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# Enhancing Critical Thinking and Physics Concept Understanding through REACT-OLabs

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**Abstract**

Students' critical thinking skills and science concepts are still lacking. This is because physics instruction tends on rote memorization, resulting in students having a superficial understanding of the material. The purpose of this study is to determine the effect of the REACT model, supported by OLabs, on students' critical thinking skills and understanding of physics concepts. The study employed a quasi-experimental design with pretest–posttest measures and a quantitative approach. The study population consisted of 11th-grade students at SMAN 1 Seputih Banyak for the 2025/2026 academic year. A sample of 70 students was selected using cluster random sampling, comprising an experimental class (using the REACT model supported by OLabs) and a control class (conventional instruction). The instrument consists of an essay test to measure both variables, with 10 items measuring critical thinking skills and 12 items measuring conceptual understanding. The data were analyzed using a MANOVA test. The results of the study indicate that the REACT model, supported by OLabs, has an impact on both dependent variables, with a significance value of 0.000 ($p < 0.05$). The average score of the experimental group (77.43) for critical thinking skills surpassed that of the control group (54. 20), as did the score for conceptual understanding (83.09 > 54.51). These findings indicate that the use of a contextual learning model combined with simulation technology can help students better understand abstract physics concepts while simultaneously improving their comprehension and critical thinking skills. The conclusion of this study is that the REACT model, supported by OLabs, is effective in improving students' critical thinking skills and understanding of physics concepts. Thus, it can serve as an innovative alternative for educators.

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## INTRODUCTION

In the face of the challenges of globalization, mastering science and technology through education is essential for addressing future challenges and opening up new opportunities (Sagala et al., 2024). Based on the findings from the Trends in International Mathematics and Science Study (TIMSS), students' cognitive abilities remain low, dropping beneath the international norm for scores of less than 500 points on average (Golding & Richardson, 2024). This is due to a teaching approach that tends to focus on rote memorization, resulting in students having a superficial understanding of the subject matter (Asfar et al., 2019). In fact, physics is a subject that requires strong analytical skills, logical reasoning, and a solid grasp of concepts so that students can systematically and scientifically solve problems related to natural phenomena.

Physics is an abstract subject; therefore, it demands that learners not just commit formulas to memory but also grasp ideas and cultivate analytical skills to address practical issues (Dessie et al., 2023; Hudha & Batlolona, 2017; Sa'Diyah et al., 2021). The process of learning physics involves scientific activities such as observing, formulating hypotheses, collecting data, and drawing conclusions, which directly train students to think critically when analyzing problems and evaluating information (Patel et al., 2024). As a foundational science, physics plays an essential part in shaping the logical and analytical reasoning of students. However, evidence from the field shows that many students still find physics difficult and burdensome (Kusuma et al., 2024; Retnawati et al., 2018; Utha et al., 2023). Abstract concepts, low student engagement, and monotonous teaching methods pose significant obstacles to achieving learning objectives. According to the findings from an initial research Sundari et al. (2021) carried out at SMAN 1 Seputih Banyak, an initial assessment indicates that students' abilities in critical thinking and their grasp of physics ideas are still quite limited. The findings from the pretest indicated that the general level of critical thinking abilities among students in Class XI 5 was only 49.54%, and those in Class XI 7 were 33.63%. One reason for weak critical thinking abilities among students is that the learning process in school does not engage students in broad critical thinking and does not provide opportunities to explore other sources, and learning is teacher-centered (Yulianto et al., 2023; Khaidir et al., 2023). Meanwhile, the findings from the conceptual understanding assessment indicated an average result of 47.77% in Class XI 5 and 31.46% in Class XI 7, which was attributed to the students' inability to communicate effectively and grasp the physics material, resulting in low conceptual understanding of physics. All of these results are still below the established Minimum Passing Score (MPS) of 75. These low levels of critical thinking and conceptual understanding are attributed to several factors, including teaching methods that remain conventional, the predominant use of textbooks as the sole learning resource, and a lack of hands-on activities that allow students to explore physics concepts independently (Kinasih et al., 2023). Given the challenges in physics education marked by abstract concepts, limited student engagement, and monotonous teaching methods, there is a need for a learning model that can contextualize physics concepts within students' real-world experiences and encourage their active participation in constructing knowledge. The REACT learning model (Relating, Experiencing, Applying, Cooperating, and Transferring) offers a more systematic approach to bridging abstract physics concepts with the real world through five mutually reinforcing stages (Crawford, 2001; Schendel et al., 2012). It is this characteristic that sets the REACT learning model apart from others. It directly designs a step-by-step learning experience that starts with concrete concepts familiar to students and progresses toward the ability to apply complex knowledge. With this approach, the REACT learning model has the potential to address the challenges of physics education by not only making abstract concepts more meaningful but also training students to think critically through the processes of experiencing, collaborating, and transferring knowledge.

The REACT learning model is part of contextual education, which highlights the connection between the concepts being studied and students' real-world experiences (Crawford, 2001). Through the "relating" and "experiencing" stages, students are encouraged to connect physics concepts with everyday phenomena and engage in hands-on exploration. The "applying" and "cooperating" stages encourage students to apply concepts through class collaboration, while the "transferring" phase assists learners in utilizing the knowledge they possess in new situations (Schendel et al., 2012). The REACT learning model continues to evolve as an effective contextual approach to enhancing student engagement and conceptual understanding (Abebe et al., 2024). Another study by Al-Mahrooqi & Al-Siyabi (2024) found that the REACT learning model is successfully

improving knowledge transfer through collaboration and practical application. A study conducted by Zhang et al. (2024) indicates that the REACT learning model can enhance students' critical thinking skills by linking learning materials to real-life contexts. However, there are still challenges in integrating the REACT learning model with digital technology to maximize its potential. To maximize the potential of the REACT learning model, it can be integrated by leveraging technologies such as OLabs simulations.

Recent research by Gupta & Singh (2023) shows that the use of digital technologies, including activities like simulations, can enhance learners' comprehension of physics concepts. OLabs (Online Laboratories) simulations have become an essential tool in science education, particularly in physics, due to their ability to provide interactive and easily accessible virtual experiments. The REACT learning model, combined with technologies such as OLabs (Online Laboratories) simulations, offers significant opportunities to create learning experiences that are more interactive, practical, and focused on developing skills relevant to the modern era (Raman et al., 2021). This simulation enables learners to conduct virtual experiments, visualize abstract physics concepts, and test hypotheses interactively without the constraints of time and space (Banda & Nzabahimana, 2021; Santyadiputra et al., 2024). A major benefit of OLabs is its capability to surmount the challenges posed by physical labs, especially in isolated regions or educational institutions with scarce resources. A study by Ratna & Adlini (2024) shows that OLabs can be an effective solution for providing access to high-quality science experiments without the need for expensive laboratory equipment.

Research by Kumar & Sharma (2023) demonstrates that utilizing OLabs improves students' grasp of physics ideas by means of visual aids and inquiry-based experiments. OLabs has been combined with different educational frameworks, including PBL (Problem-Based Learning) and REACT (Relating, Experiencing, Applying, Cooperating, Transferring), to enhance student learning outcomes. Research by Swaminathan et al. (2025) reveals that the framework for multi-aspect visualization in OLabs can enhance students' understanding of programming concepts and engagement through interactive exploration at various semantic levels.

Although previous studies have demonstrated the effectiveness of the REACT learning model and the potential of OLabs simulations separately, there are still several significant gaps that remain unaddressed. Research specifically examining the integration of REACT and OLabs simulations in high school physics education remains scarce, particularly in the context of education in Indonesia. Most existing studies have primarily tested these two approaches separately, without exploring the potential synergies that could arise from combining them. Additionally, existing studies generally focus on only one learning outcome variable, whether conceptual understanding or critical thinking skills, so no research has yet examined the simultaneous impact on both of these variables within a single integrated study. Furthermore, there is still no research that explicitly examines the effectiveness of the combination of REACT and OLabs in the context of students with low prior abilities, such as those at SMAN 1 Seputih Banyak, where students' levels of critical thinking and conceptual understanding remain far below the minimum proficiency standards.

Therefore, the purpose of this study is to explore and examine in detail how the implementation of the REACT learning model, combined with OLabs simulations, can contribute to improving students' critical thinking skills and conceptual understanding. The primary focus of this study is to identify practical solutions that address the needs of physics education in today's digital and innovation-driven era. This study aims to investigate the effect of implementing the REACT learning model, supported by OLabs simulations, on students' critical thinking skills and understanding of physics concepts.

## METHODS

This research utilized a quasi-experimental design with pretest–posttest measures and a quantitative approach, involving two classes: an experimental class and a control class. A quantitative method was selected as this research aims to examine the impact of a treatment on the dependent variable in a measurable and objective manner through statistical analysis (Agustina et al, 2024). The research took place at Seputih Banyak State High School 1, involving all 11th-grade students for the academic year 2025/2026, amounting to 323 students in total.

The sampling for this study was conducted using simple random cluster sampling, a sampling technique that can be used when the population classes are homogeneous (Djaali, 2020). Several clusters were then randomly selected to form the sample. The study sample consisted of 70 students. Class XI 7, comprising 35 students, served as the experimental class and received instruction using the REACT learning model supplemented by OLabs simulations, while Class XI 5, also comprising 35 students, served as the control class and did not receive the treatment.

This study used tests, observations, and documentation to collect data. The tests used in this study measured critical analytical abilities and comprehension of physical principles. The researchers used a test instrument consisting of an essay section (22 questions) on vector material designed to assess critical analytical abilities and comprehension of physical principles. This instrument was created using the criteria for critical thinking abilities as outlined by Ennis (2011), namely: 1) Providing a simple explanation (basic clarification); 2) Providing the basis for a decision; 3) Drawing conclusions (inference); 4) Providing further explanation (advanced clarification); and 5) Formulating strategies and tactics. Based on the indicators of conceptual understanding according to Anderson & Krathwohl (2001), namely: 1) Interpreting; 2) Exemplifying; 3) Classifying; 4) Summarizing; 5) Inferring; 6) Comparing; and 7) Explaining. The data for this research were collected by the observer, who is an educator, during the study period utilizing an observation form to evaluate how well the REACT learning approach was applied with the help of OLabs simulations, as well as documentation serving as relevant evidence.

Test instruments are deemed suitable for use after undergoing validity and reliability testing. Data were considered valid when $R_{count} > R_{table}$, with $R_{table} = 0.2826$. The reliability of test instruments is analyzed through Cronbach's alpha to assess the degree of internal consistency of the test components. The Cronbach's Alpha value for critical thinking ability was 0.695, and for conceptual understanding, it was 0.748. The data were considered reliable if $r_{11} > 0.60$. The quality of each test item was then verified by analyzing the degree of difficulty and discriminative power. Prior to further analysis, a homogeneity test was performed to see whether the variances of the experimental and control classes were equal, and a normality test was performed to confirm whether the empirical data satisfied the assumption of a normal distribution.

A normality test was conducted using the Kolmogorov–Smirnov test with the aid of SPSS software to ensure that the data were normally distributed as a prerequisite for parametric analysis. Subsequently, the data were analyzed using Multivariate Analysis of Variance (MANOVA) to determine the simultaneous effects of the REACT learning model, supported by OLabs simulations, on critical thinking skills and conceptual understanding of physics. MANOVA was chosen because two dependent variables were analyzed simultaneously. The test statistic used in MANOVA is Wilks' Lambda to determine the significance of the independent variable's effect on the two dependent variables in order to ascertain whether the treatment effect is present or not. Figure 1 is a research flowchart, a visual representation illustrating the steps of the research.

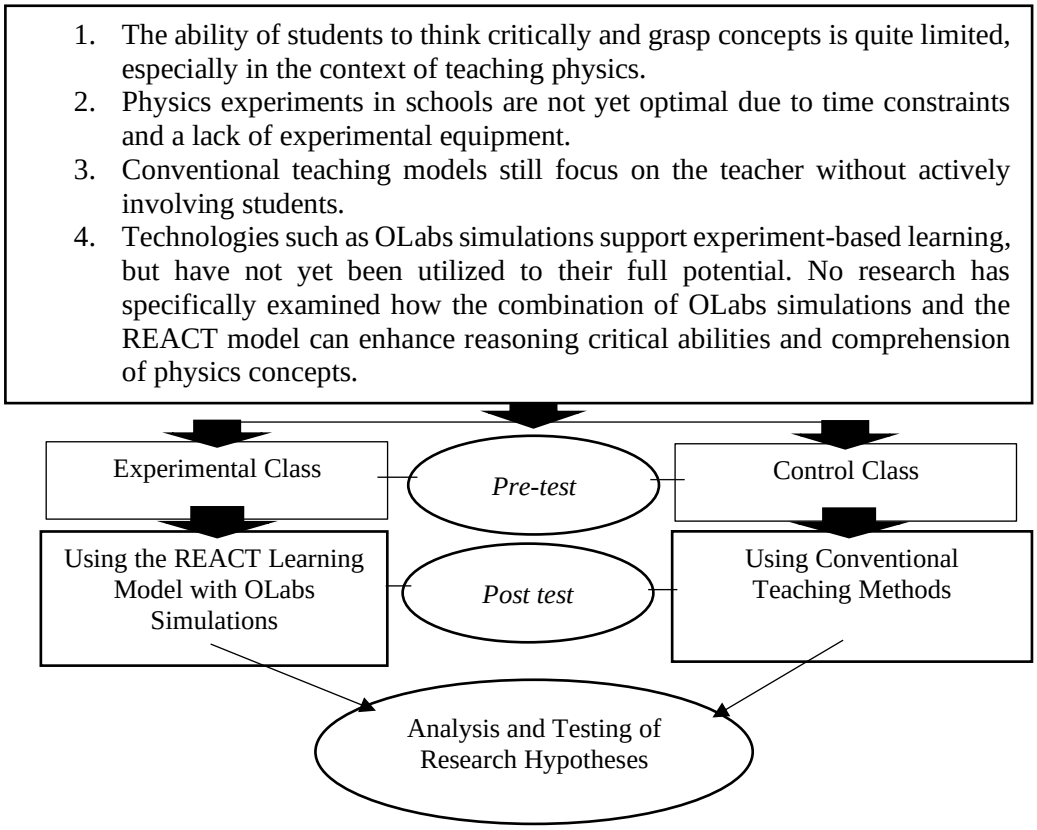


Figure 1 Research flowchart

## RESULTS AND DISCUSSION

This research was carried out by analyzing the impact of using the Olabs simulation-based learning models. Figure 2 shows an example of a simulation display on the OLabs platform, which is used in instruction to help students understand concepts visually and interactively.

Figure 2 Olabs simulation view

As an initial step, the researcher administered a pretest to the students. Critical thinking skills and understanding of physics concepts were assessed using pretest and posttest questions. The assessment consisted of 10 essay questions measuring critical thinking skills

and 12 questions measuring conceptual understanding. Pretest and posttest results for critical thinking skills are shown in Table 1.

Table 1 Pre-test and post-test data on critical thinking skills for the control group and the experimental group

| Descriptive statistics | | | | |
|---|---|---|---|---|
| | **Control Class** | | **Experimental Class** | |
| | **Pretest** | **Posttest** | **Pretest** | **Posttest** |
| N | 35 | 35 | 35 | 35 |
| Min | 30 | 40 | 20 | 69 |
| Max | 60 | 69 | 56 | 89 |
| Mean | 49.54 | 54.20 | 33.63 | 77.43 |

According to the results in Table 1, the experimental class's students' critical thinking abilities are significantly enhanced in comparison to the control class. In the experimental class, the average critical thinking abilities pretest score was 33.63, and the average posttest score rose to 77.43. Meanwhile, the control group saw only a slight increase in its average score, from 49.54 on the pretest to 54.20 on the posttest.

This difference in improvement indicates that learning using the REACT model supplemented by OLabs simulations has a greater influence on improving student ability for critical thought. The results of the pretest and posttest on conceptual understanding are shown in Table 2.

Table 2 Pre-test and post-test scores for conceptual understanding in the control class and the experimental class

| Descriptive statistics | | | | |
|---|---|---|---|---|
| | **Control Class** | | **Experimental Class** | |
| | **Pretest** | **Posttest** | **Pretest** | **Posttest** |
| N | 35 | 35 | 35 | 35 |
| Min | 28 | 45 | 21 | 71 |
| Max | 60 | 63 | 51 | 92 |
| Mean | 47.77 | 54.51 | 31.46 | 83.09 |

Based on the results in Table 2, similar results were also observed in students' understanding of physics concepts. The average score for the experimental class increased from 31.46 on the pretest to 83.09 on the posttest. The control class score, on the other hand, barely went up from 47.77 to 54.51. These data indicate that students who learned using the REACT model supplemented by OLabs simulations were able to understand physics concepts more deeply compared to pupils who acquired knowledge through conventional means.

Next, to ascertain if the pretest and posttest results from both classes were normally distributed, a normality test was performed. The Kolmogorov-Smirnov test was employed for the study's normality test, and the results are deemed normal if the significance level (Sig.) is higher than 0.05. Table 3 displays the normality test results.

Table 3 Normality test results

| **Aspect** | | **Statistic** | **df** | **Sig.** |
|---|---|---|---|---|
| Critical Thinking Skills | Pretest of the control class | 0.949 | 35 | 0.109 |
| | Posttest of the control class | 0.966 | 35 | 0.337 |
| | Pretest of the experimental class | 0.959 | 35 | 0.219 |
| | Posttest of the experimental class | 0.961 | 35 | 0.245 |
| Conceptual Understanding | Pretest of the control class | 0.938 | 35 | 0.050 |
| | Posttest of the control class | 0.946 | 35 | 0.087 |
| | Pretest of the experimental class | 0.965 | 35 | 0.318 |
| | Posttest of the experimental class | 0.963 | 35 | 0.284 |

Table 3 shows that the test results indicate that all data for the variables of critical thinking skills and conceptual understanding for both the control and experimental classes, as well as for the pretest and posttest, exhibit a significance level (Sig.) > 0.05. For critical thinking skills, the significance values range from 0.109 to 0.337. As for conceptual understanding, the values range from 0.050 to 0.318. Thus, it can be said that the data a normal distribution. The results of the homogeneity test are presented in Table 4.

Table 4 Homogeneity Test Results

| Aspect | Levene Statistic | Sig. | description |
|---|---|---|---|
| Critical Thinking Skills | 1.367 | 0.256 | Homogeneous |
| Conceptual Understanding | 1.428 | 0.238 | Homogeneous |

Homogeneity tested with Levene's test, with the criterion that if the significance value (Sig.) > 0.05 the data variances are considered homogeneous. The results of the analysis in Table 4 show that the significance value for critical thinking skills is 0.256 and for conceptual understanding is 0.238. Therefore, it may be said that the data variances from the experimental and control groups are homogeneous.

The MANOVA was carried out following the completion of the necessary tests, which included the homogeneity and normality tests. The post hoc test employs the Benferroni test if Sig. > 0.05 and the Games-Howell test if Sig. < 0.05. The Games-Howell test was employed in this investigation since the significance level (Sig.) was less than 0.05. Table 5 displays the MANOVA test results.

Table 5 Results of the MANOVA test

| Variable | Type III Sum of Squares | Mean Square | F | Sig. |
|---|---|---|---|---|
| Critical Thinking | 30964.171 | 10321.390 | 202.892 | .000 |
| Conceptual Understanding | 35125.371 | 11708.457 | 210.930 | .000 |

Understanding of physics concepts were both 0,000, which is less than the significance level of $\alpha = 0.05$. This shows that $H_1$ is accepted and $H_0$ is denied, which means that the implementation of the REACT learning model supported by OLabs simulations has a major impact on pupils' comprehension of physics concepts and critical thinking abilities. For the critical thinking ability variable, an F-value of 202.892 was also obtained, with a significance level of Sig. = 0.000 ($p < 0.05$). These outcomes show that pupils' critical thinking abilities differ significantly between those who participated in learning using the REACT model supplemented by OLabs simulations and those who participated in conventional learning. Thus, the REACT learning model, supported by OLabs simulations, has a major effect on raising students' critical thinking abilities. For the conceptual understanding variable, an F-value of 210.930 was obtained, with a significance level of Sig. = 0.000 ($p < 0.05$). These outcomes show that the REACT learning model, supported by OLabs simulations, has a major influence as well on students' understanding of physics concepts. A higher F-value for the concept comprehension variable indicates that the effect of this instructional model is relatively stronger than its effect on critical thinking skills. Overall, the results of the MANOVA test demonstrate that the REACT learning model, supported by OLabs simulations, has a significant effect on students' critical thinking skills and understanding of physics concepts.

This study was conducted at SMAN 1 Seputih Banyak by integrating the REACT (Relating, Experiencing, Applying, Cooperating, and Transferring) learning model with the aid of OLabs simulations in the experimental class (XI 7), while conventional instruction was given to the control class (XI 5). The REACT model emphasizes the connection

between physics concepts and students' real-world experiences so that learning focuses not merely on memorizing formulas but on deep conceptual understanding (Maulana et al., 2024). As stated by CORD (Center for Occupational Research and Development) (1999), the systematic steps involved in REACT learning include: 1) Relating is an approach that connects experiences or learning materials to everyday life. 2) Experiencing refers to learning with the aim of exploring, discovering, and creating. This cycle of questions aims to encourage students to think critically. 3) Applying is a learning style that applies students' ideas and learning outcomes to useful contexts. Therefore, educators should provide more practical and relevant exercises. 4) Cooperating is a form of learning where educators communicate with one another. For example, after being split up into groups, students are instructed to look for instances of the subject matter in their immediate environment. 5) Transferring is a type of learning where students use what they already know to acquire new knowledge. The systematic REACT approach helps students become more active, enthusiastic, and directly engaged with learning activities. Students within the experimental class are more confident in expressing their opinions, asking questions, and explaining physics concepts more effectively. Consequently, the experimental class students demonstrated greater improvements in critical thinking abilities and comprehension of physics concepts in comparison to the control class, which followed conventional instruction. This analysis is based on a theoretical framework that posits that the REACT (Relating, Experiencing, Applying, Cooperating, Transferring) learning model systematically guides students in building conceptual understanding through direct experience and collaboration, while also honing critical thinking and other higher-order thinking abilities (Crawford, 2001). Therefore, the presentation of the learning model syntax in Table 6 aims to clearly map the relationship between each phase of REACT, the role of OLabs, and indicators of critical thinking (Ennis, 2011) and indicators of conceptual understanding (Anderson & Krathwohl, 2001) measured in this study. The syntax of the REACT learning model supported by OLabs simulations is shown in Table 6.

Table 6 Syntax of the REACT learning model supported by OLabs simulations

| **REACT Stage** | **The Role of OLabs Simulation** | **Indicators of Critical Thinking** | **Conceptual Understanding Indicators** | **Student Activities** |
|---|---|---|---|---|
| Relating | Not yet used (initial knowledge activation phase). | Providing a simple explanation (basic clarification) of the issue. | Interpreting phenomena based on initial concepts; explaining (explaining) how concepts relate to everyday experiences. | Students observe contextual phenomena related to the learning material and express their initial opinions based on their everyday experiences. |
| Experiencing | Used as a virtual experimental platform to observe changes in variables and their results. | Explain the basis for decision-making (the bases for a decision) based on the results of observations. | Demonstrating (exemplifying) concepts using simulation results, interpreting (interpreting) data and visual images. | Students develop conceptual understanding through experiments or simulations to observe the relationships between variables. |

| REACT Stage | The Role of OLabs Simulation | Indicators of Critical Thinking | Conceptual Understanding Indicators | Student Activities |
|---|---|---|---|---|
| Applying | Used as a data source or for comparing the results of applying a concept. | Draw a conclusion (inferring) as a result or alternative solution. | Apply and explain concepts, draw conclusions (inferring) from calculation results, and compare (comparing) several results. | Students apply the concepts they have learned to solve problems or contextual questions on their own. |
| Cooperating | Used as a basis for discussion and clarification among groups | Provide further explanation (advanced clarification) and evaluate the arguments. | Classify concepts or solutions, compare (comparing) results across groups, explain the reasons for the differences. | Students work in groups to discuss their findings, compare answers, and present scientific arguments. |
| Transferring | As a conceptual reference for applying the concept to a new context. | Developing strategies and tactics (strategies and tactics) for solving new problems. (Designing problem-solving strategies). | Summarize key concepts, illustrate (exemplifying) new applications, explain how the concepts relate to other contexts. | Students apply the concepts they have learned to new situations or problems and reflect on the problem-solving strategies they used. |

Instruction in the experimental class was conducted using physics textbooks, student worksheets, and OLabs simulations as supplementary learning materials. The learning process is implemented using the REACT model, which is designed to actively engage students in building conceptual understanding and developing critical thinking skills. During the Relating stage, students are guided to open themselves up to new information by observing contextual phenomena or issues presented through images and videos. This activity was followed by a discussion and brainstorming session so that students could restate the initial concepts they had understood and relate them to their daily experiences. During the Experiencing stage, students are trained to develop an awareness of the learning process through concept exploration activities using OLabs simulations. Students conduct virtual experiments by varying relevant parameters and observing the resulting changes. Through this activity, students are guided to interpret data from simulations, illustrate concepts based on their observations, and explain the reasoning behind the decisions made during the experimental process. Through practical experiences, this stage aids students in gaining a deeper comprehension of hands-on experiences and visualizations of abstract concepts. The applying stage focuses on students' ability to solve difficulties by applying the concepts they have acquired. At this stage, students represent concepts in the form of tables, diagrams, graphs, or mathematical calculations based on the results of simulations and experiments. Students are then guided to compare the results they obtained, draw conclusions from the data, and describe how the concepts and the results relate to each other. This activity trains students to think logically, critically, and systematically when applying physics concepts as problem-solving tools. Next, In the cooperating stage,

students collaborate in groups to discuss and compare the results of their learning activities. Students classify the concepts or solutions they have identified, provide further explanations for the differences in results among groups, and respond to their peers' opinions in a scientific manner. Students gain critical thinking abilities as well as a deeper comprehension of subjects through group discussions by collaboratively evaluating arguments and clarifying concepts. The transferring stage is designed to train pupils to apply the ideas they have learned to novel circumstances or issues. Students are asked to develop problem-solving strategies within the context of daily existence and to write a reflection on their learning. At this stage, students summarize key concepts, provide examples of how these concepts apply in different contexts, and explain the connection between physics concepts and real-world phenomena. As a result, learning emphasises both the acquisition of concepts and the flexibility with which students can apply them.

This is consistent with the assertion that the REACT learning model emphasizes students' active engagement in the learning process by linking prior knowledge to meaningful learning experiences, thereby fostering the simultaneous development of conceptual understanding and critical thinking skills (Akay & Kanadli, 2021; Maulana et al., 2024). In line with this study, which indicates a positive relationship between the REACT learning model supported by Olabs simulations, critical thinking abilities, and concept comprehension through contextual learning that emphasizes the connection between real-world experiences and physics concepts, this approach is capable of improving the effectiveness of the study process and the learning results of the pupils.

According to the study's findings, students who used the REACT model in conjunction with OLabs simulations significantly improved their critical thinking abilities and comprehension of physics subjects when compared to the control group. The experimental class's average critical thinking abilities posttest score was 77.43, but the control class score was only 54.20. Similarly, in terms of conceptual understanding, the experimental class achieved an average score of 83.09, far exceeding the control class's score of 54.51. The higher average scores in the experimental group indicate that the teaching method used is more effective in helping students develop critical thinking skills and conceptual understanding. These findings were supported by the results of the MANOVA test, which showed a significance level of 0.000 ($p < 0.05$) and high calculated F-values of 202.892 for critical thinking and 210.930 for conceptual understanding. The greater improvement observed in the experimental group is consistent with a number of earlier research studies. This reinforces previous research findings and expands upon them, particularly in the context of integrating OLabs simulations into vector-related material. Thus, the REACT learning model supported by OLabs simulations has been shown to have a positive and significant effect on both of these skills.

The findings of this research show that the REACT learning model, supported by OLabs simulations, not only enhances conceptual understanding but also simultaneously develops students' critical thinking skills. The MANOVA test results, yielding a significance level of 0.000 with a high calculated F-value, indicate that the difference The difference in performance between the experimental and control class is not the consequence of chance, but rather the outcome of the given treatment (Almira et al., 2023). An observed power value of 1.000 for both variables indicates that the statistical power is at the maximum level. This means the probability of rejecting the null hypothesis ($H_0$) when the alternative hypothesis ($H_1$) is true is 100%. The result demonstrates that the achievement gap between the experimental and control class is not the result of chance or sampling error but rather a real effect of the treatment administered. Thus, the test results are not only statistically significant ($p < 0.05$), but also possess very high reliability and consistency.

The success of the REACT model in enhancing critical thinking skills and conceptual understanding is closely tied to its syntactic characteristics, which explicitly cultivate both of these abilities. The Relating stage trains students to identify and connect concepts with real-world phenomena, which serves as the foundational step in building meaningful understanding (Crawford, 2001). At this stage, students are presented with contextual problems that spark curiosity and encourage them to draw upon prior knowledge, in line with the structured learning principle that emphasizes the importance of prerequisite knowledge in building new understanding (Luh & Unix, 2024). Research by Haetami et al., (2024) also confirms that the REACT model is effective in improving students' learning outcomes and critical thinking skills across various educational levels.

The Experiencing stage is at the core of OLabs simulation-based learning. Through virtual experiments, students can manipulate variables, observe changes, and interpret data directly. OLabs simulations allow students to experience physical phenomena that are difficult or even impossible to conduct in a real laboratory due to limitations in equipment and materials. The visualizations generated help students build accurate mental models of abstract concepts, thereby deepening their understanding (Halliday et al., 2024). A recent literature review by Maisaroh (2025) indicates that the use of physics simulations such as OLabs can enhance students' understanding of abstract concepts, their scientific process skills, and their motivation to learn. This is supported by findings that the development of OLabs-assisted instructional materials is suitable for use in physics education and can improve students' physics proficiency (Purwati et al., 2025). Furthermore, virtual laboratories have been shown to make a substantial positive contribution to improved learning outcomes, particularly in terms of conceptual understanding Ulfia and Wahyuni (2025), and approaches that combine technology such as OLabs with hands-on practice can significantly enhance the quality of physics education (Dewa et al., 2025).

The application stage provides pupils with the chance to use the ideas they have learned to solve problems. Activities that involve representing concepts in the form of tables, graphs, or mathematical calculations develop analytical and systematic thinking skills (Anderson & Krathwohl, 2001). Students do not merely memorize formulas but understand how those formulas are derived and how they are applied in different contexts. This strengthens conceptual retention and the ability to transfer knowledge. Research on physics learning indicates that effective instructional models must close the theory-practice divide through hands-on experience (Lembang et al., 2025).

The Cooperating stage fosters the negotiation of meaning through social interaction within the group. According to Vygotsky (2024), social interaction within the zone of proximal development enables students to achieve a higher level of understanding than if they were learning individually. In this study, group work during the Cooperating stage helped students identify misconceptions, refine their understanding, and collaboratively build knowledge. Collaboration in physics learning is becoming increasingly important in the digital age, where students need to develop communication and cooperation skills (Hidayah & Derlina, 2025). Findings by Harianto (2024) also reveal that structured group discussions during the cooperating stage significantly improve critical thinking abilities, as pupils get used to exploring various aspects.

The transferring stage is designed to train students to apply concepts they have learned to new situations or problems. Students are asked to develop problem-solving strategies in the context of daily life and to write learning reflections. In this stage, students summarize key concepts, provide examples of how to apply concepts in different contexts, and explain the relationship between physics concepts and real-world phenomena. Thus, learning focuses not only on mastering concepts but also on students' ability to apply concepts

flexibly. Findings by Ambarita et al. (2025) reinforce that the ability to transfer knowledge is a key indicator of successful meaningful learning.

The results of this study are congruent with those of other investigations. Hamid et al. (2024) showed in their study that high school students' comprehension of physics ideas is significantly impacted by the REACT-based contextual learning methodology. Akay & Kanadli, (2021) when compared to conventional approaches, the REACT model significantly improves academic success and learning retention, according to their meta-analysis of 42 studies. Maulana et al. (2024) stated that physics learning using the computer simulation-assisted REACT model is capable of significantly improving students' conceptual mastery and critical thinking skills. Research by Kansil et al. (2024) also found that the REACT model supported by a virtual lab effectively improves students' critical thinking skills regarding sound wave material.

This study reinforces and expands upon these findings and demonstrates its effectiveness through a comprehensive multivariate statistical analysis. The novelty of this study compared to previous studies lies in the integration of OLabs simulations, which have not been widely used in REACT research, and the use of MANOVA to measure the simultaneous impact on two dependent variables.

The findings of this study indicate that the REACT learning model, supported by Olabs simulations, can serve as an innovative alternative for physics educators to enhance the quality of learning. The integration of this technology not only strengthens students' critical thinking skills and conceptual understanding but also encourages higher-level thinking skills relevant to the demands of the 21st century. School support in providing access to virtual laboratories and training for educators is crucial for effective implementation. The application of this learning model aligns with Vygotsky's social constructivism theory, which emphasizes the role of interaction in constructing knowledge, and reinforces Ausubel's concept of meaningful learning, which emphasizes the connection between new knowledge and existing cognitive structures. Thus, the Olabs-assisted REACT learning model makes a tangible contribution to creating physics learning that is contextual, meaningful, and student-centered.

The further use of OLabs simulations in learning provides a more realistic and flexible learning experience. Students can repeat experiments, observe the details of phenomena, and understand abstract concepts through clear visualizations. Students are able to learn in their own way and at their own speed as a result, without being constrained by time limitations or the availability of laboratory equipment. These positive impacts demonstrate that the OLabs-assisted REACT model is not only cognitively effective but also supports the creation of inclusive, customized instruction based on each student's unique needs.

Although the implementation of the REACT learning model supported by OLabs simulations has shown significant results, there are several limitations that need to be considered. This study only included 11th-grade students from a single school; therefore, further research with a larger sample size from various schools and regions is needed to ensure more representative results. Additionally, the OLabs simulation requires a reliable internet connection, meaning not all schools can implement it optimally. Furthermore, the short duration of the study has not yet allowed for an assessment of the long-term impact on students' non-cognitive skills.

## CONCLUSION

This study reveals that the use of the REACT learning model supported by OLabs simulations was successfully implemented to enhance critical thinking skills and conceptual understanding of physics. The model proved effective in yielding significant improvements in both aspects, as demonstrated by the results of the Multivariate Analysis

of Variance (MANOVA). The greater improvement in the experimental class compared to the control class indicates that the REACT model with its stages of relating, experiencing, applying, cooperating, and transferring, supported by OLabs simulations, is capable of creating contextual and meaningful learning, thereby making students more active in building conceptual understanding and honing their critical thinking skills.

Notwithstanding this, this study has limitations because it involved students from only one school and had a comparatively brief duration of implementation. Therefore, to test this model, more research is advised on more abstract physics material using a research design that includes measurements of non-cognitive aspects such as motivation and collaboration, as well as conducting a comparative study with other virtual platforms to enrich the understanding of the specific advantages of the OLabs simulation in improving the quality of physics learning.

## CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

## AUTHOR CONTRIBUTIONS STATEMENT

All authors were directly involved in every phase of this research. RVS was responsible for developing the initial concept, collecting and analyzing data, presenting the research findings, and editing the final manuscript. AS and ADY were responsible for validating all data. All authors reviewed and approved the final version of this document.

## AI DISCLOSURE STATEMENT

The authors used ChatGPT, DeepSeek, and DeepL solely for translation and proofreading during the manuscript preparation process. After thoroughly reviewing and revising the entire text using these tools, they take full responsibility for the accuracy and content of the information contained in this work. Without the use of artificial intelligence, the authors completed every step of the research design, data collection, data analysis, and conclusion-drawing process.

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