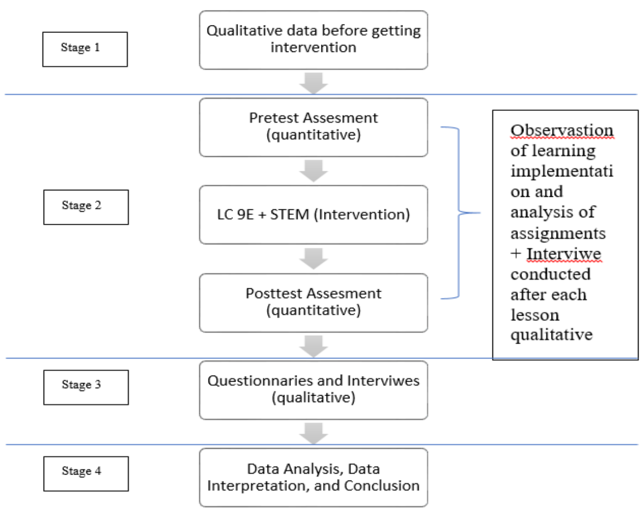

Figure 1. Research Design

The design used is the embedded experimental strategy design, as shown in Figure 1, with several steps. The mixed method embedded experimental design begins with a qualitative before intervention method, which involves interviewing teachers and students regarding the learning process. The second stage is the QUAN premeasure, which includes a pretest conducted quantitatively to analyze Science Process Skills on the topic of static fluids. The pretest is carried out by administering a multiple-choice test to students to assess their Science Process Skills. The pretest data collected represents students' responses to provide information about their initial Science Process Skills in static fluids before learning takes place.

After the pretest, interviews are conducted again with several samples categorized as having good Science Process Skills previously and those who do not have a sufficient understanding of the concepts. This data is qualitative. The intervention is carried out by applying the 9E learning cycle model with STEM, referring to the Lesson Plan. During learning activities (Qual during intervention), qualitative data is embedded through observation, documentation, and field notes on the implementation of learning during the treatment. QUAN postmeasure involves conducting a posttest for Science Process Skills on static fluids. The concept mastery posttest is carried out by administering the same multiple-choice test to students as used in the pretest(Bahşi̇ & Açikgül Firat, 2020). The posttest data collected represents students' responses to provide information about their Science Process Skills in static fluids after learning has taken place(Uysal & Cebesoy, 2020). After the posttest, qualitative data is collected through interviews. The research instruments include observation sheets, interview guidelines, and SPS test. This instrument has a value of rn=0.694 which is categorized as having high reliability and the questions used are in the medium category. the questions used are multiple choicemultiple tests with 12 items for assessing science process skills. The questions are distributed into two topics, 6 questions for Pascal's Law and 6 questions for Archimedes' Principle. The next step is the qualitative after intervention, which involves administering questionnaires and conducting interviews regarding the implementation of learning. Interviews are also conducted after each learning session during the LC 9E + STEM treatment process.

This study involved 32 participants from SMK Muhammadiyah 1 Lamongan, employing a comprehensive approach using multiple-choice questions and observational assessments to evaluate students' Science Process Skills (SPS). The study was conducted over two cycles, each including a pretest, intervention using the 9E Learning Cycle Model integrated with the STEM approach, and a posttest
The pretest and posttest results are analyzed quantitatively and qualitatively to assess the improvement in SPS students. This step is followed by interpreting all the data that has been analyzed quantitatively and qualitatively to draw conclusions(Akgül et al., 2024). Data analysis on the obtained quantitative data includes the Normality Test, Difference Test and Average Normalized Gain (N-gain) Calculation. Meanwhile, qualitative data analysis is performed through Data Reduction, Coding, Data Interpretation, and Conclusion Drawing(Creswell & Creswell, 2018)

Result and Discussion

The study was conducted in two cycles: the first cycle focused on Pascal's Law, and the second cycle centered on Archimedes' Principle. In this research, a pretest, an intervention using the 9E Learning Model integrated with the STEM approach, and a posttest were carried out. The results are presented in Table 1.

Table 1. Pretest and Posttest Results

Test	Mean score	Standart deviation
Pretest	40.83	±2.48
Posttest	78.33	±1.03

The significant improvement from the pre-test to the post-test highlights the effectiveness of the intervention. The average pre-test score was 40.83 (SD = ±2.48), indicating a relatively low baseline understanding of the topics covered. However, following the intervention, the post-test scores showed a marked increase to 78.33 (SD = ±1.03), suggesting substantial improvement in students' comprehension and skills.

At Normality Test (Kolmogorov-Smirnov test) was conducted to check the normality of the pre-test and post-test data. The results indicate that both the pre-test ($p = 0.174$) and post-test ($p = 0.099$) scores were normally distributed ($p > 0.05$), allowing for the use of parametric statistical tests .Difference Test, paired samples t-test was conducted to compare the pre-test and post-test scores. The results revealed a statistically significant difference between the pre-test (M = 40.83, SD = 2.48) and post-test (M = 78.33, SD = 1.03) scores, confirming that the intervention had a significant impact on students' learning outcomes ($p < 0.05$).

The substantial improvement in the post-test results can be attributed to the use of the 9E Learning Model integrated with the STEM approach, which effectively enhanced students' understanding of both Pascal's Law and Archimedes' Principle. The integration of practical, problem-solving activities, and STEM-based projects likely facilitated deeper learning and engagement, enabling students to connect theoretical concepts with real-world applications.

This finding aligns with previous studies that emphasize the positive impact of STEM integration and inquiry-based models in improving conceptual understanding and science process skills(Uysal & Cebesoy, 2020). The low standard deviation in the post-test scores also suggests a more consistent level of understanding across the student group, indicating that the intervention was broadly effective.

This table clearly shows the progressive improvement across both cycles, with significant gains made in Cycle 1 and further improvements in Cycle 2

Table 2. Scores by Cycle

Sps component	Pretest	Cycle 1 (pascal's law)	Cycle 2 (archimedes' principle)
Observing	45	65	80
Classifying	40	60	78
Measuring	42	62	79
Inferring	38	58	77
Predicting	41	61	78
Communicating	39	60	78

The two-cycle approach of the study revealed interesting patterns in skill development. In the first cycle, focusing on creating a flood-resistant garage prototype, students showed initial hesitation, particularly in connecting theoretical concepts to practical applications. However, by the end of this cycle, there was a noticeable improvement in their ability to use scientific equipment and interpret data. For example, in studying hydrostatic pressure for the garage system, students progressed from struggling with pressure sensor readings to confidently designing their own experiments to test pressure-depth relationships.

The second cycle, which focused on creating a wave-powered electricity generator prototype, demonstrated more significant gains, building on the foundation laid in the first cycle. Students exhibited increased confidence and independence in their approach to experiments and data analysis. For instance, when studying Archimedes' principle for the buoy system, students not only accurately predicted the buoyancy of various objects but also designed and conducted experiments to test factors affecting buoyancy that were not explicitly covered in the curriculum.

Qualitative insights from the study provided rich context to these quantitative improvements. Teacher interviews revealed a transformation in students' approach to learning. One teacher noted, "The structured yet flexible nature of the 9E model, combined with STEM activities, has dramatically improved students' ability to think critically and solve problems independently"(Dewanto et al., 2024; Haetami, 2023; Safitri et al., 2024).

Student feedback also provided valuable insights. A student remarked, "The STEM approach helped me understand complex concepts like Pascal's law much better(Istiana et al., 2023; Wildani & Budiyono, 2022). Discussing with my partner made the ideas clearer and more applicable in designing the hydraulic flood-resistant garage system. This sentiment echoes the findings of Tullis & Goldstone, who noted that peer discussion in science learning not only improves understanding but also boosts confidence in tackling complex topics(Tullis & Goldstone, 2020).

Field notes captured the progression from initial hesitancy to active engagement. By the second cycle, students were observed formulating hypotheses and designing their own experiments for the wave-powered electricity generator system, demonstrating a high level of engagement and application of scientific thinking. This observation is supported by recent work from(Antonio & Prudente, 2023), who found that "students exposed to integrated STEM and inquiry-based learning models show a marked increase in their ability to formulate scientific questions and design experiments independently".

Table 3. Improvement Analysis (N-gain Values)

Sps component	N-gain value	Gain category
Observing	0.64	Medium gain
Classifying	0.63	Medium gain
Measuring	0.64	Medium gain
Inferring	0.63	Medium gain
Predicting	0.63	Medium gain
Communicating	0.64	Medium gain

Observational skills demonstrated remarkable progress, with scores increasing from 45 to 80. This enhancement was particularly evident during the Elicitation and Engagement stages of the 9E Learning Cycle. For instance, in a fluid pressure experiment addressing flood-submerged cars, students used advanced pressure sensors in a water tank setup to design a prototype hydraulic garage system. This hands-on STEM activity not only captured students' interest but also sharpened their observational skills(Hiğde & Aktamış, 2022). As students manipulated variables and observed real-time pressure changes, they developed keen attention to detail. This aligns with Li (2022) finding that "integrating technology in hands-on activities significantly enhances students' ability to make precise observations and connect them to theoretical concepts"(Li et al., 2022).

Classification skills improved substantially, with scores rising from 40 to 78. The Exploration and Explaination stages of the 9E cycle were instrumental in this improvement. Students engaged in activities requiring them to categorize fluids based on various properties such as viscosity, density, and flow characteristics. The STEM approach integrated mathematical concepts, allowing students to create quantitative classifications (Shernoff et al., 2017). For example, students developed viscosity scales and used them to classify household liquids that could be used in the flood-resistant hydraulic garage system.

Measurement skills saw a significant boost, with scores increasing from 42 to 79. The Evaluate and Extend stages of the 9E cycle, combined with the technology component of STEM, were crucial in this improvement (Unlu et al., 2015). Students used various tools to measure fluid properties and their effects accurately. In one particularly engaging activity during the second cycle, students designed and conducted experiments to measure the electrical output of their wave-powered electricity generator prototypes using digital multimeters. This hands-on experience with real-world applications allowed students to refine their measurement techniques and understand the practical implications of their work. The iterative nature of the project enabled students to make multiple measurements, analyze the data, and make improvements to their designs based on their findings. As noted by Son and Ha (2024), "The use of digital literacy and digital tools in measurement activities not only improves accuracy but also enhances students' understanding of measurement principles and error analysis"(Son & Ha, 2024). In this case, the use of digital multimeters to measure electrical output provided students with immediate, precise feedback, helping them to better understand the relationship between wave motion and energy generation.

Inferring skills demonstrated substantial growth, with scores rising from 38 to 77. The Echo, Exploration and Explanation (E3) stages of the 9E cycle provided a platform for students to analyze experimental data and draw conclusions. For instance, after collecting data on buoyancy forces for the floating garage, students inferred the relationship between object density and fluid displacement. The engineering aspect of STEM encouraged students to apply these inferences to real-world problems, such as designing floating devices for flood-resistant garages. This approach is supported by recent research from DeSutter & Stieff (2017), who found that "when students apply scientific inferences to engineering challenges, they develop a more robust understanding of underlying principles"(DeSutter & Stieff, 2017).

Prediction skills showed marked improvement, with scores increasing from 41 to 78. The Elaborate and Extend stages were pivotal in developing these skills. Students used their understanding of fluid principles to predict outcomes in new scenarios. For example, they predicted the behavior of fluids in differently shaped containers and verified their predictions through experiments on the hydraulic garage model. prediction activities that are immediately followed by verification experiments significantly enhance students' ability to connect theoretical knowledge with practical outcomes(Baumert et al., 2010; Lestari et al., 2023)

Communication skills saw substantial enhancement, with scores rising from 39 to 78. The E-Search stage was instrumental in this improvement. Students presented their findings through various media, including oral presentations, written reports, and digital presentations. For instance, students created video presentations explaining Pascal's principle and its applications in hydraulic garage systems for flood prevention. This multifaceted approach to scientific communication is supported by recent research from Pujiana et al. (2024), who noted that diverse communication methods in science education not only improve students' ability to articulate complex ideas but also enhance their understanding of the subject matter(Pujiana et al., 2024).

In conclusion, the integration of the 9E Learning Cycle Model with STEM approaches proved highly effective in enhancing students' science process skills in the challenging topic of static fluids, with practical applications in addressing flooding issues and renewable energy(Abdurrahman et al., 2023). The combination of structured learning cycles, hands-on STEM activities, and collaborative strategies created a rich learning environment that fostered significant improvements across all SPS components

Conclusion

This study demonstrated the effectiveness of integrating the 9E Learning Cycle Model with STEM approaches in enhancing students' Science Process Skills (SPS) for static fluid concepts. The research showed significant improvements in all SPS components, with Results showed significant improvements across all SPS components, with N-gain values ranging from 0.63 to 0.64, indicating medium gains. Students demonstrated enhanced abilities in observing, classifying, measuring, inferring, predicting, and communicating scientific concepts. The integrated approach also facilitated the practical application of knowledge, demonstrated through student projects like flood-resistant garage prototypes and wave-powered electricity generators. These findings suggest that the combination of the 9E Learning Cycle with STEM not only strengthens scientific skills but also promotes real-world problem-solving, making it a promising framework for future science education.

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The authors declare no conflict of interest.

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