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# The Effectiveness of Introduction, Connection, Application, Reflection, and Extension Learning Model Based on PhET Simulation in Improving Students' Cognitive Ability on Dynamic Fluid Material

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## Abstract

This research aimed to assess the enhancement and effectiveness of the ICARE instructional approach, utilising PhET simulations, in augmenting students' cognitive abilities. The study employed a quantitative quasi-experimental design utilising a non-equivalent control group design. The sampling technique in this study was Convenience sampling involving 68 grade XI students (32 experimental class students and 36 control class students) in one of the public high schools in Bandung City. Student cognitive data was collected using a multiple-choice test instrument consisting of 23 questions designed by the researchers. Data analysis was employed to assess the improvement of cognitive ability through N-Gain calculation. In addition, statistical tests and effect size were used to evaluate the effectiveness of the ICARE learning model based on PhET simulation. The findings indicated that the group implementing the ICARE learning model based on PhET simulation demonstrated a greater cognitive ability enhancement than the group solely utilising the ICARE learning model. Statistical analyses revealed a significant disparity in cognitive ability improvement between students utilising the PhET-based ICARE learning model and those solely employing the ICARE learning model. Furthermore, effect size calculations indicated a notable discrepancy in cognitive ability enhancement between the experimental and control groups, characterised by a high category distinction. Therefore, it can be concluded that research using the ICARE learning model based on PhET simulation effectively improves students' cognitive abilities on dynamic fluid material.

**Keywords:** cognitive ability; dynamic fluids; ICARE learning model; PhET simulation

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## INTRODUCTION

Education serves as the primary mechanism for the advancement of both the nation and the state. Education today must be adapted to the development of the 21st century so that students' competencies increase so that they become human resources capable of facing global competition and challenges by the demands of the times ( Keane & Keane, 2014; Pratiwi et al., 2019). There is a paradigm shift in learning in the 21st century. First, learning must direct students to seek information from various sources actively. Second, learning must provide

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direction so students can formulate, identify, and analyse problems.

In 21st-century learning, the importance of deep cognitive knowledge skills in the context of life about a problem, event, or occurrence is highly emphasised. In this century, students are required to actively seek learning resources to have a broad knowledge of cognitive abilities as a provision for their learning (Haliza, 2022; Mardhiyah et al, 2021; Rahayu, 2022). According to (Vidayanti et al., 2017), cognitive abilities significantly enhance students' thinking skills. This is because cognitive abilities are related to a person's level of intelligence and are one of the assessment criteria in the education system in Indonesia. This statement is in line with the statement of Nabilah et al. (2020) that in learning in Indonesia, there is one assessment: the assessment of cognitive aspects. Therefore, cognitive abilities are related to intelligence and an important indicator of academic success. With good cognitive abilities, individuals can solve problems effectively, make the right decisions, and learn better (Auliyah et al., 2023). However, the level of cognitive ability is still relatively low.

The results of a preliminary study of 27 cognitive ability test items on Dynamic Fluid material conducted at one of the Bandung City public high schools showed that 95% of students had scores below the MCC (Minimum Completeness Criteria). The MCC value applied in the school is 75, while the average value obtained by students is 47.89. The average student score on the Principle of Continuity subconcept is 54.08, while the average score on the Bernoulli's Law subconcept is 43.64. In addition, the average student score on the understanding aspect (C2) was 46.71, the applying aspect (C3) was 50.72, and the analysing aspect (C4) was 42.67.

Based on the literature study, research conducted by Hardianti (2018) regarding the examination of students' cognitive abilities in high school physics subjects shows that students' cognitive abilities are still relatively low. The percentage of students who could answer questions at the C1 level was 37%, C2 was 23%, C3 was 30%, and C4 was 7%. Furthermore, research conducted by Novitasari et al. (2023) revealed that 89.5% of students still need help understanding the material at school, especially in high school physics, especially on the topic of fluids. They need help analysing physics problems due to the requirement of comprehending numerous formulas. The same thing was also seen in a study by Hamundu et al. (2023), which showed that students had difficulty understanding the concepts of Continuity Equation, the Bernoulli Principle, and the Torricelli Theorem.

In addition, the researchers conducted interviews at one of the public high schools in Bandung City. Interviews with physics teachers showed complaints about students' low cognitive abilities, lack of interaction, and teacher-centred learning. The process is limited to delivering material and asking questions, which are then discussed together in class.

The low cognitive ability of students to solve physics problems can be caused by the lack of learning activities that stimulate the construction of knowledge and connect it to everyday life. As explained in the theory of constructivism, according to Jean Piaget, individuals need to apply their concepts to the world to understand it (Suryana et al., 2022). Meanwhile, physics as "a way of investigating" expressed in Mahardika et al. (2023) requires physics learning to be active through various activities such as investigating natural phenomena, asking questions, practising problems, discussing, and conducting

experiments. Hence, it is imperative to develop a suitable physics learning model to guide students in enhancing their cognitive abilities in physics.

An engaging learning model will encourage students to be more active, help strengthen their understanding of the material, and stimulate cognitive abilities toward physics learning. An engaging and interactive learning model that promotes student participation is the ICARE (introduction, connection, application, reflection, and extension) learning model (Efendi et al., 2023; Salyers et al., 2010; Siahaan et al., 2020). A teacher takes on the role of facilitator in the ICARE learning model (Byrum, 2013; Siahaan et al., 2020). Put another way, the ICARE learning model positions the student in the centre of all learning activities (the student centre). By emphasising each of the ICARE learning model's stages, educators can alter their students' classroom experience (Byrum 2013; Mahdian et al., 2019; Siahaan et al., 2020).

The ICARE model at the introduction stage allows students to observe phenomena in their daily lives, inspiring them to be more engaged and pique their curiosity. At the connection stage, the teacher links the knowledge that students already have with the material to be learned so that students can build their knowledge (Destari et al., 2021; Mahdian et al., 2019; Rahmadhani & Wahyuni, 2020). Students get to put what they have learned in experimental activities to use by solving challenges in a more realistic, open-ended setting during the application stage so that the knowledge gained by students can become stronger and last longer in their memories (Sinuraya et al., 2019). During the reflection stage, pupils can review previously covered material. During the final step, known as extension, students are allowed to broaden and intensify their learning, enhancing their comprehension of the study materials and gaining a more profound understanding (Hoffman & Ritchie, 1998; Destari et al., 2021). Each stage has its own impact, but overall, the application stage is often considered to have the greatest effect in reinforcing and retaining students' knowledge.

Motivating students to have a high enthusiasm for learning is possible through the ICARE learning model. A student's learning ability can be defined by how highly motivated they are (Filgona et al., 2020; Hardre et al., 2007; Rahman, 2021). Therefore, the ICARE learning model can potentially enhance pupils' cognitive capabilities. This information is evidenced by the results of previous research conducted by Muharti & Setiawan (2016), demonstrating that the ICARE learning model can enhance pupils' cognitive abilities with a very large category of elasticity material. In addition, findings from studies performed by Asri, Rusdiana, & Feranie (2017) demonstrated the ICARE learning model combined with science magic can improve students' cognitive abilities.

Byrum (2013) stated that the ICARE learning model has several advantages, including (1) Motivating students to be more active and increasing their curiosity, (2) Training students to build their knowledge, (3) Providing students with opportunities to apply the concepts they have learned, (4) Offering students the chance to revisit the learning material, thereby strengthening their knowledge and ensuring it lasts longer in memory, (5) Allowing teachers greater flexibility in designing lessons, enabling them to transform students' learning experiences. However, implementing the ICARE model also has drawbacks, such as requiring a significant amount of time for students to understand the problems presented (Musri, 2020) fully. Therefore, visualisations of abstract or difficult-to-imagine concepts are needed to help

students better grasp the given problems (Musri, 2020; Sinuraya et al., 2019).

One alternative to mitigate these weaknesses is integrating PhET Simulations with the ICARE learning model. This is because PhET Simulations can visualise the unseen and provide multiple representations, such as macroscopic, microscopic, and graphical (Muzana et al., 2021). PhET simulation media are used to help students understand physics concepts visually, using dynamic graphics that explicitly bring to life the visual and conceptual models used by expert physicists (Wieman et al., 2010).

In this study, PhET simulations address the limitations of experimental equipment, particularly in the context of dynamic fluids, as dynamic fluids is an abstract physics concept that is difficult to experiment on directly. Laboratory experiments still need to be better implemented, primarily due to inadequate laboratory facilities (Anggereni et al., 2021). PhET (Physics Education Technology) simulations can make lessons more interesting because students can explore as well as play on simulations.

Learning that utilises PhET simulation produces a better student cognitive understanding than learning that does not use PhET simulation (Adams, 2010; Banda & Nzabahimana, 2021; Martanti et al., 2021). Moreover, studies executed by Saputra et al. (2020) revealed that the control group did not see nearly as much improvement in learning outcomes as the experimental group that employed PhET simulation media. This is because PhET simulation has several advantages.

The benefits of Incorporating PhET simulation into the learning process, as stated by Finkelstein et al., (2006) include (1) presenting information related to physics concepts that are quite complex; (2) providing convenience for users and completeness of content; (3) ability to inspire more students to study; (4) works even when not connected to the internet.

This research used the PhET simulation to supplement the ICARE learning model. Applying PhET is carried out at the application stage after students identify phenomena in everyday life related to the concepts to be learned. Furthermore, students analyse physics-related factors or quantities related to these phenomena using simulations from PhET Colorado, edu. The novelty of this research lies in integrating the ICARE learning model with PhET simulations, which is expected to enhance the effectiveness of the learning process further.

This study aimed to evaluate whether the ICARE learning model, which is based on PhET simulation, is effective in increasing students' cognitive abilities. Additionally, the results of this study were intended to determine whether or not the cognitive abilities of high school students improved when they were exposed to the topic of dynamic fluid. When it comes to improving students' learning outcomes, it is anticipated that the findings of this study will be one of the effective learning alternatives.

## METHOD

The research methodology employed in this investigation is quantitative research. The research methodology employed is a quasi-experimental design. The research design employed in this study is a nonequivalent control group design (Creswell, 2019; Gopalan et al., 2020; Scher et al., 2015). This design uses two classes: the experimental class (using the ICARE learning model based on PhET simulation) and the control class (using the ICARE learning model without learning media based on PhET simulation). The research strategy of the

nonequivalent control group design is presented in Table 1.

Table 1 Nonequivalent control group research design

| Class | Pre-test | Treatment | Post-test |
|---|---|---|---|
| Experiment | $O_1$ | X | $O_2$ |
| Control | $O_1$ | - | $O_2$ |

(Gall et al., 2003)

Notes:
$O_1$ : Giving pre-test questions that are done before the learning
$O_2$ : Administration of posttest questions conducted after being given learning
X : Learning treatment with ICARE model (Introduction, Connection, Application, Reflection, Extension) based on PhET

Students from one of Bandung City's public high schools enrolled in the eleventh grade were the subjects of this research. Two XI classes representing the total population were used as samples for this investigation. The selection of samples in the present research employed a convenience sampling strategy. According to Creswell's (2019) definition, this technique involves selecting participants based on their willingness to participate. The study included 68 students, with 32 students in the experimental class and 36 in the control class. The participant taken as a participant is a class without learning about dynamic fluid material. The research was conducted in as many as four meetings in each class with a time allocation of 10 MH (Meeting Hours). One MH is equivalent to 40 minutes. At the first meeting, students were given a pre-test for 2 MH. The second meeting discussed the concept of the Continuity Principle for 3 MH, and the third meeting discussed Bernoulli's Law and its application for 3 MH. After learning, on the fourth meeting, students were given a posttest for 2 MH.

Before being applied to the research, the study's assessment tools underwent expert evaluation and pilot testing to ensure viability. Two lecturers and one teacher carried out judgement expert or assessment by experts on this research test instrument to test the cogency of the content and suitability with the desired indicators. After expert judgment, the test instrument was tested on a group of students who had studied dynamic fluid material. The test results were then tested for validity and reliability.

The validity test analysed using Rasch modelling is called Unidimensionality (Sumintono & Widhiarso, 2015). The unidimensionality of an instrument is able to be determined by the raw variance explained by measures using Winstep software version 4.5.0, which is obtained from the output menu table 23.0: Item dimensionality. The results of the unidimensionality test for the cognitive ability test instrument indicate that the raw variance explained by measures obtained from the 27-item test instrument trial is 35.5%. According to the interpretative criteria proposed by Sumintono & Widhiarso (2015), this value indicates that the instrument meets the criteria for unidimensionality. Therefore, it can be asserted that the instrument employed in this study can measure a single variable without being subject to the impact of other factors. In conjunction with the raw variance value explained by measures, the unidimensionality of the test instrument can also be seen from the unexplained variance value in $^{\text{the first}}$ contrast. An instrument can have good unidimensionality if the unexplained variance in $^{\text{first}}$ contrast is less than 15% (Fisher, 2007). The outcomes of the examination of instruments used to assess cognitive ability in this study

showed the value of unexplained variance in first contrast of 13.7%, so it can be said that the instruments used in this study have a good quantity of unidimensional test instruments.

In addition, all items undergo a validity test to ascertain their quality. The validity test of the question items is obtained from the output of Table 10.1: Item fit order. The item fit order provides information regarding each item's eligibility through the utilisation of the outfit means square (MNSQ), outfit Z-standard (ZSTD), and point measure correlation (Pt Measure Corr.).

The validity assessment of each item yielded 15 items that met the criterion of being "Very suitable", seven items that were "Suitable", 1 item that was "Less suitable", and four items that were “Not suitable”. From these results, the researchers decided to reduce as many as 4 items that were not suitable because they were considered unfit compared to other questions or not in accordance with Rasch's analysis. Meanwhile, one item that needed to be more suitable was decided to be revised. Thus, of the 27 items, the number of questions that meet the item-fit criteria and are suitable for use in this study is 23 items, namely nine items on the aspect of understanding (C2), ten items on the aspect of applying (C3), and four items on the aspect of analysing (C4).

The reliability test in this study was analysed by Rasch modelling using Winstep software version 4.5.0 in the output menu Table 3 Summary statistic. The data obtained on the Summary statistic menu include person reliability (p), item reliability (r), and Cronbach alpha (KR-20). The outcomes of the assessment of the cognitive aptitude test instrument's reliability showed that the person's reliability is 0.76 with the interpretation of “Enough.” The results of this interpretation indicate that there may be a lack of samples and items on this research test instrument. This is because a sample with a broad ability range and a substantial quantity of objects is required to get a high person reliability coefficient. (Sumintono & Widhiarso, 2015). The item reliability value was obtained at 0.93 with the interpretation of “Very Good.” The results of the interpretation of this item's reliability indicate that the cognitive ability test instrument used in this study was declared very good regarding the consistency of the weight of the questions and answer choices. Then, the Cronbach alpha value (KR-20) was obtained at 0.76 with the interpretation of “High.” The results of this interpretation indicate that the cognitive ability test instrument in this study is of good quality, so this test instrument can identify the relationship between students (person reliability) and items (item reliability).

From the analysis of test instruments using Rasch modeling, it is possible to deduce that the cognitive ability assessment tools employed in this investigation are valid and reliable.

The test instrument was used in the pre-test and post-test. N-Gain average analysis is the method utilised to ascertain the development of students' cognitive abilities after collecting pre-test and post-test scores. According to Hake (1999), the acquisition category is detailed in Table 2.

Table 2 N-gain classification

| N-Gain Value | Category |
|---|---|
| $(< g >) \geq 0.70$ | High |
| $0.07 > (< g >) \geq 0.30$ | Moderate |
| $(< g >) < 0.30$ | Low |

(Hake, 1999)

Subsequently, employ statistical tests and effect size analysis to ascertain the efficacy of the ICARE learning model utilising PhET simulation in enhancing students' cognitive abilities. The equation used to calculate the effect size

according to Thalheimer & Cook (2002).

If the magnitude of the effect size is known, then an interpretation is made based on the effect size value. The criteria for interpreting the effect size value according to Becker (2000) are shown in Table 3.

Table 3 Interpretation of effect size value

| Effect Size | Interpretation |
|---|---|
| $0.20 \le d < 0.50$ | Low |
| $0.50 \le d < 0.80$ | Moderate |
| $0.80 \le d \le 2.00$ | High |

(Becker, 2000)

## RESULT AND DISCUSSION

### Improvement of Cognitive Ability

The study's cognitive ability test tool uses Lorin W. Anderson and David R. Krathwohl's updated Bloom's taxonomy. This test instrument consists of 23 items, including 9 on the aspect of understanding (C2), ten on the aspect of applying (C3), and four on the aspect of analysing (C4). The pre-test and post-test outcomes were analysed using the N-Gain formula. The average value and normalised gain for the control and experimental classes are shown in Table 4.

Table 4 Comparison of mean scores on pre- and post-tests and n-gain

| Class | *Pre-test* | *Posttest* | <g> | Category |
|---|---|---|---|---|
| Experiment | 24.46 | 77.31 | 0.70 | High |
| Control | 24.28 | 55.43 | 0.41 | Moderate |

According to the data in Table 4, the experimental class had an N-Gain value of 0.70, which falls into the "High" category, whereas the control class had an N-Gain value of 0.41, falling into the "Moderate" group.

Moreover, the enhancement of students' cognitive capacities in every area may be discerned from the test scores acquired by students on each item administered in the pre-test and post-test. This study covers three aspects: aspects of understanding (C2), aspects of applying (C3), and aspects of analysing (C4). Table 5 analyses the mean scores obtained on the pre-test and posttest for every cognitive ability aspect in both the experimental and control groups.

Table 5 N-gain for each aspect of cognitive ability

| Aspects | Experiment | | Control | |
|---|---|---|---|---|
| | <g> | Category | <g> | Category |
| Understanding (C2) | 0.80 | High | 0.49 | Moderate |
| Applying (C3) | 0.66 | Moderate | 0.38 | Moderate |
| Analysing (C4) | 0.62 | Moderate | 0.36 | Moderate |

Figure 1 shows the N-Gain for each cognitive ability aspect of students in the experimental and control groups when represented graphically.

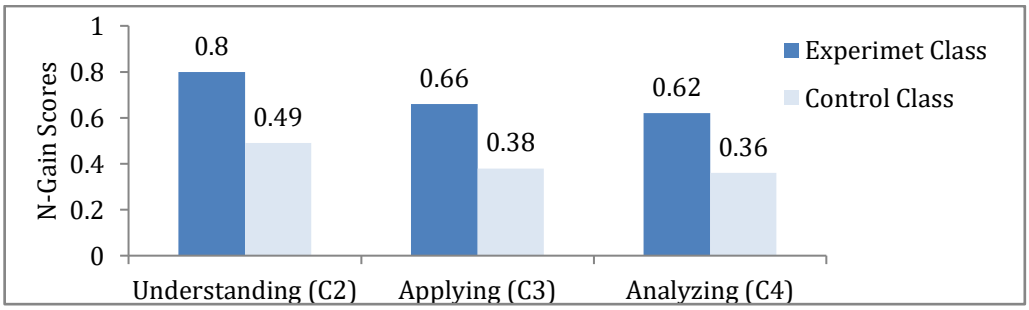



Figure 1 N-gain comparison chart for every aspect of cognitive ability

It is evident from Table 5 and Figure 1 that the experimental class exhibited an average normalised gain score of <g> for aspects of cognitive ability understanding (C2) of 0.80 with the category “High”, aspects of applying (C3) of 0.66 with the category “Moderate”, and aspects of analysing (C4) of 0.62 with the category “Moderate”. The average normalised gain score <g> in the control class for aspects of cognitive ability to understand (C2) of 0.49 with the category “Moderate”, aspects of applying (C3) of 0.38 with the category “Moderate”, and aspects of analysing (C4) of 0.36 with the category “Moderate.”

**Effectiveness of ICARE Learning Model based on PhET Simulation**

Effectiveness assessment is conducted to quantify the degree to which using the ICARE learning model, which is based on PhET simulation, enhances students' cognitive capabilities in the context of dynamic fluid content. The statistical analysis included doing a normality test, a homogeneity test, and a hypothesis test using IBM SPSS Statistics 26 software. The normality test aims to ascertain whether the samples obtained from the population exhibit a normal distribution. The number of samples in this study was more than 50. Therefore, the normality test analysis used the Kolmogorov-Smirnov test. The results of the normalcy test analysis are shown in Table 6.

Table 6 Results of the normality test

| Data Sources | Kolmogorov-Smirnov[a] | | | Interpretation |
|---|---|---|---|---|
| | *Statistic* | df | Sig. | |
| N-Gain Experimental Class | 0.175 | 32 | 0.014 | Not normally distributed |
| N-Gain Control Class | 0.113 | 36 | 0.200* | Normally distributed |

Table 6 indicates that the control class N-Gain score has a significance value of 0.200. Based on the experimental class N-Gain, with a significance value of more than 0.05 (0.200 > 0.05), the data may be inferred to follow a normal distribution. Moreover, the experimental class's N-Gain has a significance value of 0.014, less than 0.05. Therefore, it may be inferred that the data does not follow a normal distribution. The non-normally distributed values are due to outliers or extreme values in the average N-Gain data. This indicates that there are data points significantly different from most other data points in the dataset. These non-normal values may arise from significant differences in students' cognitive abilities. To address this, the researchers need to conduct an analysis using a homogeneity test.

The homogeneity test is employed to ascertain whether the collected data originates from a uniform population. The results of the analysis are shown in Table 7.

Table 7 Results of the homogeneity test

| Data Sources | *Levene Statistic* | df1 | df2 | Sig. |
|---|---|---|---|---|
| Average N-Gain of Experimental and Control Classes | 1.613 | 1 | 66 | 0.209 |

The significant value of the average change in N-Gain in the experimental and control classes, as indicated in Table 7, is 0.209. As the obtained significance value is greater than 0.05 (0.209 > 0.05), it is possible to conclude that the data distribution is homogeneous. In homogeneous data that deviates from a normal distribution, hypothesis testing is conducted through non-parametric statistics, specifically the Mann-Whitney (U) test. This test aims to ascertain whether the means of two unpaired

samples differ. The hypothesis used in this investigation is as follows:

- $H_0$: There is no discernible disparity in enhancing cognitive capacities between cohorts of students who use the PhET-based ICARE learning model and those who utilise the ICARE learning model.
- $H_1$: There is a substantial disparity in enhancing cognitive capacities between student groups that use the PhET-based ICARE learning model and those that employ the ICARE learning model.

The Mann-Whitney (U) test analysis results can be seen in Table 8.

Table 8 Results of the Mann-Whitney Test (U)

| Data Sources | Asymp. Sig. (2-tailed) | Decision |
|---|---|---|
| N-Gain of Experimental Class and Control Class | 0,000 (Asym.Sig. < 0,05) | $H_0$ is rejected $H_1$ is accepted |

Based on the data analysis results, the null hypothesis ($H_0$) is dismissed, and the alternative hypothesis ($H_1$) is confirmed. The findings suggest a statistically significant disparity exists in the enhancement of cognitive abilities between student cohorts utilising the PhET-based ICARE learning model and those utilising the ICARE learning model solely.

The effectiveness of applying the PhET simulation-based ICARE learning model to enhance students' cognitive capacities was further examined by measuring Cohen's effect size. This analysis is conducted by comparing the control and experimental groups. Before computing the effect size (d), the researchers first computed the mean value of the experimental and control groups, together with the standard deviation. The effect size computation yielded a value of 1.64, which falls under the "High" category. Therefore, the ICARE learning model, which utilises the PhET simulation, effectively enhances students' cognitive abilities.

The data collected in this study indicated that both the experimental and control classes had an augmentation in cognitive ability. Nevertheless, the experimental class demonstrated a greater cognitive ability enhancement than the control class. This discovery aligns with research conducted by Asri et al. (2017) and Muharti (2016), which asserts that the ICARE learning model can enhance students' cognitive abilities.

Based on the data analysis, the N-Gain value for the class that implemented the ICARE learning model integrated with PhET simulations is 0.70, whereas the N-Gain value for the class that used only the ICARE learning model is 0.41. This indicates that the ICARE learning model based on PhET simulations significantly improves students' cognitive abilities, particularly in the topic of dynamic fluids. The ICARE learning model, which is based on PhET simulation, allows students to engage in active listening and practical application of the content so that the problems faced by students can be expressed in discussions and solved together.

The cognitive abilities of pupils In the experimental group in this research were enhanced due to the provision of a comprehensible visualisation. Implementing the ICARE learning model, which uses PhET simulations, in the experimental class provides students with the chance to frequently engage in experimental activities (Darwis & Hardiansyah, 2023; Martanti et al., 2021; Masruroh et al., 2020; Rahma, 2022). The students are required to identify hypotheses and examine the practicum outcomes using the PhET simulation supplied in the worksheet.

Through experimental activities using PhET simulation, students' thinking skills continue to develop, and they interpret and link events during the

experiment and build a concept in students. Furthermore, incorporating the ICARE learning model in conjunction with PhET simulation enables students to actively engage in rebuilding knowledge at the application stage when the PhET simulation is used.

According to Jean Piaget's constructivist theory, the primary factor determining learning is the individual (student). At the same time, social interactions serve as a stimulus that induces internal cognitive conflicts within the individual (Suryana et al., 2022). This study's PhET simulations support constructivist theory by providing an interactive learning environment where students can experience cognitive conflicts through virtual experiments. These conflicts then catalyse students to collaborate with their classmates in solving problems on the worksheets, reinforcing conceptual understanding, and building new knowledge.

In addition, the outcomes of the learning model effectiveness analysis indicate that the ICARE learning model utilising PhET simulation is efficacious in enhancing students' cognitive abilities. Consequently, the implementation of the ICARE learning model utilising PhET simulation holds significant significance and warrants noting due to its impact on students' cognitive abilities. The ICARE learning model based on PhET simulation focuses on activities oriented towards improving cognitive abilities. This is because, in the ICARE learning model based on PhET simulation, there are activities such as displaying phenomena, answering questions, and experiments using PhET simulation to test hypotheses.

Utilising the ICARE learning model, which illustrates phenomena in the introductory and extension phases, generates great student motivation to learn. This aligns with the findings of multiple studies, which indicate that the ICARE learning model can maximise the active role of students in learning activities (Abdan, 2019; Saputri et al., 2022; Siahaan et al., 2020). By displaying phenomena, student motivation can increase. This increase in motivation can be observed from students' active participation level during the learning process. This increase in motivation affects students' cognitive abilities. Motivation is the basis for students to obtain maximum learning results (Filgona et al., 2020; Hardre et al., 2007; Rahman, 2021).

Question and answer activities in the ICARE learning model can help prevent student boredom in learning, particularly when linked to PhET simulation media, which can enhance student engagement and visualise dynamic fluid concepts more engagingly. This is because question-and-answer activities can generate curiosity from students and arouse high interest in the material being studied. In addition, students can expand their knowledge through PhET simulation-based experimental activities as part of this learning model. The use of PhET simulation in learning allows students to conduct experiments repeatedly. The experiments presented are based on real situations, thus reducing the risk of errors or accidents in direct experiments. In these experimental activities, students observe, work on their initiative, make hypotheses before experiments, and conclude experimental results.

The experimental activities in the ICARE learning model integrated with PhET simulations provide students with learning experiences that help them retain the material studied. Thus, the information students absorb is more likely to be stored in long-term memory. This is because, through PhET simulation-based experimental activities, students can observe and directly find the concept of the material in question.

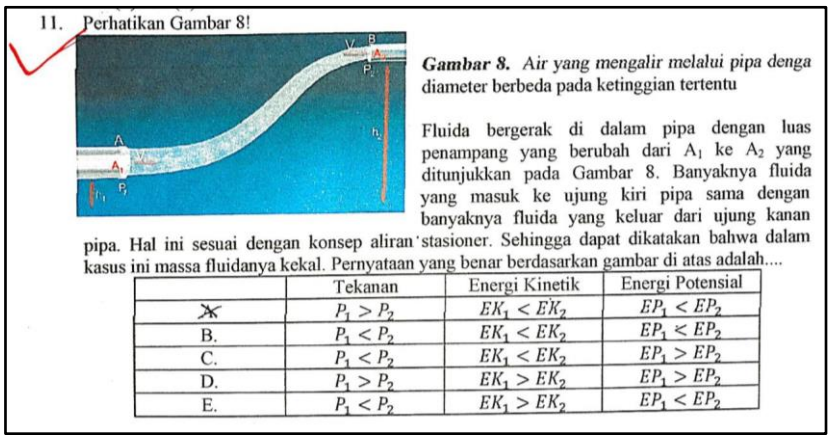
This is in line with the view found by Dahar (1996) in Latukau (2022), which states that students will be directly involved in using their mental processes to find a concept or principle through the discovery process. This will strengthen students' memory of understanding the material for a longer period.

In addition, one of the reasons the ICARE learning model based on PhET simulation is effective with high categories is that it emphasizes cognitive abilities at each stage of learning. The aspects of cognitive abilities in this study are as follows:

**Understanding (C2)**

The understanding aspect (C2) is trained through the introduction, connection, and reflection stages. In the introduction stage, students are trained to ask, answer, or express their ideas. The researchers then provide stimuli so students can practice understanding skills through discussions about exploring initial concepts. At the connection stage, there is a question-and-answer interaction between researchers and students based on the experience or knowledge possessed by students. In addition, the researchers also displayed a video demonstrating the practical application of the material in daily life at this stage. Furthermore, at the reflection stage, one group of students was asked to make a presentation, and the researchers played a role in correcting students' misunderstandings by emphasising concepts that were still wrong and providing opportunities for students to ask questions.

One of the questions measuring the C2 aspect is question number 11. From the posttest results, the percentage of students answering this question correctly is significantly higher in the experimental class (78%) than in the control class (19%). Examples of student answers can be seen in Figure 2.



11. Perhatikan Gambar 8!



***Gambar 8.*** *Air yang mengalir melalui pipa denga* diameter berbeda pada ketinggian tertentu

Fluida bergerak di dalam pipa dengan luas penampang yang berubah dari $A_1$ ke $A_2$ yang ditunjukkan pada Gambar 8. Banyaknya fluida yang masuk ke ujung kiri pipa sama dengan banyaknya fluida yang keluar dari ujung kanan pipa. Hal ini sesuai dengan konsep aliran stasioner. Sehingga dapat dikatakan bahwa dalam kasus ini massa fluidanya kekal. Pernyataan yang benar berdasarkan gambar di atas adalah....

| | Tekanan | Energi Kinetik | Energi Potensial |
|---|---|---|---|
| A. | $P_1 > P_2$ | $EK_1 < EK_2$ | $EP_1 < EP_2$ |
| B. | $P_1 < P_2$ | $EK_1 < EK_2$ | $EP_1 < EP_2$ |
| C. | $P_1 < P_2$ | $EK_1 < EK_2$ | $EP_1 > EP_2$ |
| D. | $P_1 > P_2$ | $EK_1 > EK_2$ | $EP_1 > EP_2$ |
| E. | $P_1 < P_2$ | $EK_1 > EK_2$ | $EP_1 < EP_2$ |

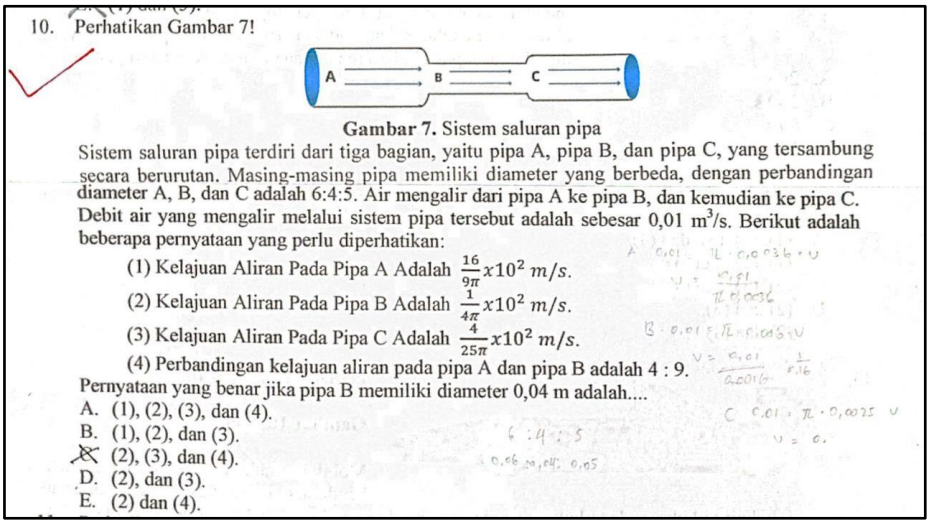
Figure 2 Examples of student answers for question number 11

The use of PhET simulations in the experimental groups' learning has proven effective in enhancing student' ability to master the C2 aspect, as indicated by their performance. In learning with the ICARE model based on PhET simulations, students not only passively receive information but also interact directly with visual simulations depicting water flow phenomena and Bernoull's principle. In contrast, students who learned using the ICARE model without PhET did not have the same interactive visualisations. They may have relied solely on verbal explanations or static images, which provide a less intuitive understanding of the phenomena.

**Applying (C3)**

The ability to apply (C3) is an ability that involves using a procedure to complete a training task (Anderson & Krathwohl, 2001; Cressa & Mukhlis, 2023; Inayah dkk., 2022). The aspect of applying (C3) is trained through the application stage. Students must solve the problems presented in the student worksheets by applying the concepts they have learned at this stage. In the application stage, students are allowed to conduct experiments and apply their knowledge and skills. During experiments through PhET simulations, students can reconstruct their knowledge and improve cognitive abilities in learning materials. Students conducting experiments aim to effectively address challenges, facilitating their comprehension of the subject matter.

One of the questions measuring the C3 aspect is question 10. According to the posttest results, the percentage of students answering correctly on this question is significantly higher in the experimental class (44%) than in the control class (3%). Examples of student answers can be seen in Figure 3.


10. Perhatikan Gambar 7!




**Gambar 7.** Sistem saluran pipa

Sistem saluran pipa terdiri dari tiga bagian, yaitu pipa A, pipa B, dan pipa C, yang tersambung secara berurutan. Masing-masing pipa memiliki diameter yang berbeda, dengan perbandingan diameter A, B, dan C adalah 6:4:5. Air mengalir dari pipa A ke pipa B, dan kemudian ke pipa C. Debit air yang mengalir melalui sistem pipa tersebut adalah sebesar 0,01 $m^3/s$. Berikut adalah beberapa pernyataan yang perlu diperhatikan:

(1) Kelajuan Aliran Pada Pipa A Adalah $\frac{16}{9\pi} x10^2\ m/s.$

(2) Kelajuan Aliran Pada Pipa B Adalah $\frac{1}{4\pi} x10^2\ m/s.$

(3) Kelajuan Aliran Pada Pipa C Adalah $\frac{4}{25\pi} x10^2\ m/s.$

(4) Perbandingan kelajuan aliran pada pipa A dan pipa B adalah 4 : 9.

Pernyataan yang benar jika pipa B memiliki diameter 0,04 m adalah....

A. (1), (2), (3), dan (4).
B. (1), (2), dan (3).
C. (2), (3), dan (4).
D. (2), dan (3).
E. (2) dan (4).

Figure 3 Examples of student answers for question number 10

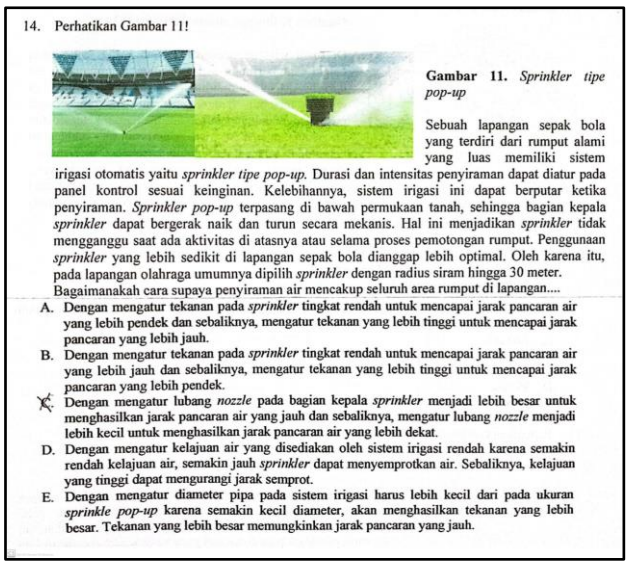
In the ICARE learning model with PhET simulations, students can interactively observe and manipulate physical variables such as pipe cross-sectional area, fluid flow rate, and water discharge. This simulation allows students to see how changes in one variable directly affect other variables. This interaction enhances students' analytical skills and helps them understand the mathematical relationships between physical variables. It makes them better prepared to answer questions requiring logical reasoning and precise calculations, such as those in C3.

**Analysing (C4)**

The improvement of the analysing aspect (C4) was trained at the extension stage, where the researchers asked questions and explained to students the topic related to dynamic fluid phenomena, which was an extension of the material. The researchers gave students time to think about answering, and then they explained the question.

One of the questions measuring the C4 aspect is question 14. According to the posttest results, the percentage of students answering correctly on this question is significantly higher in the experimental class (63%) than in the

control class (14%). Examples of student answers can be seen in Figure 4.



14. Perhatikan Gambar 11!

**Gambar 11.** *Sprinkler tipe pop-up*

Sebuah lapangan sepak bola yang terdiri dari rumput alami yang luas memiliki sistem irigasi otomatis yaitu *sprinkler tipe pop-up.* Durasi dan intensitas penyiraman dapat diatur pada panel kontrol sesuai keinginan. Kelebihannya, sistem irigasi ini dapat berputar ketika penyiraman. *Sprinkler pop-up* terpasang di bawah permukaan tanah, sehingga bagian kepala *sprinkler* dapat bergerak naik dan turun secara mekanis. Hal ini menjadikan *sprinkler* tidak mengganggu saat ada aktivitas di atasnya atau selama proses pemotongan rumput. Penggunaan *sprinkler* yang lebih sedikit di lapangan sepak bola dianggap lebih optimal. Oleh karena itu, pada lapangan olahraga umumnya dipilih *sprinkler* dengan radius siram hingga 30 meter.
Bagaimanakah cara supaya penyiraman air mencakup seluruh area rumput di lapangan....

A. Dengan mengatur tekanan pada *sprinkler* tingkat rendah untuk mencapai jarak pancaran air yang lebih pendek dan sebaliknya, mengatur tekanan yang lebih tinggi untuk mencapai jarak pancaran yang lebih jauh.
B. Dengan mengatur tekanan pada *sprinkler* tingkat rendah untuk mencapai jarak pancaran air yang lebih jauh dan sebaliknya, mengatur tekanan yang lebih tinggi untuk mencapai jarak pancaran yang lebih pendek.
C. Dengan mengatur lubang *nozzle* pada bagian kepala *sprinkler* menjadi lebih besar untuk menghasilkan jarak pancaran air yang jauh dan sebaliknya, mengatur lubang *nozzle* menjadi lebih kecil untuk menghasilkan jarak pancaran air yang lebih dekat.
D. Dengan mengatur kelajuan air yang disediakan oleh sistem irigasi rendah karena semakin rendah kelajuan air, semakin jauh *sprinkler* dapat menyemprotkan air. Sebaliknya, kelajuan yang tinggi dapat mengurangi jarak semprot.
E. Dengan mengatur diameter pipa pada sistem irigasi harus lebih kecil dari pada ukuran *sprinkle pop-up* karena semakin kecil diameter, akan menghasilkan tekanan yang lebih besar. Tekanan yang lebih besar memungkinkan jarak pancaran yang jauh.

Figure 4 Examples of student answers for question number 14

Students in the experimental class exhibited better analytical skills than those in the control class, who only received explanations from the teacher without engaging in direct experimental experiences. PhET simulations help students connect theory with practice. They can observe how theoretical principles are applied in virtual experiments and relate them to real-world situations. This capability enhances conceptual understanding and analytical skills in questions requiring the application of theory.

Thus, it is concluded that the ICARE learning model utilising PhET simulation effectively enhances students' cognitive abilities because the learning process shows a learning atmosphere with full seriousness and enthusiasm from students. PhET simulation becomes a solution because it can present visualisations that help students illustrate abstract physics concepts, thus attracting their interest in learning the material.

## CONCLUSION

Based on the research results and data analysis, there is a significant difference in cognitive ability improvement between the students using the ICARE learning model integrated with PhET simulations and the group using only the ICARE learning model. Therefore, the ICARE learning model based on PhET simulations is highly effective in enhancing students' cognitive abilities in dynamic fluids. For future research, it is recommended that PhET simulation experiments be conducted using laptop devices. Laptops are considered more efficient and provide optimal performance compared to smartphones, which often encounter issues with access speed and smoothness in running simulations.

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