Journal of Educational Analytics (JEDA)
Vol. 5 No. 2 (2026): May 2026: 504-517

Cognitive Conflict Learning Model Assisted by PhET Simulations to Reduce Misconceptions and Improve Students' Conceptual Understanding

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A R T I C L E I N F O

Keywords: Cognitive Conflict, Phet Simulation, Misconception, Conceptual Understanding, Science Learning.

Received : 20, March
Revised : 25, April
Accepted: 15, May

A B S T R A K

This study aims to analyze the effectiveness of a cognitive conflict-based learning model assisted by PhET simulations in reducing misconceptions and improving students' conceptual understanding in science learning. This study employed a quantitative approach with a quasi-experimental method and a nonequivalent control group design. The population of this study consisted of fifth-grade students at SD Inpres 12/79 Macanang, which has parallel classes. Class VA served as the control class, while Class VB served as the experimental class. The research instruments consisted ,of a diagnostic misconception test and a conceptual understanding test administered before and after the learning process. The data were analyzed using the percentage of misconception reduction, N-Gain, and a test of differences in the improvement of conceptual understanding.The results showed that students' misconceptions in the experimental class decreased from 62.50% to 24.30%, while those in the control class decreased from 60.80% to 43.70%. The average conceptual understanding score of students in the experimental class increased from 46.25 to 81.40, with an N-Gain of 0.65, whereas the control class increased from 45.70 to 68.20, with an N-Gain of 0.41. These findings indicate that the cognitive conflict-based learning model assisted by PhET simulations is more effective than conventional instruction in reducing misconceptions and improving students' conceptual understanding in science learning. This model can serve as an alternative science learning strategy that is interactive, meaningful, and oriented toward conceptual change.

DOI : https://doi.org/10.55927/jeda.v5i2.24

ISSN-E: 2830-0432
https://journaljeda.my.id/index.php/jeda

INTRODUCTION

Natural Science learning, or science education, plays an important role in developing students' ability to understand natural phenomena scientifically. Science does not only consist of a collection of facts, concepts, laws, and theories, but also involves scientific thinking processes that require students to observe, ask questions, predict, verify, reason, and draw conclusions based on evidence (Putri et al., 2025). Therefore, science learning should not merely focus on memorizing subject matter, but should also be directed toward developing accurate, deep conceptual understanding that students can use to explain various events in everyday life (Foza & Bahri, 2025).

However, in school practice, students' conceptual understanding of science often remains problematic. Many science concepts are abstract, dynamic, and not always easy to observe directly (Nasroellah et al., 2025). Concepts such as force, motion, energy, electricity, heat, light, sound, pressure, changes in states of matter, and interactions between objects are often difficult to understand if they are delivered only through verbal explanations, static images, or memorized definitions. As a result, students may remember scientific terms but may not necessarily be able to explain the meaning of concepts, relationships between variables, or their application in real situations (Safitri & Kusnawan, 2024).

One of the main issues in science learning is the emergence of misconceptions. Misconceptions occur when students' initial understanding differs from scientifically accepted concepts. Students do not enter the classroom as blank slates; rather, they bring prior knowledge formed through everyday experiences, environmental observations, explanations from others, and information from various sources (Hayati et al., 2022). This prior knowledge can support the learning process, but it can also become an obstacle when it does not align with scientific concepts. In science learning, misconceptions are often found in concepts closely related to everyday life, because students feel that they already understand these phenomena based on personal experience (Yuliati, 2019).

Misconceptions should not be viewed as simple errors that can easily be eliminated through direct explanation. Incorrect understandings are often deeply embedded in students' cognitive structures, causing them to maintain their initial conceptions even after receiving new information from the teacher (Fariza et al., 2025). If not addressed properly, misconceptions can hinder subsequent learning because science concepts are generally interconnected and hierarchical. Students who hold misconceptions about basic concepts will experience difficulties when learning more complex concepts. Therefore, science learning requires strategies that not only convey scientific information but also challenge students' initial understanding and guide them in reconstructing correct concepts (Suprapto, 2020; Vosniadou, 2020).

One relevant approach to overcoming misconceptions is the cognitive conflict approach. This approach is based on a constructivist perspective, which views knowledge as being actively constructed by students through the interaction between prior knowledge and new experiences. Cognitive conflict occurs when students encounter a discrepancy between their predictions, beliefs, or initial conceptions and the facts, phenomena, or observational results obtained during learning (Parwati et al., 2019). This discrepancy can encourage students to become dissatisfied with their initial understanding and to seek new explanations that are more logical and consistent with scientific evidence.

A cognitive conflict-based learning model can serve as an alternative for promoting conceptual change among students. In this model, learning usually begins by eliciting students' initial conceptions through questions, predictions, or contextual problems. Students are then confronted with phenomena or experiments that contradict their initial assumptions (Makhrus et al., 2014). Once cognitive conflict emerges, the teacher guides students to engage in exploration, discussion, verification, reflection, and conceptual reconstruction. Thus, learning does not merely function as a process of knowledge transfer, but also as a process of improving students' cognitive structures (Mufit et al., 2023).

Although the cognitive conflict-based learning model has considerable potential, its implementation requires appropriate media or learning experiences. Cognitive conflict will not emerge strongly if students cannot see, prove, or directly experience the discrepancy between their predictions and scientific facts. On the other hand, not all science concepts can be easily demonstrated through real experiments in the classroom. Some concepts require specific laboratory equipment, take a long time to observe, are difficult to observe directly, or may pose risks if carried out by students. This condition requires learning media that can present science phenomena in a concrete, visual, interactive, and easily manipulable manner.

PhET simulations are one form of learning media that can support the implementation of the cognitive conflict model in science learning. PhET provides various interactive simulations that allow students to observe phenomena, manipulate variables, test predictions, and directly see cause-and-effect relationships (Narulita et al., 2024). Through PhET simulations, students can conduct virtual experiments in a safer, more flexible, and more engaging way. Students do not merely become recipients of information; they can also explore concepts through variable manipulation and observation of changes that occur within the simulation.

The integration of PhET simulations into a cognitive conflict-based learning model has a strong relationship with efforts to reduce misconceptions and improve students' conceptual understanding of science. PhET simulations can serve as a trigger for cognitive conflict because they are able to display phenomena that may differ from students' initial predictions (M. Hasanah et al., 2019). Meanwhile, the cognitive conflict model functions as a pedagogical framework that guides students to compare predictions with observational results, discuss differences, find scientific explanations, and reconstruct their understanding. Through this combination, students do not merely observe concept visualizations, but also experience scientific thinking processes that promote conceptual change (Nilam et al., 2025).

The use of a cognitive conflict-based learning model assisted by PhET simulations is also aligned with the need for science learning that is more active, meaningful, and student-centered (Fitrianingsi et al., 2023). This type of learning provides opportunities for students to express their initial ideas, test the validity of those ideas, discuss them with peers, and construct conclusions based on evidence. This process is important because strong conceptual understanding is not formed through memorization, but through learning experiences that enable students to connect scientific concepts with observable phenomena that can be explained logically (Sari, 2017).

Based on the discussion above, research on a cognitive conflict-based learning model assisted by PhET simulations is important to conduct. This study seeks to examine how the integration of the cognitive conflict approach and interactive simulation media can help students overcome misconceptions and improve their conceptual understanding of science. This study is expected to provide theoretical contributions to the development of conceptual change-based learning, as well as practical contributions for teachers in designing science learning that is more effective, interactive, and suitable for the characteristics of abstract science concepts.

LITERATURE REVIEW

Science learning has characteristics that differ from memorization-based learning because science does not only consist of a collection of facts and terms, but also emphasizes scientific processes in understanding natural phenomena (Ikhsan & Sukaria, 2018). In science learning, students are expected to be able to observe, classify, predict, interpret data, draw conclusions, and use scientific concepts to explain events that occur in their surrounding environment. Therefore, conceptual understanding is one of the important aspects that needs to be developed in science learning.

Conceptual understanding can be defined as students' ability to explain a concept correctly, connect one concept with another, provide examples and non-examples, and apply the concept in new situations (Suprapto, 2020). Students who have good conceptual understanding are not only able to remember definitions, but are also able to explain the scientific reasons behind a phenomenon. In contrast, students who merely memorize concepts tend to experience difficulties when faced with contextual problems or phenomena that differ from the examples commonly given by the teacher.

In the context of science learning, conceptual understanding is very important because science concepts are interconnected. Errors in understanding basic concepts can affect students' ability to understand subsequent concepts. For example, misconceptions about the concept of force can influence students' understanding of motion, energy, and work. Similarly, misconceptions about electricity can hinder students' understanding of current, voltage, resistance, and electric circuits. Therefore, science learning needs to be designed to build correct conceptual understanding from the beginning (Dewi et al., 2021).

Efforts to overcome misconceptions are closely related to the theory of conceptual change. This theory emphasizes that learning is not merely the addition of new information to students' minds, but may also involve the reorganization of students' existing prior understanding. In science learning, conceptual change is needed when students' initial concepts conflict with scientific concepts. Posner, Strike, Hewson, and Gertzog developed one of the conceptual change theories that has been widely used as a foundation in science education (Önal, 2025). They explain that conceptual change occurs when students become dissatisfied with their initial concepts and then encounter new concepts that are intelligible, plausible, and useful for explaining phenomena. Their classic article on the accommodation of a scientific conception has become an important reference in conceptual change studies (Lim & Hew, 2014)

Within this framework, learning needs to create conditions that allow students to question their initial understanding. Teachers cannot simply provide definitions or scientific explanations; they need to present learning experiences that make students aware of discrepancies between their initial predictions and scientific facts (Arifin et al., 2025). Thus, conceptual change requires learning strategies that can challenge misconceptions while guiding students to construct new understanding. A cognitive conflict-based learning model is one of the learning strategies developed based on the principles of conceptual change. Cognitive conflict occurs when students find discrepancies between their initial conceptions and the facts, phenomena, data, or observational results obtained during learning. This discrepancy creates a state of cognitive imbalance, encouraging students to seek new explanations that are more appropriate.

In cognitive conflict-based learning, teachers usually begin by eliciting students' initial conceptions. After that, students are asked to make predictions about a phenomenon. The teacher then presents an event, demonstration, experiment, or simulation whose results differ from students' predictions. The difference between prediction and observation becomes the trigger for cognitive conflict. Next, students are guided to explore, discuss, reflect on their understanding, and construct more accurate scientific concepts (Ikhsan & Sukaria, 2018).

Cognitive conflict-based learning model is effective in improving conceptual understanding and remediating misconceptions in science learning. The model includes key syntax such as activating preconceptions and misconceptions, presenting cognitive conflict, discovering concepts and equations, and reflection (Mufit et al., 2023). The strength of the cognitive conflict approach lies in its ability to encourage students to actively compare their initial understanding with scientific evidence. Students do not merely receive information from the teacher; they experience a thinking process that requires them to re-evaluate their initial beliefs. Thus, cognitive conflict can serve as a bridge between students' prior knowledge and the scientific concepts to be learned.

PhET simulations are interactive learning media developed by the University of Colorado Boulder to help students understand science and mathematics concepts. PhET provides various simulations that allow students to observe phenomena, manipulate variables, conduct virtual experiments, and visualize cause-and-effect relationships. In science learning, this medium is highly relevant because many science concepts are abstract, microscopic, or difficult to observe directly. PhET states that the design of its simulations is developed based on research on how students learn, including think-aloud interviews with students to understand how interface design and simulation interactions support learning. PhET also emphasizes that its simulations include interactivity, animation, dynamic feedback, and opportunities for productive exploration that are not always available in ordinary learning media.

PhET simulations have several advantages in science learning. First, PhET can visualize concepts that are difficult to observe directly, such as particle motion, electric current, force, fields, energy, heat, or waves. Second, PhET allows students to manipulate variables so they can observe the changes resulting from certain treatments. Third, PhET provides opportunities for students to conduct repeated exploration without safety risks and without the limitations of laboratory equipment. Fourth, PhET can be used to support inquiry-based learning, discovery learning, problem-based learning, and cognitive conflict-based learning (Diab et al., 2024)

The integration of a cognitive conflict-based learning model with PhET simulations has a strong theoretical and pedagogical foundation. Cognitive conflict requires phenomena that can challenge students' initial understanding, while PhET can provide visual and interactive phenomena that students can manipulate directly. Thus, PhET can function as a medium for generating cognitive conflict, while the cognitive conflict model functions as a learning framework that guides the process of conceptual change (D. I. Hasanah & Wasis, 2021).

In science learning, cognitive conflict becomes more meaningful when students can directly observe the difference between their predictions and the results of observation. For example, before using a simulation, students may be asked to predict what will happen if the magnitude of force is increased, if electrical resistance is added, or if the temperature of a substance is increased. After that, students use PhET simulations to test their predictions. If the simulation results differ from their initial predictions, cognitive conflict emerges and encourages students to re-evaluate their understanding. Hasanah et al. found that a cognitive conflict strategy assisted by PhET simulations was able to reduce students' misconceptions on wave material. In that study, the average percentage of students experiencing misconceptions in the pretest was 53.53%, which then decreased to 7.65% after treatment using a cognitive conflict strategy assisted by PhET (Yani & Widiyatmoko, 2023)

Reducing misconceptions and improving conceptual understanding are two interrelated goals. Students who still hold misconceptions tend to have difficulty understanding scientific concepts deeply (Amiruddin et al., 2024). Conversely, when misconceptions are successfully reduced, students have a greater opportunity to build correct conceptual understanding. A cognitive conflict-based learning model assisted by PhET can support both goals through several mechanisms. First, learning begins by identifying students' initial understanding. Second, students are confronted with phenomena that contradict their initial predictions. Third, students conduct exploration using simulations to obtain evidence. Fourth, students discuss their findings and construct scientific explanations. Fifth, the teacher provides reinforcement so that the concepts formed are aligned with scientific concepts

METHODOLOGY

This study employed a quantitative approach with a quasi-experimental method and a nonequivalent control group design. The study involved two classes: an experimental class that received treatment through a cognitive conflict-based learning model assisted by PhET simulations, and a control class that received conventional instruction. Both classes were given a pretest and posttest to determine changes in students' misconceptions and conceptual understanding in science learning. The population of this study consisted of fifth-grade students at SD Inpres 12/79 Macanang, which has parallel classes. Class VA served as the control class, while Class VB served as the experimental class. The independent variable in this study was the cognitive conflict-based learning model assisted by PhET simulations, while the dependent variable was students' misconceptions.

Learning in the experimental class was implemented through five stages: eliciting students' initial conceptions, presenting cognitive conflict situations, exploring concepts using PhET simulations, discussing and reconstructing concepts, and reflecting on and reinforcing concepts. In the control class, learning was conducted using the instructional model commonly applied by the teacher. The research instrument was a diagnostic test of students' science conceptual understanding on the topic of force and motion. This diagnostic test was used to identify emerging misconceptions. The instrument was validated by experts and piloted before being used in the study.

The data were analyzed quantitatively. Misconception reduction was analyzed by comparing the percentage of misconceptions before and after the learning process. The improvement of conceptual understanding was analyzed using N-gain. Furthermore, differences in improvement between the experimental class and the control class were tested using an independent sample t-test when the data were normally distributed and homogeneous, or the Mann–Whitney U test when the data did not meet parametric assumptions. The model was considered effective if the experimental class showed a greater reduction in misconceptions and a higher improvement in conceptual understanding than the control class.

RESEARCH RESULT

The research findings show that the cognitive conflict-based learning model assisted by PhET simulations was able to reduce students' misconceptions. In the experimental class, the percentage of misconceptions decreased from 62.50% in the pretest to 24.30% in the posttest. Meanwhile, in the control class, misconceptions decreased from 60.80% to 43.70%. The greater decrease in misconceptions in the experimental class indicates that learning that presents cognitive conflict and is supported by interactive simulations is more effective in helping students correct their inaccurate prior understanding.

Students' conceptual understanding of science also improved more significantly in the experimental class than in the control class. The average pretest score in the experimental class was 46.25 and increased to 81.40 in the posttest, with an N-Gain score of 0.65. In the control class, the average pretest score was

45.70 and increased to 68.20, with an N-Gain score of 0.41. These results indicate that the cognitive conflict-based learning model assisted by PhET had a positive impact on improving students' conceptual understanding.

The effectiveness of learning in the experimental class occurred because students were actively involved in the process of eliciting initial conceptions, presenting cognitive conflict, exploring concepts using PhET simulations, discussing, reconstructing concepts, and reflecting. PhET simulations helped students observe science phenomena visually and interactively, enabling them to compare their initial predictions with observational results. The discrepancy between predictions and simulation results encouraged students to revise their inaccurate prior understanding.

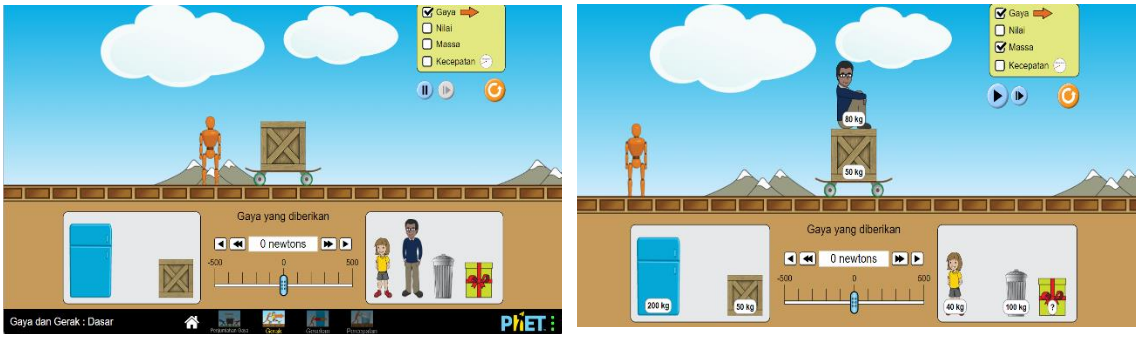

Figure 1. Learning Motion Concepts Through PhET Simulation

Thus, the cognitive conflict-based learning model assisted by PhET simulations can serve as an effective alternative strategy in science learning to reduce misconceptions and improve students' conceptual understanding. This model is highly relevant for science topics that are abstract, difficult to observe directly, and potentially lead to misconceptions.

Table 1. PhET-Assisted Cognitive Conflict Learning Syntax

Step	Objective	Main Contribution
Elicitation of Initial Conceptions	To identify students' prior understanding	Identifies the types of misconceptions held by students
Presentation of Cognitive Conflict	To reveal the inconsistency between students' predictions and scientific facts	Challenges students' incorrect initial understanding
Exploration Using PhET	To test predictions through interactive simulation	Provides visual evidence to support conceptual change
Discussion and Concept Reconstruction	To discuss observation results and construct scientific concepts	Reduces misconceptions and helps students develop new concepts
Reflection and Concept Reinforcement	To emphasize the correct final concept	Strengthens students' conceptual understanding

Based on the table, each step in the cognitive conflict approach assisted by PhET simulations has a complementary function in the learning process. The stage of eliciting students' initial conceptions serves to identify their prior understanding, while the presentation of cognitive conflict functions to challenge initial beliefs that are inconsistent with scientific concepts. Furthermore, the exploration stage using PhET simulations provides students with opportunities to test their predictions and obtain direct visual evidence. The discussion and conceptual reconstruction stage helps students rebuild their understanding based on observation results, while the reflection and concept reinforcement stage ensures that the conceptual changes that occur become more stable. Thus, the effectiveness of learning does not lie merely in the use of PhET as a medium, but in its integration into a systematic cognitive conflict syntax.

The success of the cognitive conflict-based learning model assisted by PhET simulations in reducing misconceptions and improving students' conceptual understanding of science is inseparable from the systematically implemented learning stages. Each step in the cognitive conflict approach has an important function in guiding students from inaccurate initial understanding toward more scientifically accurate understanding. In this study, the learning stages included eliciting students' initial conceptions, presenting cognitive conflict, exploring through PhET simulations, discussing and reconstructing concepts, and reflecting on and reinforcing concepts.

The first stage is eliciting students' initial conceptions. At this stage, the teacher provides guiding questions, contextual phenomena, or simple problems related to the science concept being studied. The purpose is to determine students' initial understanding before they receive the learning treatment. This stage is very important because misconceptions cannot be corrected if the teacher does not first identify the forms of initial understanding held by students. Through prediction activities or initial responses, students are given the opportunity to express their ideas openly. In the context of this study, eliciting students' initial conceptions helps identify students who understand the concept correctly, students who do not yet understand the concept, and students who hold misconceptions.

The second stage is the presentation of cognitive conflict situations. After students' initial conceptions are identified, the teacher presents phenomena that potentially contradict students' initial predictions or beliefs. At this stage, cognitive conflict begins to emerge when students find that their initial answers or predictions do not match the facts presented. This discrepancy creates curiosity, doubt, and dissatisfaction with their initial understanding. This condition becomes the starting point for conceptual change because students begin to realize that the knowledge they possess is not yet fully able to explain phenomena correctly.

The third stage is concept exploration using PhET simulations. At this stage, PhET serves as an interactive medium that helps students test predictions, observe phenomena, and manipulate variables. Students do not merely observe demonstrations presented by the teacher, but are directly involved in a virtual inquiry process. Through simulations, students can try various conditions, compare results, and observe cause-and-effect relationships visually. This activity is very helpful in science learning because some concepts are difficult to observe directly through real experiments. With PhET, abstract concepts become more concrete, making it easier for students to understand why their initial predictions were inaccurate.

The fourth stage is discussion and conceptual reconstruction. After students obtain data or observation results from the simulation, they are guided to discuss their findings. At this stage, students compare their initial predictions with the results of exploration, explain the differences found, and reconstruct their understanding based on evidence. Discussion becomes an important part because conceptual change does not occur only through observation, but also through argumentation, clarification, and negotiation of meaning. The teacher acts as a facilitator who helps students connect simulation results with correct scientific concepts. Thus, students do not merely know that their predictions were wrong, but also understand why certain scientific concepts are more appropriate for explaining the phenomena.

The fifth stage is reflection and concept reinforcement. At this final stage, students are asked to conclude the learning outcomes, restate the concepts in their own words, and connect the concepts with other phenomena in everyday life. Reflection is important to ensure that conceptual change truly occurs and does not stop at temporary understanding. The teacher reinforces correct concepts, clarifies remaining misunderstandings, and emphasizes relationships among concepts. This stage helps students consolidate new knowledge so that their conceptual understanding becomes more stable.

Based on this explanation, it can be understood that each stage in the cognitive conflict-based learning model contributes to reducing misconceptions and improving conceptual understanding. Eliciting initial conceptions functions to reveal students' thinking structures; presenting cognitive conflict functions to challenge misconceptions; PhET exploration functions to provide visual and interactive evidence; discussion functions to support the reconstruction of understanding; and reflection functions to strengthen the scientific concepts that have been constructed. The combination of these five stages makes learning more meaningful because students do not merely receive concepts from the teacher, but personally experience the process of changing their understanding.

CONCLUSION

Based on the research findings and discussion, it can be concluded that the cognitive conflict-based learning model assisted by PhET simulations is effective in reducing students' misconceptions and improving their conceptual understanding of science. This effectiveness is indicated by the greater decrease in the percentage of misconceptions in the experimental class compared to the control class. This finding shows that learning activities beginning with the elicitation of students' initial conceptions, the presentation of cognitive conflict, exploration through PhET simulations, discussion, conceptual reconstruction, and reflection can help students recognize discrepancies between their prior understanding and scientific concepts. The improvement in students' conceptual understanding of science in the experimental class was also higher than that in the control class.

Cognitive conflict-based learning assisted by PhET provides students with opportunities to predict, observe, manipulate variables, compare observation results, and construct scientific explanations based on evidence. This process makes learning more active, meaningful, and oriented toward conceptual change.

RECOMMENDATIONS

Based on the research findings, science teachers are advised to use the cognitive conflict-based learning model assisted by PhET simulations as an alternative learning strategy, particularly for concepts that often lead to misconceptions. Teachers need to design guiding questions, prediction activities, worksheets, and discussion scenarios that can generate cognitive conflict in a focused manner. The use of PhET should not be limited to a demonstration medium; instead, it should actively involve students in exploring, manipulating variables, and drawing conclusions based on observational results.

FURTHER RESEARCH

This study can be further developed using different science topics, broader educational levels, or stronger research designs. Future researchers may also examine the effect of the cognitive conflict-based learning model assisted by PhET on other variables, such as critical thinking skills, science process skills, problem-solving ability, learning motivation, or concept retention. In addition, further research is recommended to use more in-depth diagnostic instruments, such as a four-tier diagnostic test, so that students' misconceptions can be identified more accurately.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support of the PGSD program leadership and the science education lecturers for facilitating this study. Sincere thanks are extended to the undergraduate participants who took part in the midterm assessment and to the expert reviewers for their constructive feedback on the instruments and manuscript. We also appreciate the administrative assistance provided by the laboratory and office staff during data collection.

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