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Development of the 5E-POW (Predict–Observe–Write) Learning Model Assisted by Virtual Simulation to Reduce Pre-service Teacher Misconceptions on the Topic of Fluids

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ABSTRACT

Misconceptions about fluid mechanics are persistent and require instructional strategies by which conceptual conflict, reflection, and visualization are integrated. In this study, a virtual simulation-assisted 5E-POW (Predict–Observe–Write) learning model was developed and preliminarily implemented to reduce pre-service teachers' misconceptions about fluid mechanics. The ADDIE model, comprising Analysis, Design, Development, Implementation, and Evaluation, was employed. The preliminary implementation involved 18 pre-service teachers from the 2024 cohort. Data were collected using expert validation sheets and a 29-item four-tier diagnostic test administered before and after implementation. The data were analyzed using validity analysis, misconception reduction analysis, normality testing, and a paired-samples t-test. The developed learning model, learning instruments, and virtual simulation media met the validity criteria, although minor revisions to the simulation media were required. Following implementation, decreases in misconception percentages were found for hydrostatic pressure (49.71%), Pascal's law (35.20%), Archimedes' principle (49.34%), discharge and continuity (47.00%), and Bernoulli's principle (55.00%). The pretest and posttest data were normally distributed, and a significant difference was found between the two measurements. These findings indicate that the developed model is feasible and shows potential for reducing pre-service teachers' misconceptions about fluid mechanics. Its contribution lies in integrating the 5E Learning Cycle, the POW strategy, and virtual simulation into a single instructional framework. Further controlled studies with larger samples are required to establish its effectiveness.

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I. Introduction

In the Industrial Revolution 4.0 era, various aspects of life, including education, have been significantly influenced by technological developments through the rapid growth of information and communication technology systems that are integrated into society and the learning process [1],[2]. In response to these developments, the improvement of education quality becomes essential through the transformation of learning services, teaching strategies, and instructional management, so that citizens' right to quality education is fulfilled [3]–[5]. The learning process itself involves the delivery of knowledge through appropriate media and must be systematically planned, so that curriculum, learning resources, teaching materials, facilities, and evaluation processes are considered as interconnected educational components [6]–[10]. Furthermore, the need for flexible, innovative learning by which students' understanding and cognitive development are supported through effective teaching methods and facilities is underscored by technological advancements [11],[12]. In physics education, meaningful learning can be achieved through scientific activities by which communication, understanding, and observation of natural phenomena are integrated, so that students' engagement is enhanced and learning boredom is reduced [13],[14].

Physics is included in science learning, in which theoretical analysis is prioritized. In physics learning, ideas, concrete rules, and decisions that are based on natural phenomena are generally examined scientifically using theoretical concepts [15]. Physics can be described as the science by which the basic laws of the universe and the interactions of matter and energy within it are investigated, with theoretical learning and the creation of quality content, such as experimental activities by which experience is prioritized [16]-[18]. Good physics learning is also seen from a systematic structure and active student involvement [19]-[21]. In physics as a subject, the essence of physics learning lies in the examination of concepts, principles, concrete phenomena, and hypotheses through conceptual understanding and practical application [22]-[24]. Help is needed by students in learning physics, and their motivation is shallow because the material is difficult and tedious (monotonous) [25]-[28]. Attention, motivation, learning, and achievement can be hindered by boring learning [29]. This becomes an obstacle for participants in strengthening their understanding of the concepts of physics learning material.

Misconceptions are consistently incorrect cognitive patterns and can be manifested at various levels of education [30]. This misconception is primarily attributed to domain-general heuristics that arise from the overgeneralization of perceptual-motor experience and physical objects [31]. Conceptual change is not easy, because a decline in the same conceptual understanding may be experienced by students, and educational research and teaching are influenced by the identification of misconceptions [32]. Unfortunately, such misconceptions are often built over time; they are begun in primary school and are persisted as greater competence is gained by students [33]. Apart from that, if the next generation of young people become even more critical of teachers, these misconceptions will be transmitted back to students, so that they are prevented from solving problems [34],[35].

Students' misconceptions need to be remediated by educators, because conceptual understanding can be hindered and learning achievement can be reduced by misconceptions in science education [36]–[38]. In previous studies, several remediation approaches, such as guided inquiry, scientific learning, and the Predict–Observe–Write (POW) strategy, have been implemented, so that conceptual change is facilitated through active learning experiences [39]–[45]. In addition, the 5E Learning Cycle model has been widely recognized as an effective inquiry-based model by which exploration, experimentation, and conceptual reconstruction processes are supported [41]. However, these approaches were generally applied separately in previous studies, and conventional learning activities continued to be relied on, without the integration of interactive digital learning media. Consequently, research by which it is examined how technology-based media can systematically combine the 5E Learning Cycle and the POW strategy to optimize misconception remediation is still limited. Therefore, the novelty of this study lies in the development of an integrated learning framework by which interactive media, the 5E Learning Cycle, and the POW strategy are combined simultaneously, so that students' conceptual reconstruction processes are strengthened.

Practicum activities are considered important in science learning because direct experiences by which abstract scientific concepts are understood are provided by them [46]. Through experimentation and observation, scientific principles are expected to be verified and conceptual understanding to be improved by students. Nevertheless, procedural completion rather than reflective thinking is often emphasized by conventional practicum activities, leading to misconceptions that persist after instruction is provided. In previous studies, the improvement of practicum implementation or laboratory activities was mostly focused on independently, without the integration of reflective learning strategies into the experimental process [47]–[50]. As a result, the remediation process has not been fully optimized, so that students are encouraged to evaluate and reconstruct their misconceptions critically. In this context, the novelty of the present study lies in the integration of reflective POW stages directly into practicum-oriented learning activities that are supported by interactive media, so that experiments are not only conducted by students, but scientific reflection on conceptual errors is also carried out.

The Predict–Observe–Write (POW) strategy has been reported to improve students' conceptual understanding, because they are engaged by it in prediction, observation, and reflective writing activities [46]. It was demonstrated by previous findings that misconceptions could be reduced by the POW strategy, because their initial predictions are actively compared with observed scientific phenomena by students [47]–[50]. However, the POW strategy was primarily implemented as a standalone learning activity in earlier studies, and it was rarely integrated within a broader inquiry-based instructional model. In addition, digital interactive media have been utilized in limited studies, so that the prediction and observation stages in real-time learning environments are supported. A research gap in the integration of reflective strategies, inquiry-based learning, and technology-based visualization tools for the remediation of misconceptions is indicated by this. Therefore, the novelty of this research lies in the development of an interactive learning environment in which POW procedures are systematically embedded within the 5E Learning Cycle, so that deeper conceptual understanding is supported.

The exploration phase in the 5E Learning Cycle model is essential because phenomena are enabled to be investigated and knowledge to be constructed by students through active inquiry [51]–[55]. Despite its advantages, it was found by several studies that extensive instructional time is often required by the exploration stage and that all students may not be effectively engaged during classroom implementation [55],[56]. Previous attempts to improve this phase mainly involved collaborative learning or modified practicum activities [57]–[61]. Nevertheless, it has been explored in a few studies how interactive digital media and structured reflective strategies can be integrated into the exploration phase, so that learning efficiency and conceptual engagement are improved simultaneously. Consequently, a gap remains in the design of technology-supported exploration activities by which both inquiry and conceptual reflection are facilitated. The novelty of this study lies in the embedding of interactive simulations and POW-based reflective tasks into the exploration phase of the 5E Learning Cycle, so that a more efficient and cognitively engaging learning process is created.

Misconceptions frequently occur in physics learning, especially in topics related to Pascal's Law and fluid mechanics, because these concepts are abstract and difficult for students to visualize [62]–[68]. Worksheets, conventional experiments, or direct instruction were generally used in previous remediation efforts, so that these misconceptions were addressed. However, dynamic visualization and interactive conceptual experiences by which students are helped to effectively reconstruct their understanding are often not provided by such approaches. Moreover, studies in which inquiry learning, reflective strategies, and interactive media are integrated specifically for Pascal's Law remain very limited. This condition highlights a significant research gap in the development of integrated learning media for the remediation of misconceptions in fluid mechanics. Accordingly, the novelty of this research lies in the creation of an interactive physics learning media that is specifically designed for Pascal's Law instruction, in which visualization technology, the 5E Learning Cycle, and the POW strategy are integrated into a comprehensive remediation model.

Previous studies have applied the 5E Learning Cycle, Predict–Observe–Write activities, and virtual simulations to support conceptual understanding; however, these components have generally been examined separately. For example, POW has been developed to improve students' conceptual understanding of fluid topics [68], while cognitive conflict strategies have been used to correct pre-service teachers' misconceptions in other scientific domains [69]. Nevertheless, limited evidence is available on the systematic integration of the 5E Learning Cycle, POW activities, and virtual simulations for diagnosing and reducing pre-service teachers' misconceptions in fluid mechanics using a four-tier diagnostic test. Therefore, this study contributes an instructional framework in which POW activities and virtual simulations are embedded within the exploration phase of the 5E Learning Cycle. This study aims to develop and validate the virtual simulation-assisted 5E-POW learning model and to conduct a preliminary evaluation of changes in pre-service teachers' misconceptions about fluid mechanics following its implementation.

II. Method

In this research, a 5E-POW learning model and virtual simulation are being developed using ADDIE's research design. The ADDIE model is adopted as the design framework because of its emphasis on learner-centered instruction, its systematic and phased approach, and its integration of systems thinking in the study of human learning. As illustrated in Figure 1, five key stages are comprised by the ADDIE framework: Analyze, Design, Develop, Implement, and Evaluate.

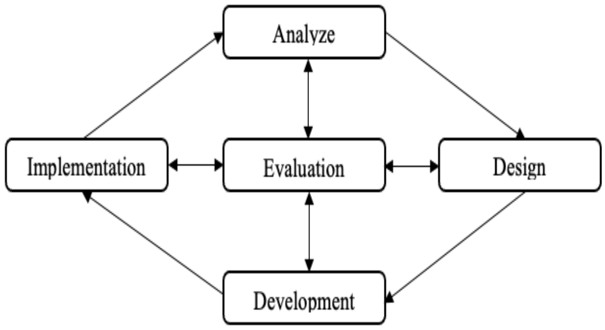

Figure 1. Research Design [70]

In this study, the ADDIE development model, by which the stages of Analysis, Design, Development, Implementation, and Evaluation are included, is used, so that a 5E-POW learning model that is assisted by virtual simulation is developed and pre-service teacher misconceptions about fluid material are reduced. In the analysis stage, learning needs are identified, pre-service teacher misconceptions and pre-service teacher characteristics are analyzed, and curriculum and literature reviews are conducted on learning models and the use of virtual simulation. In the design stage, the syntax of the 5E-POW model, learning tools, research instruments, and virtual simulation designs are developed in accordance with the fluid concept indicators. Furthermore, during the development stage, product development is carried out through a learning model, virtual simulation media, and supporting devices, which are then validated by experts, so that the product's feasibility is determined. During implementation, the developed product is used in the learning process, so that the model's effectiveness in reducing pre-service teacher misconceptions is assessed. In the final stage, namely evaluation, the entire development process and its results are assessed through data analysis of validity, practicality, and effectiveness, so that a learning model that is suitable for physics learning is obtained.

Data were collected by a set of test items being administered to the pre-service teacher. The sample was comprised of a single class of 18 pre-service teachers who were selected through simple random sampling, specifically third-semester participants from the 2024 cohort at a university in East Java, Indonesia. Pre-service teachers' conceptual understanding was assessed using a diagnostic test that was designed, so that their strengths and weaknesses in physics were identified [71]. The analysis was focused on misconceptions in the static and dynamic fluid subtopics. A four-tier diagnostic test by which students' confidence levels in their third-tier responses are also captured was used in the study [72],[73].

The data sources in this study were of two main types: validity data and pre-service teacher misconception test results. The validity data consisted of the validity of the virtual simulation media, the validity of the 5E-POW learning model, and the validity of the research instrument, which were assessed by experts, so that the product's feasibility before implementation in learning was determined. Meanwhile, the test result data were obtained through the implementation of a pretest and a posttest using a four-tier diagnostic test (4-tier test) instrument, so that changes in pre-service teacher misconceptions on fluid material before and after the implementation of the 5E-POW learning model assisted by virtual simulation were identified and analyzed. The data were then used, so that the effectiveness of the developed learning model in reducing pre-service teacher misconceptions. The 4-tier question categories are shown in Table 1.

After all the data were collected, they were processed using several data analysis techniques, so that the feasibility and effectiveness of the developed product were determined. Validity data analysis was conducted on the virtual simulation media, the 5E-POW learning model, and the research instrument, so that the level of product feasibility was determined on the basis of expert assessments. Furthermore, misconception reduction analysis was carried out using data from the pretest and posttest four-tier diagnostic test (4-tier test), by which the analysis of the decrease in the quantity of misconceptions, N-gain calculations for the increase in pre-service teacher conceptual understanding, normality tests for the data distribution, and t-tests for the significance of differences in results before and after the application of the 5E-POW learning model assisted by virtual simulation on fluid material were included.

Validity data analysis aims to determine the extent to which the learning tools and supporting instruments meet the established criteria. The learning tools that are used in the research are valid and reliable. The validity criteria are shown in Table 2.

Table 1. Categories of pre-service teacher Responses and Their Conceptual Levels [74]

Criteria	Answer Combinations			
	Tier 1	**Tier 2**	**Tier 3**	**Tier 4**
Understand	True	Certain	True	Certain
No Understanding of the concept	True	Certain	True	Uncertain
	True	Certain	False	Uncertain
	True	Uncertain	True	Uncertain
	True	Uncertain	True	Certain
	True	Uncertain	False	Uncertain
	False	Certain	True	Uncertain
	False	Certain	False	Uncertain
	False	Uncertain	True	Uncertain
	False	Uncertain	False	Uncertain
Misconception	True	Certain	False	Certain
	True	Uncertain	False	Certain
	False	Certain	False	Certain
	False	Uncertain	False	Certain
Error	False	Certain	True	Certain
	False	Uncertain	True	Certain

Table 2. Validity Criteria

Validation score interval	Category	Description
1.0 < SV < 1.5	Invalid	Not yet usable
1.6 < SV < 2.5	Less Valid	Usable with many revisions
2.6 < SV < 3.5	Valid	Usable with minor revisions
3.6 < SV < 4.0	Very Valid	Usable without revisions

The presence of misconceptions was examined using a four-tier diagnostic test. Subsequently, the proportion of misconceptions among the pre-service teachers was calculated based on equation (1).

$$\Delta m = \%\,\text{Mposttest} - \%\,\text{Mpretest} \qquad (1)$$

Information:

Δm	:	Reduction of Misconceptions
% Mposttest	:	The percentage misconception of pre-service teachers during the posttest
% Mpretest	:	The percentage misconception of pre-service teachers during the pretest

A decrease in pre-service teacher misconceptions after the implementation of the 5E-POW model, which is supported by virtual simulations, is indicated by a negative Δm value. If the Δm value is zero, it means that an increase or a decrease in the number of misconceptions is not experienced by the pre-service teacher after the implementation of the 5E-POW model assisted by virtual simulation. If Δm is positive, it means that an increase in the number of misconceptions was experienced by the pre-service teacher after the implementation of the 5E-POW model assisted by a virtual simulation.

A conceptual understanding test is used, so that the improvement in pre-service teacher understanding is

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measured. The gain in conceptual understanding can be calculated using equation (2) [75]:

$$\langle g \rangle = \frac{(\langle S_f \rangle - \langle S_i \rangle)}{(100 - \langle S_i \rangle)} \quad (2)$$

Information:
$\langle g \rangle$: gain score
$\langle S_f \rangle$: posttest score
$\langle S_i \rangle$: pretest score

The gain value that is calculated using Equation (2) is then interpreted based on the normalized gain criteria that are presented in Table 3:

Table 3. Criteria N-Gain

Score $\langle g \rangle$	Criteria
$\langle g \rangle \geq 0.70$	High
$0.70 > \langle g \rangle \geq 0.30$	Medium
$\langle g \rangle < 0.30$	Low

A normality test was conducted using SPSS. If the significance value is > 0.05, the sample is placed in the normal category; otherwise, it is not. After the normality test, a paired t-test was conducted, so that it was determined whether misconceptions were decreased after the study. If the significance value is < 0.05, it can be concluded that misconceptions were decreased after the implementation of the 5E-POW Model Assisted by Virtual Simulation.

III. Results and Discussion

In this research, the ADDIE development model, by which five stages are consisted of, is used: Analysis, Design, Development, Implementation, and Evaluation. The use of the ADDIE model in this research is aimed, so that the media/learning development process is carried out systematically, in a structured manner, and continuously at each stage. Therefore, the research results and discussion are presented in depth for each step in the ADDIE model, so that the processes of needs identification, product design, development, implementation, and evaluation are explained in detail and comprehensively. In this presentation, the research's contributions and findings can be demonstrated by each development stage.

Analyze

This phase aims to identify pre-service teacher misconceptions. Apart from the identification of pre-service teacher misconceptions, the causes of these misconceptions are also identified in the analysis phase. Accordingly, potential solutions can be proposed so that misconceptions among pre-service teachers are reduced. On the basis of the identification results, several factors have been identified as contributors to these misconceptions. The factors that cause misconceptions among pre-service teachers are that incorrect knowledge of the phenomena being observed is already held by the pre-service teacher. Another factor by which misconceptions among pre-service teachers is that the pre-service teacher cannot be helped by the learning that is carried out by teachers to change misconceptions into scientific conceptions. The causes of these misconceptions are aligned with research [66], which states that teacher and pre-service teacher factors are the main drivers of misconceptions, so that the learning in the following material is made challenging to understand.

Design

Two activities were carried out during the design phase. The first step is the design of a learning model by which pre-service teachers transition from misconceptions to scientifically accurate conceptions is supported. The second is the design of a virtual simulation, so that pre-service teachers' misconceptions are remediated. The 5E learning model (POW) is used, so that misconceptions are remediated. Several syntaxes are used by 5E-POW: engagement, exploration, explanation, elaboration, and evaluation (predict-observe-write). Further details regarding the syntax of the implemented learning model are presented in Table 4. Apart from the design of a new learning model, the virtual simulation also serves as a medium by which changes in pre-service teacher concepts are facilitated.

Table 4. Virtual simulation-assisted 5E-POW syntax

Syntax	Activities
Engage	The activity phase, also known as the attention-getting phase, is when the teacher asks questions about the topics students will study in class. The purpose of these questions is to identify students' initial conceptions and determine their preconceptions before the learning process begins. In this phase, the teacher's questions are used to engage students' interest in learning and to foster cognitive conflict.
Explore (Predict-Observe-Write)	In this phase, the teacher invites students to explore with their classmates. Teachers should divide students into groups to make coordinating the class easier. At this stage, students are prompted to make and evaluate their predictions before examining the material, while also documenting the results of experiments performed using virtual simulations.
Explain	The teacher uses the explain phase to allow students to explain what they learned during the exploration process. In this phase, discussions are held with classmates to communicate individual/group knowledge.
Elaborate	The elaborate phase serves as the expansion stage, during which the teacher deepens students' understanding of the material through detailed explanations. Teachers may also provide additional applications, different from those

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Syntax	Activities
	presented in the previous phase, to enhance students' comprehension of the topic.
Evaluate	The teacher conducts an evaluation to determine how well students have grasped the material presented. Teachers can also evaluate how students understand concepts by observing how their thinking changes.

Development

The development stage includes the creation of 5E-POW learning scenarios, the development of virtual simulations, the development of 4-Tier instruments on fluid topics, validation by experts, and their revision on the basis of input, so that 5E-POW assisted by virtual simulations is created. On the basis of the validity data analysis, the four-tier diagnostic test (4-tier test) instrument and the developed learning tools were categorized as valid, so that they were made suitable for use in the learning process without revision being required. It is indicated by these results that the components of the instrument and the learning tools are aligned with the learning indicators, the research objectives, and the characteristics of fluid material, and that the identification and reduction of pre-service teacher misconceptions can be optimally supported by them. Furthermore, it was indicated by the validator's assessment that the very good feasibility criteria were met by the content, construction, language, and syntax of the 5E-POW learning model.

Meanwhile, the developed virtual simulation-assisted learning media were found to be valid and usable for learning. However, several revisions were required on the basis of the validator's suggestions and input. The revisions were aimed at improving the display, the interactivity, the clarity of the fluid concept visualization, and the ease of use for the pre-service teacher during the learning process. With these revisions, the implementation of the 5E-POW learning model is expected to be more optimally supported by the learning media, so that the effectiveness of learning in reducing pre-service teacher misconceptions about fluid material is increased.

On the basis of the validity analysis, all components of this study were found to be valid and suitable for use in the learning process. These findings include the validity of the virtual simulation media, the 5E-POW learning model, and the research instruments, all of which received positive assessments from expert validators. It is indicated by the validity that the material, construct, presentation, language, and learning objectives are met by each developed component, and that the physics learning process can be supported by it, particularly in the reduction of pre-service teacher misconceptions about fluids.

Validation was conducted by two experts in their fields; for details on the validation results, Table 5 can be referred to.

Table 5. Assessment by a material and media expert

Validator	Score Validation	Category
Material expert validator 1	3.0	Valid
Material expert validator 2	3.2	Valid

It is suggested by the results from the validation analysis that the 5E-POW learning model, when it is supported by virtual simulations, can be effectively employed in teaching. The average score percentage of the two validators is 87.5%. On the basis of feedback and evaluations from two validators, revisions were made before the 5E-POW model with virtual simulation support was finalized for classroom use. Details of the validators' input can be found in Table 6.

Table 6. Material expert revision

Before Revision	After Revision
Typos in the text need to be corrected.	Typos in the text have been completely corrected.
Calculation errors in virtual simulations.	Calculations in virtual simulations have been improved.

Implementation

After improvements were made to the developed virtual simulation, it was obtained and made ready for use, so that misconceptions about fluids were hoped to be reduced. The developed virtual simulation is shown in Figure 2.

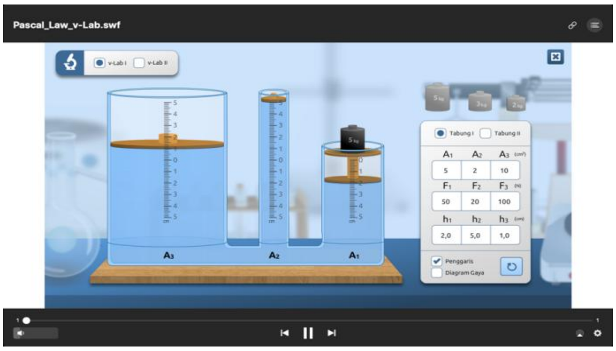


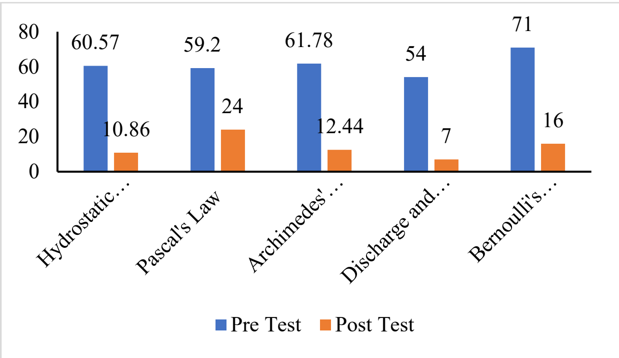
Figure 2. The final result of the virtual simulation has been developed.

After limited trials were conducted, the developed learning models and media were implemented in the next phase. This study was conducted with one class, and pretests and posttests were used, so that changes in pre-service teacher conceptions were observed. So that the reduction in pre-service teacher misconceptions, the pretest and posttest scores were analyzed using normality tests followed by t-tests as part of a statistical approach. The results of these tests for all pre-service teachers are presented in Table 7.

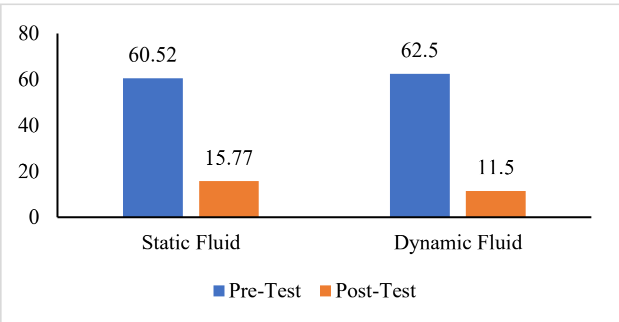
Table 7. Normality and Paired Sample Test Results

	Shapiro Wilk		Paired Samples Test		
Class	Statistic	Sig.	Correlation	Sig.	df
Pretest	0.921	0.054	0.646	0.01	24
Posttest	0.943	0.176			

As is shown in Table 7, a p-value greater than 0.05 was yielded by the normality test, by which it is indicated that the data are normally distributed according to the SPSS analysis. In addition, a p-value below 0.05 is shown by the t-test results, by which it is suggested that pre-service teacher misconceptions are effectively reduced by the 5E-POW model when it is integrated with virtual simulations. The decrease in misconceptions across key material indicators, including hydrostatic pressure, Pascal's law, Archimedes' principle, discharge and continuity, and Bernoulli's principle, is depicted by Figure 3(a).



(a)



(b)

Figure 3. (a) Misconception Value for Each Sub-Material (b) Misconception Value for Each Topic

In these results, a more significant misconception, namely 71.00, is had by the Bernoulli's principle material. The most significant reduction in misconceptions occurred in the debit and continuity material. This is shown by the pretest score of 54.00 and the posttest score of 7.00. Furthermore, the results are supported by the diagrams for each topic, namely static and dynamic fluids. A reduction in pre-service teacher misconceptions is indicated by Figure 3(b). In the pretest, misconceptions were recorded at 60.52 for static fluid topics and 62.50 for dynamic fluid topics, by which it is suggested that misconceptions were more prevalent in fluid dynamics. A substantial decrease in misconceptions that are related to fluid dynamics is made evident by the posttest score of 11.50. This reduction is further illustrated in Figure 4.

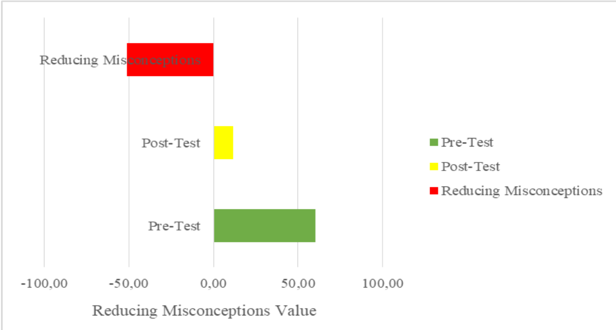


Figure 4. Reducing Misconceptions

This is based on the results of the reduction of misconceptions about the material that was given to the pre-service teacher. The average reduction in misconceptions was 50.48, indicating a decrease in pre-service teacher misconceptions.

Misconceptions can be led to by personal factors of the mind, so remediation must be facilitated by teachers, so that they are prevented from becoming obstacles to pre-service teacher learning progress [38]. A problem that often needs to be clarified in physics learning is that physics is often taught by teachers by having the pre-service teacher memorize formulas without the concepts being understood [36],[37]. So that physics concepts are understood, the application of the material that is being taught must be understood by the pre-service teacher, so that learning is based on evidence, such as practical work by which hypotheses are tested [41]. That shows that, so that the understanding of physics concepts is strengthened, learning is not only about the memorization of formulas but also about the formula's hypothesis being able to be proven by the pre-service teacher. Pre-service teacher learning must be facilitated by a teacher through the testing of hypotheses, so that misconceptions are prevented.

It was shown by findings at the identification stage that misconceptions that stem from mistakes in the interpretation of a concept were held by many pre-service teachers, and that the pre-service teacher needed to be helped by teachers to change their conceptions. To strengthen these findings, references to the causes of misconceptions in other articles are added. One way by which misconceptions are reduced is the application of cognitive conflict strategies [65]. It is indicated that the implementation of cognitive conflict strategies is facilitated by the developed model, so that misconceptions are reduced [65]. That is done through research in which misconceptions are reduced.

Changes in pre-service teacher conceptual understanding can be facilitated by virtual media through virtual simulations in the development of learning models. Virtual simulations have become an alternative solution for cost, time efficiency, space, and safety, and visually rich learning experiences and immediate feedback by which misconceptions can be reduced are offered by them [38]. On the basis of expert reviewers' validation, an average score above 85% was achieved by the developed virtual simulation, by which its readiness for implementation in pre-service teacher learning is indicated. Furthermore, virtual simulations have been shown to help remediate pre-service teacher misconceptions in fluid topics, as is indicated by results from the four-tier diagnostic test. Accordingly, this diagnostic test is implemented within the framework of a newly developed learning model, namely the 5E-POW (Predict–Observe–Write) approach.

A positive impact on the pre-service teacher, particularly in the correction of their prior misconceptions, is had by the 5E-POW learning model that is supported by virtual simulations. Misconceptions arise due to overgeneralization that is based on perceptual-motor experience [31]. From learning using 5E-POW, pre-service teachers' ability to understand fluid material is increased. This was obtained on the basis of an increased learning correlation value of 0.646, which is in the high category. Pre-service teachers' understanding of the material is increased, and their misconceptions are decreased, as a result of virtual simulations that are supported by appropriate learning methods. Appropriate pedagogical approaches and technology are involved in one appropriate learning model [42]. In virtual simulation as a pedagogical medium, pre-service teachers' motor perception undergoes reconstruction, so that a new understanding, by which previous misconceptions are remediated, is led to. This virtual simulation is packaged in the 5E-POW learning method in fluid materials.

Both learning media and pedagogical strategies are enhanced by the integration of the 5E-POW approach with virtual simulations. Through the structured stages of engagement, exploration, explanation, elaboration, and evaluation (predict–observe–write), pre-service teacher misconceptions are effectively reduced by this model. The reduction in misconceptions about fluid topics is made evident when the 5E-POW sequence is applied systematically. Moreover, it is indicated by validation results that this approach is applicable in classroom learning. The innovative aspect of this model lies in its use of specially designed virtual simulations. Through the use of information technology in educational innovation, such as virtual applications, a different atmosphere in the appreciation of the pre-service teacher learning process can be created [15]. This is evident in the 5E-POW learning method; beyond the complex stages, new understandings among the pre-service teachers can also be fostered by the influence of virtual simulation media. Due to the novelty of the methods and media that are used, they are well-suited for implementation in the education sector.

The success of this research in the reduction of pre-service teacher misconceptions is influenced by the implementation of learning strategies by which conceptual change, or gradual shifts in pre-service teacher concepts, is facilitated. Through the 5E-POW learning model assisted by virtual simulation, information is not only passively received by the pre-service teacher, but they are also guided, so that conceptual understanding is rebuilt based on learning experiences that are gained through prediction, observation, discussion, and reflection. Through this process, their initial conceptions are allowed to be compared by the pre-service teacher with observed scientific phenomena, so that their understanding of correct scientific concepts is reconstructed. This finding is aligned with previous research, which suggests that misconceptions can be reduced through learning in which conceptual change and active pre-service teacher involvement in experiential scientific learning are facilitated [32]-[38].

Furthermore, the success of this research is also supported by the implementation of cognitive conflict strategies that are integrated into the 5E-POW syntax. Cognitive conflict strategies emerge when discrepancies between their initial predictions and the results of observations that are obtained through virtual simulation and exploration activities are discovered by the pre-service teacher. Through this situation, the pre-service teacher are encouraged to reevaluate their understanding and to replace incorrect concepts with more appropriate scientific concepts. The cognitive conflict process is also strengthened by the use of virtual simulation, because visualizations of fluid concepts can be seen by the pre-service teacher in a more concrete, interactive way, so that conceptual reconstruction is facilitated. Thus, learning is enhanced by the integration of cognitive conflict strategies, virtual simulation, and the 5E-POW model, so that pre-service teacher misconceptions about fluid material are reduced [38]-[65].

IV. Conclusion

This study produced a virtual simulation-assisted 5E-POW learning model for diagnosing and reducing pre-service teachers' misconceptions about fluid mechanics. The developed model, learning instruments, and simulation media met the validity criteria, although minor revisions to the simulation media were required. Following its preliminary implementation in one class, decreases in misconception percentages were observed across hydrostatic pressure, Pascal's law, Archimedes' principle, discharge and continuity, and Bernoulli's principle. These findings indicate that the model is feasible and shows preliminary potential for supporting misconception remediation through prediction, observation, reflection, and visualization activities. Limitation: However, this study still has limitations because the developed virtual simulation has not been integrated into a single application, and the research is still conducted on a limited sample within a single class. Future research: Therefore, it is recommended that a more integrated, interactive, and adaptive virtual simulation platform be developed through further research, and that the effectiveness of the 5E-POW model be tested on a wider range of physics materials and a larger number of samples, so that stronger generalization of the results is obtained.

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Declarations

Author contribution	**:**	Oka Saputra led the conceptualization and design of the study, conducted data collection and bibliometric analysis, performed data visualization and interpretation, and drafted the original manuscript. Aisyah Nur Fadillah and Hanandita Veda Saphira contributed to the conceptual framework, validated the analysis, critically reviewed and revised the manuscript, and supervised the research process.
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