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Altering misconceptions: how e-rebuttal texts on Newton's laws reconstructs students' mental models

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This study aims to explore how e-rebuttal texts on Newton's laws can reconstruct students' mental models by altering existing misconceptions. A mixed methods approach (quantitative and qualitative) was used in the research. Participants were 31 students (15 boys and 16 girls, aged 15–16 years) in the 10th grade of one public high school in Sukabumi, West Java, Indonesia. The instrument used Multi-representation on Tier Instrument of Newton's laws (MOTION), consists of 36 subject matter questions about Newton's First Law, Newton's Second Law, Newton's Third Law, and the type of forces. The data were analyzed using the categories of conception, mental model, and correction of a mental model. The result shows positive changes in each mental model from the pre-test to the post-test. The rate of correction in students' mental models from pre-test to post-test occurred primarily in the Acceptable Correction (ACo) category. It was concluded that e-rebuttal texts can be used to reconstruct students' mental models in conceptual change to become Scientific (SC) models. Other researchers may use learning models and strategies to involve students in groups to facilitate the discussion process.

KEYWORDS

conceptual change, e-rebuttal texts, mental model, misconceptions, Newton's laws

1 Introduction

Many studies show that students in physics classes already have basic concepts that they acquire from everyday experience (Kulgemeyer and Wittwer, 2022; Ladachart et al., 2022; Ozkan and Selcuk, 2016). Nevertheless, often the initial conception does not match the scientific conception. This situation is known by several terms such as alternative conception, misconception, conceptual difficulty, initial conception, and initial framework (Gurel et al., 2015; Prinz et al., 2022; Yürük and Eroğlu, 2016).

1.1 Mental models and conceptual change in physics learning

Misconception can be caused by the student's internal factors (mental models) and the student's external factors (learning strategies, textbooks, language, and media) (Braasch et al., 2013; Hunsu et al., 2023; Ipek and Calik, 2008; Kaltakçi and Didiş, 2007; Kaya et al., 2022; Majid and Suyono, 2018; Nurdini et al., 2019). Regarding internal factors, mental models are one of the causes of students' misconceptions. This is instigated by errors in modeling phenomena, especially abstract phenomena that are tough to grip with appropriate mental models, and students are unpredictable in their descriptions of physical phenomena. Mental models are ideas of student thinking used to describe, understand, and explain complex phenomena as a result of cognitive processes (Kurnaz and Eksi, 2015; Majid and Suyono, 2018; Wiji and Mulyani, 2018; Yildirir and Demirkol, 2018).

Mental models can be categorized as scientific, synthetic, and initial according to the student's level of understanding (Kurnaz and Eksi, 2015; Sung et al., 2021). A scientific mental model is a mental model that conforms to scientific concepts, a synthetic mental model is a mental model that partially conforms to scientific concepts, and an initial mental model is a mental model that does not conform to scientific concepts. Scientific mental models occur when students' conceptions are in concept understanding, partial understanding, or a combination of conceptual understanding and partial understanding for several questions that use the same concept. Synthetic mental models occur when students' conceptions are in a combination of understanding the concept of understanding with misconceptions, not understanding, or non-coding for several questions that use the same concept. Initial mental models occur when students' conceptions are misconceptions, do not understand, non-coding, or a combination of all three for several questions that use the same concept. Therefore, mental model identification can be done after identifying the student's conception.

Mental models should be identified early on. Knowing a student's mental model can help teachers find misconceptions, difficult knowledge for students, and initial concepts of students (Wiji and Mulyani, 2018). Since the learning process involves structuring mental models, this helps determine appropriate learning strategies to avoid misconceptions (Kurnaz and Eksi, 2015; Varela et al., 2020). Students who are able to develop more complete mental models have better learning outcomes and achievements. The structuring of mental models can occur through a process of conceptual change (Fratiwi et al., 2020; Podschuweit and Bernholt, 2018; Samsudin et al., 2015). Posner et al. (1982) suggested that changing students' conceptions requires certain conditions, i.e., (1) dissatisfaction, namely students need to be faced with problems that make them aware that there are inconsistencies with their conceptions when faced with the process of explaining physical phenomena, (2) intelligibility, so that students can accommodate a new concept, the new concept must be clear and easy for students to understand, and not contain complexities, especially when the new concept is used to explain physical phenomena or solve physics problems, (3) plausibility, new concepts need to be seen as logical and acceptable by common sense (reasonable) by students. That logic must be shown by the suitability of the new conception with events that can be felt and observed or experienced in everyday life, and (4) fruitfulness, so that the new concept received by students can be accommodated, it must be shown that the new concept has better performance compared to the old conception when used to explain physical phenomena and solve physics problems. If this can happen, students will feel the usefulness of the new concept so that students will not hesitate to accommodate it into a new concept to replace the old concept.

Four conditions from Posner et al. (1982) can arise through the learning process. This is because one of the causes of alternative concepts lies in the student's external factors (environment). Zhou et al. (2016) showed that science (including physics) learning should develop students' concepts and help students overcome learning difficulties. However, in many cases, the learning process fails to improve the inadequate student's initial conceptions and may even exacerbate students' misconceptions. A number of studies have examined the effects of conceptual change approaches on alternative concepts and mental models in physical learning (Çil and Çepni, 2016; Gadgil et al., 2012; Mason and Zaccoletti, 2021; Suhandi et al., 2017; Wenning, 2008; Yürük and Eroğlu, 2016). The results show that the conceptual change approach is effective in changing conceptions and mental models.

1.2 Rebuttal texts and the role of digital media in misconception Reduction

According to Sarwar et al. (2024), one approach to change the conception is to use text mode. One of them is rebuttal texts (refutational texts). A rebuttal texts is a text that refutes misconceptions by presenting a general misconception, an explicit disclaimer that the description is a misconception, and a scientific explanation. The effectiveness of rebuttal text is related to making students aware of their concept's limitations, the differences between their concepts and scientific concepts, and understanding the truth of scientific concepts (Mason et al., 2019; Prinz et al., 2022). Disclaimers also draw students' attention to new information they need to learn, trigger cognitive conflict, and integrate correct information. In addition, Braasch et al. (2013) argue that rebuttal texts are effective guides for contextualizing prior knowledge and its use.

Rebuttal texts differ from traditional texts (such as textbooks) that only explain concepts, they are often difficult for students to understand and cannot effectively change students' concepts. Several studies have shown that the use of rebuttal text is effective in changing students' conceptions (Caleon and Subramaniam, 2013; Will et al., 2019). Mason et al. (2019) stated a rebuttal text presents the possibility that students hold misconceptions, the refutation that the misconceptions are not scientific concepts, and an explanation consistent with scientific concepts so can help students change their conceptions. Additionally, using rebuttal text can make students' mental models more scientific (Schroeder and Kucera, 2022; Tippett, 2010).

Based on the research of Bunawan et al. (2015), the use of texts does not hold students' attention, so they are less active in the learning process. Students expect learning media that are interesting, easy to understand, easy to use, and encourage students to actively participate in the learning process (Kahnbach et al., 2024; Li et al., 2024; Mondragon-Estrada et al., 2023). Therefore, teachers can use digital media in the learning process, including the texts they use. Digital media that arouse student interest can be effectively used to correct student misconceptions (Karaoglan Yilmaz et al., 2018; Nurdini et al., 2020; Suhandi et al., 2017). The use of digital media also makes it easier for students to understand abstract concepts because they can be visualized (Lechner et al., 2024; Li et al., 2023; Sakurai and Goos, 2023). Integrating the use of rebuttal text into digital media and inserting videos, animations or simulations can make the used text more interactive. Simulations also enable students to conduct comprehensive investigations (control variables) to more effectively change misconceptions and change students' mental models. The integration of interactive media-based rebuttal text is called e-rebuttal texts. Figure 1 shows the difference between the structure of e-rebuttal texts and common rebuttal texts.

Each section of the e-rebuttal texts includes instructions that prompt students to engage in specific activities. These activities are aligned with the structure of the e-rebuttal texts. Additionally, the e-rebuttal texts integrate various multimedia elements, such as graphics, text, videos, simulations, animations, and images. These elements simulate experiments and physical phenomena, making the learning content more engaging. This approach encourages active student participation and enhances understanding of physical concepts (Georgiou et al., 2021; Jian-hua and Hong, 2012). Research by Jiang et al. (2018) demonstrated that students are more likely to accept conflicting evidence from integrated studies (e.g., control variables) compared to observational studies when revising their initial concepts. Simulations integrated into rebuttal texts can facilitate this process. Moreover, interactive media have been found to save time and resources while enabling the visualization of abstract physical concepts by presenting dynamic information not available in traditional text (Ozkan and Selcuk, 2015). Studies by Aslan and Demircioğlu (2014) further highlight that computer-based media support knowledge construction, assist in learning challenging and abstract concepts, and enhance students' conceptual understanding, particularly in physics.

When teaching physics, we often see misconceptions about some concepts such as force and motion (Bayraktar, 2009; Liu and Fang, 2016; Poutot and Blandin, 2015; Saglam-Arslan and Devecioglu, 2010), optical geometry (Kaltakci-Gurel et al., 2017), electricity and magnetism (Leppavirta, 2012; Peşman and Eryilmaz, 2010), and fluids (Nurdini et al., 2020; Purwanto et al., 2018; Samsudin et al., 2018). However, the concept of force is a fundamental concept in the study of physics, especially the concept of force in Newton's laws. Saglam-Arslan and Devecioglu (2010) showed that many students struggled to understand basic concepts such as force, acceleration, displacement, and gravitational acceleration. Nevertheless, Newton's laws are important because they can be easily applied by students in their daily lives and provide a basis for further study of physics (Ferreira et al., 2017). Previous research has revealed several alternative concepts that appear in Newton's laws material. That is, (1) if a force is acting on an object, the object will move in the direction of the acting force, (2) when the force acting on the object is constant, objects move at a constant speed, (3) objects in motion eventually come to a stop when no force acts, (4) the acceleration of a falling object is affected by the mass of the object, (5) that only gravity acts on falls object (Wenning, 2008).

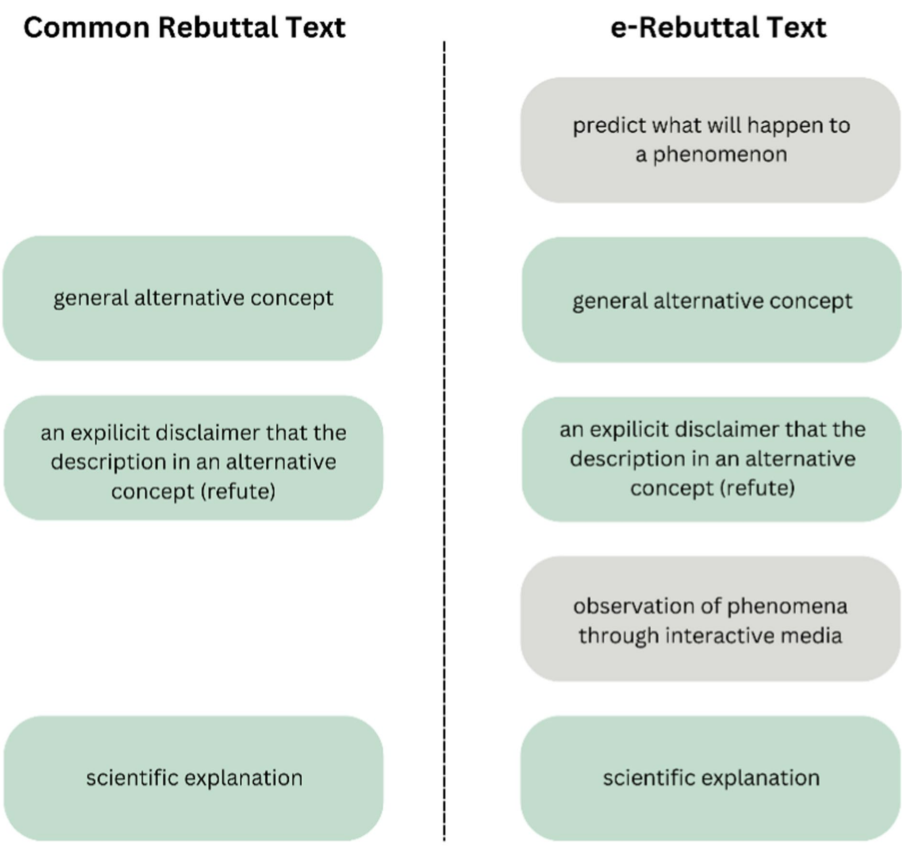

FIGURE 1
The difference between the structure of e-rebuttal texts and common rebuttal texts.

Furthermore, a study by Kurnaz and Eksi (2015) suggests that most students (56.28%) have a synthetic mental model of the concept of friction. In line with this, 10% of students have a scientific mental model, 63% of students have a synthetic mental model and 27% of students have an early mental model, based on preliminary research by researchers. This indicates that up to 63% of students do not fully understand Newton's laws. Students can only use concepts of certain phenomena, but cannot use those concepts to explain other, more complex phenomena. For example, students can establish that act and reaction forces are exaggerated not only by the mass of an object but also by the acceleration of the object. However, students cannot apply the concept of action and reaction forces to two objects that interact but do not cause displacement. Additionally, up to 27% of students cannot use concepts to explain phenomena. For example, students cannot use the concept of action and reaction forces for two objects colliding, two objects interacting but not causing displacement, or two objects interacting with each other causing displacement.

This research highlights the untapped potential of e-rebuttal texts in addressing misconceptions and reconstructing students' mental models. Although previous studies have shown the effectiveness of rebuttal texts and computer-based media in mitigating misconceptions and improving conceptual understanding, their integration into a cohesive, interactive digital format specifically tailored for teaching Newton's Laws remains relatively unexplored. This study pioneers an innovative approach by combining e-rebuttal texts with multimedia elements, including videos, animations, and simulations, designed to enhance engagement and comprehension. By centering on the reconstruction of students' mental models, this research seeks to fill a critical gap in leveraging interactive digital tools for conceptual change in physics education. Accordingly, this study aims to investigate the extent to which e-rebuttal texts on Newton's Laws can reshape students' mental models by addressing and correcting existing misconceptions. Therefore, this study aims to explore how e-rebuttal texts on Newton's Laws can reconstruct students' mental models by altering existing misconceptions.

2 Research method

The research method used is a mixed method of collecting quantitative and qualitative data (Dawadi et al., 2021). Quantitative research methods used to determine the students' conceptions and the rate of change in students' mental models after e-rebuttal texts, while qualitative methods used to determine the process of students' mental models change. Research design used embedded mixed methods. The embedded mixed methods design simultaneously combines quantitative and qualitative research methods. Quantitative data were obtained based on pre-test and post-test results. Then, qualitative data were obtained when the learning process was based on student responses to e-rebuttal texts. Additionally, the process of changing mental models is also used as a qualitative data analysis. Quantitative and qualitative data obtained from studies were used simultaneously to interpret the results.

2.1 Participants

Participants in this study were 31 students (15 boys and 16 girls, aged 15–16 years) in the 10th grade of one public high school in Sukabumi, West Java, Indonesia. These students followed the Indonesian national curriculum, specifically the 2013 curriculum, which includes physics as a mandatory subject. The physics curriculum for 10th-grade students consists of four hours per week (each session lasting 45 min). Participants study using an e-rebuttal texts on Newton's laws material. Their prior knowledge was assessed through a diagnostic test before the intervention. Learning is held for three weeks in January 2020 (before the Covid-19 pandemic spreads in Indonesia).

2.2 Instrument

The instrument in this study, in the form of a diagnostic test, was used to identify students' mental models. This test was developed from a standard test, the Force Concept Inventory (FCI). In addition, the test was developed in two-tier tests, the first tier being the usual multiple-choice procedure and the second tier being the reason in the form of open-ended tests. Students give reasons for possible answers in the first tier. The student's answers are collected, then the most common reasons are used as the choice of reasons for the four-tier test. For the purpose of pre-test and post-test, this instrument was also developed in the form of multiple representations in verbal, pictorial and mathematical form. Based on the test results, the easiest representation for students will be used as a pre-test and the most difficult will be used as a post-test for each sub-material. This is to prevent students from perceiving similarities in the problems they are working on. This test is hereafter referred to as Multi-representation on Tier Instrument of Newton's laws (MOTION). MOTION consists of 36 sub-material questions about Newton's First Law, Newton's Second Law, Newton's Third Law and type of forces. Each subject matter consists of nine questions in three formats. An example of MOTION is shown in Figure 2.

From Figure 2, it can be seen that the first tier is a multiple-choice answer format. The second tier is the student's confidence in the first-tier response options, in the form of "sure" and "not sure." The third tier is the choice of reasons for the first-tier answers, and the fourth tier is the student's level of confidence in the choice of reasons in the fourth tier, in the form of "sure" and "not sure."

The instrument was first tested before being used in research. This instrument was distributed to 92 students, and 23 students each worked on sub-materials of Newton's First Law, Newton's Second Law, Newton's Third Law, and the type of forces in three expressions. After that, an instrument analysis was carried out which included validity and reliability tests. Test validity and reliability through Rasch analysis (Samsudin et al., 2020). The validity test shows that the sub-materials of Newton's First Law and the Types of Forces fall under the 'excellent' category with a value raw variance explained by measures greater than 60%, while the sub-materials of Newton's Second Law and Newton's Third Law are categorized as 'good' with values raw variance explained by measures above 40%. Meanwhile, the reliability test reveals that the Cronbach's alpha values for Newton's First Law, Newton's Second Law, Newton's Third Law, and Types of Forces are 0.89, 0.94, 0.87, and 0.95, respectively. These values indicate that all sub-materials meet the 'very good' criteria, as they exceed the threshold of 0.8. The results of this validity and reliability test show that MOTION can be used effectively and reliably.

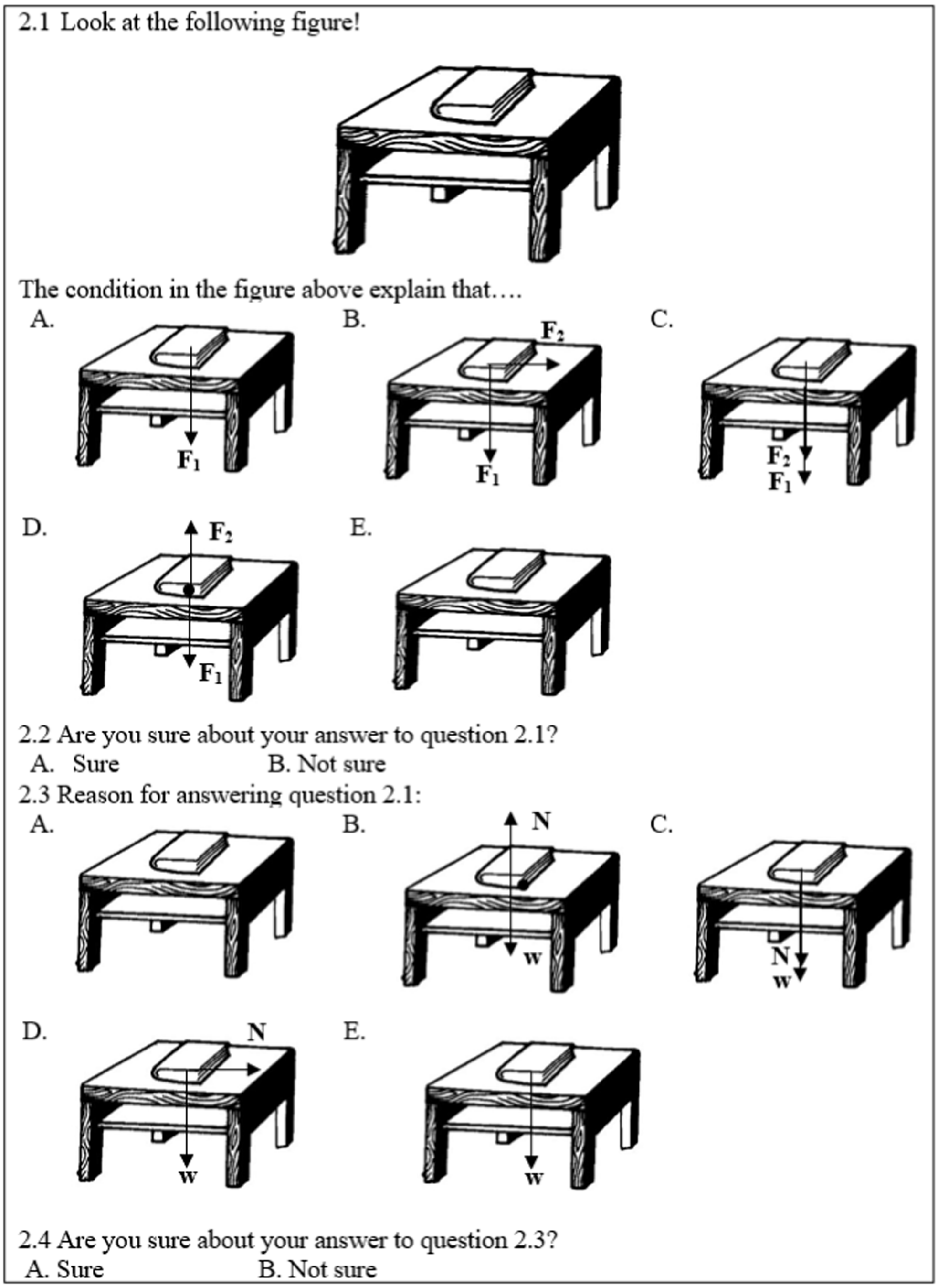

FIGURE 2
Example of MOTION in pictorial representation.

2.3 Data analysis

Before analyzing the student's mental model, first, the students' conceptions must be analyzed. Based on the results of student responses to MOTION, student conceptions can be classified into several categories identified by Gurel et al. (2015) as shown in Table 1.

Students' mental models can be seen based on the conception of each sub-material (Kurnaz and Eksi, 2015) as shown in Table 2. Correction of a student's mental model is an important analysis because it allows one to see if a student has corrected their mental model. Mental model improvement categories can be divided into three categories shown in Figure 3, Acceptable Correction (ACo), No Acceptable Correction (NAC), and No Correction (NCo).

The ACo category is an acceptable correction, namely from the initial (IN) or synthetic (SY) model to scientific (SC) and from the IN model to SY. The NAC category is an unacceptable repair, namely from SY or SC to IN and from SC to SY. While the NCo category is a model that does not change from beginning to end. The mental

TABLE 1 Conceptions category for four-tier test.

Conceptions categories	First tier	Second tier	Third tier	Fourth tier
Sound understanding (SU)	Correct	Sure	Correct	Sure
Partial understanding (PU)	Correct	Sure	Correct	Not sure
	Correct	Not sure	Correct	Sure
	Correct	Not sure	Correct	Not sure
	Correct	Sure	Incorrect	Sure
	Correct	Sure	Incorrect	Not sure
	Correct	Not sure	Incorrect	Sure
	Correct	Not sure	Incorrect	Not sure
	Incorrect	Sure	Correct	Sure
	Incorrect	Sure	Correct	Not sure
	Incorrect	Not sure	Correct	Sure
	Incorrect	Not sure	Correct	Not sure
No understanding (NU)	Incorrect	Sure	Incorrect	Not sure
	Incorrect	Not sure	Incorrect	Sure
	Incorrect	Not sure	Incorrect	Not sure
Misconception (MC)	Incorrect	Sure	Incorrect	Sure
No coding (NC)	If not filling one or more tier			

TABLE 2 Category of students' mental model.

Mental models categories	Symbol	Conceptions categories
Scientific (SC)		Students' conceptions are in the SU, PU or combination of SU and PU categories for the three questions
Synthetic (SY)		Students' conceptions are in the combination category between SU and PU with NU, MC, and NC for the three questions
Initial (IN)		Students' conceptions are in the NU, MC, NC categories, or a combination of NU, MC and NC for the three questions

model correction category has several possibilities as shown in Figure 3.

2.4 E-rebuttal texts

E-rebuttal texts is different from rebuttal texts in general, with a structure as shown in Figure 1. First, students predict what will happen to the presented phenomenon. By predicting activities, student's initial conceptions (mental models) can be examined. Misconceptions are then presented that often appear with the refutation proposition. Students then observe what happens to the phenomenon. Observational activities can lead to cognitive

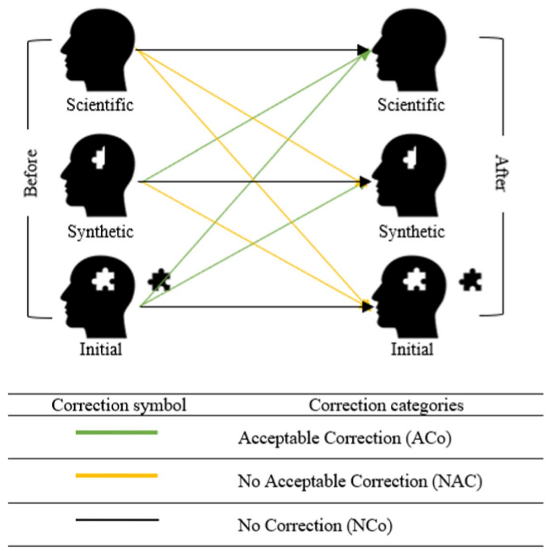

FIGURE 3
Possible correction of mental model from pre-test to post-test results.

conflict when students' predictions and observations do not match. This activity is performed using simulations and videos that the students can operate themselves. Finally, a scientific explanation of the concept is presented. This activity can build the conceptions of the students. In addition, students can also write their own answers on e-rebuttal texts.

E-rebuttal texts is web-based and can be accessed through the quiz.tioc1.com site. E-rebuttal texts can be opened from a computer, laptop or mobile phone. An example display (in Indonesian) from a laptop is shown in Figure 4.

The readings listed on the e-rebuttal texts display in Figure 4 is:

A child is about to go on an excursion using a pickup truck as shown in Figure 1. The car is initially at rest.

Predict what will happen to the child if the car that was initially at rest suddenly moves and the car that was initially moving suddenly stops!

3 Results and discussion

Students' mental models can be analyzed based on the category of students' conceptions. The distribution of students' conceptions is shown in Table 3.

Mental models can be divided into three, namely Scientific (SC), Synthetic (SY), and Initial (IN). The percentage of students' mental models for the pre-test and post-test is presented in Figure 5.

Based on Figure 5, it can be seen the comparison of the percentage of students' mental models. During the pre-test, the highest percentage was in the Synthetic (SY) category at 68%, Initial (IN) at 26%, and Scientific (SC) at 6%. At the time of post-test, the highest percentage of mental models was in the SY category at 57%, SC at 37%, and IN at 6%. The percentages for the Scientific (SC) model improved from pre-test to post-test, whereas the percentages for the SY and IN models reduced. Based on this comparison, e-rebuttal texts can be used to construct students' mental models into SC models. This is

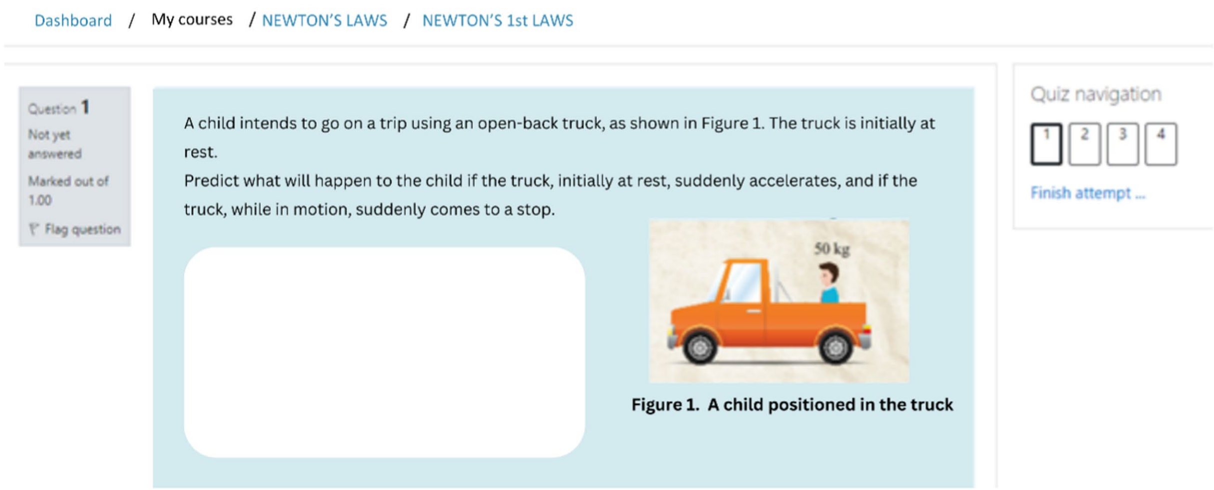

FIGURE 4
Example display of e-rebuttal texts from laptop.

in accordance with the research of Lem et al. (2017) which states that rebuttal texts is effective for changing students' mental models. The interactive media used allows students to carry out integrated investigations, can simulate various experiments and physical phenomena and their processes, and visualize abstract concepts (Jian-hua and Hong, 2012; Jiang et al., 2018; Nurdini et al., 2020; Ozkan and Selcuk, 2015; Wang et al., 2021).

The distribution of students for each mental model at the pre-test and post-test for each subject matter is shown in Table 4. Based on Table 4, the distribution of students for each mental model at the pre-test and post-test for each sub-material of Newton's Law was obtained. Based on the percentage of each mental model, there is an improvement from the pre-test to the post-test. Furthermore, it was analyzed regarding the correction of students' mental models during the pre-test and post-test. This is done to obtain information about the mental model after the learning process with e-rebuttal texts. The description of the overall mental model correction from pre-test to post-test is shown in Table 5.

Based on Table 5, it can be seen that the most frequent corrections occurred in SY with 45 corrections, followed by corrections from SY to SC with 35 changes. Corrections from the pre-test to the post-test are not yet fully SC. Overall, the percentage of students' mental model correction categories can be seen in Figure 6.

Based on Figure 6, it can be seen that after the implementation of e-rebuttal texts, there was a correction in students' mental models. The most correction occurred in the Acceptable Correction (ACo) category. That is, students' mental models can be corrected through e-rebuttal texts. However, there are still students who maintain the IN and SY mental models which may contain misconceptions. This is because misconceptions are difficult to change in a short time. As revealed by Liu and Fang (2016), Samsudin et al. (2019), and Will et al. (2019) that misconceptions are difficult to change and require a long process if these conceptions are closely attached to students' thinking.

Based on Figure 7, the highest total correction in students' mental models occurred in the Acceptable Correction (ACo) category of 52%. That is after the implementation of e-rebuttal texts, students' mental models experienced acceptable corrections. Corrections from IN to SY are the most common corrections. However, the SY mental model is a mental model that some still have a conception in the NU, MC, or NC categories. In the No Acceptable Correction (NAC) category, 6% occurred. In the No Correction (NCo) category, the most occurred in SY at 39%.

One example of the answer S08 on e-rebuttal texts for Newton's First Law is question number 1 (N1). In N1 is the concept of inertia, namely on the occasion that a glass of water without a cover is in a bus and the bus suddenly brakes. At the pre-test, S08 did not have an misconception, but in the post-test, S08 had an misconception. During the pre-test, S08 said that the water in the glass would spill forward when the bus suddenly braked. This is due to the reaction of the water. The answer choice S08 is correct but the reasons given are wrong, and S08 is sure of the answer choices and reasons. Therefore, S08 is in the PU category. However, during the post-test, S08 said that the water in the glass would spill forward and then backwards due to the action of the bus driver. The answer choices and reasons S08 are wrong and are sure of the answer choices and reasons so that S08 has an misconception. When viewed from S08's answer on e-rebuttal texts, S08 correctly predicts inertia occasions. However, when explaining the results of observations for the concept of a moving object that will continue to move as long as there is no external force that affects it, the answer S08 does not fit the context presented.

When explaining the results of predictions and observations, S08 answered that there was an inertia characteristic, but did not explain further which object had an inertia characteristic of the event. In addition, this can also be caused by different representations at pre-test and post-test. The representation used during the pre-test was pictorial while the post-test was verbal. In addition to having a difficulty level in the "difficult" category, verbal representations are also possible to generate misconceptions (Braasch et al., 2013; Majid and Suyono, 2018; Yumuşak et al., 2015). In accordance with the statement of Soysal and Yilmaz-Tuzun

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TABLE 3 The distribution of students' conceptions on pre-test and post-test.

No.	Sound understanding (SU)		Partial understanding (PU)		No understanding (NU)		Alternative conception (AC)		No coding (NC)	
	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-
N1	-	S02, S04, S05, S06, S10, S12, S13, S15, S16, S17, S19, S20, S21, S24, S27, S28, S30, S31 **(58%)**	S06, S08, S13, S18, S19, S23, S27, S28 **(26%)**	S01, S09, S14, S18, S23, S25, S26, S29 **(26%)**	S03, S15, S30 **(10%)**	-	S01, S02, S04, S05, S07, S10, S11, S12, S14, S16, S17, S20, S21, S22, S24, S25, S26, S29, S31 **(61%)**	S03, S07, S08, S11, S22 **(16%)**	S09 **(3%)**	-
N2	S01, S02, S05, S12, S15, S17, S19, S20, S23, S31 **(32%)**	S02, S08, S10, S11, S15, S16, S20, S22, S23, S24, S25, S27, S28, S31 **(45%)**	S06, S16, S18, S21 **(13%)**	S03, S04, S05, S12, S13, S17, S18, S19, S21, S26, S29, S30 **(39%)**	-	-	S03, S04, S07, S08, S10, S13, S14, S24, S25, S26, S28, S29, S30 **(42%)**	S01, S06, S07, S09, S14 **(16%)**	S09, S11, S22, S27 **(13%)**	-
N3	S12 **(3%)**	S14, S17, S21, S25 **(13%)**	S05, S06, S07, S17, S19, S22, S23, S24 **(26%)**	S01, S07, S12, S18, S20, S23, S27, S30 **(26%)**	S01, S09, S13, S20, S27 **(16%)**	-	S02, S04, S08, S10, S11, S14, S15, S16, S18, S21, S25, S26, S28, S30, S31 **(48%)**	S02, S04, S05, S06, S08, S09, S10, S11, S13, S15, S16, S19, S22, S24, S26, S28, S29, S31 **(58%)**	S03, S29 **(7%)**	S03 **(3%)**
N4	-	S14, S20, S21, S23, S25 **(16%)**	S02, S05, S07, S10, S11, S12, S14, S15, S16, S17, S18, S19, S20, S23, S31 **(48%)**	S01, S02, S03, S05, S06, S08, S10, S11, S12, S13, S22, S24, S29, S31 **(45%)**	S01, S03, S13, S27, S30 **(16%)**	S30 **(3%)**	S04, S06, S08, S22, S24, S25, S26, S28, S29 **(29%)**	S04, S07, S15, S16, S17, S18, S19, S26, S27 **(29%)**	S09, S21 **(7%)**	S09, S28 **(7%)**
N5	S18 **(3%)**	S02, S05, S07, S08, S10, S11, S12, S16, S18, S19, S20, S22, S23, S24, S27, S29, S30, S31 **(58%)**	S01, S09, S20, S23, S26 **(16%)**	S01, S06, S14, S21, S25 **(16%)**	S03, S04, S30 **(10%)**	-	S02, S05, S06, S07, S08, S10, S11, S12, S14, S15, S16, S17, S19, S21, S22, S24, S25, S27, S28, S29, S31 **(68%)**	S03, S13, S15, S17, S26, S28 **(19%)**	S13 **(3%)**	S04, S09 **(7%)**
N6	S22 **(3%)**	S02, S10, S14, S19, S20, S23, S24, S25 **(26%)**	S04, S06, S08, S09, S14, S24, S29, S30 **(26%)**	S04, S05, S08, S11, S13, S15, S17, S22, S27, S29, S30, S31 **(39%)**	S01, S02, S03, S10, S13, S19, S20, S31 **(26%)**	-	S07, S11, S12, S15, S16, S17, S18, S21, S23, S25, S26, S27, S28 **(42%)**	S01, S03, S06, S07, S09, S12, S16, S18, S21, S26, S28 **(35%)**	S05 **(3%)**	-
N7	S02, S04, S05, S10, S11, S25, S27 **(23%)**	S01, S02, S10, S12, S16, S17, S18, S19, S21, S22, S23, S24, S27, S28, S31 **(48%)**	S03, S07, S08, S13, S17, S18, S19, S22, S28, S30 **(32%)**	S04, S05, S06, S08, S09, S11, S13, S14, S15, S20, S25, S26, S29, S30 **(45%)**	S01, S09, S20, S23 **(13%)**	-	S06, S12, S14, S15, S16, S21, S24, S26, S29, S31 **(32%)**	S03, S07 **(7%)**	-	-

(Continued)

TABLE 3 (Continued)

No.	Sound understanding (SU)		Partial understanding (PU)		No understanding (NU)		Alternative conception (AC)		No coding (NC)	
	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-
N8	-	S01, S18, S27, S31 **(13%)**	S04, S05, S08, S15, S17, S18, S21, S22, S23, S25, S27 **(35%)**	S02, S03, S05, S06, S08, S09, S10, S11, S13, S14, S16, S17, S19, S20, S21, S22, S24, S25 **(58%)**	S02, S03, S09, S13, S19, S30, S31 **(23%)**	S30 **(3%)**	S01, S06, S07, S10, S11, S12, S14, S16, S20, S24, S26, S28, S29 **(42%)**	S04, S07, S12, S23, S26, S29 **(19%)**	-	S15, S28 **(7%)**
N9	S02, S31 **(7%)**	S01, S02, S05, S08, S09, S11, S12, S13, S18, S20, S21, S22, S23, S24, S31 **(48%)**	S01, S03, S10, S11, S16, S21, S23, S25, S26, S27, S29 **(35%)**	S03, S04, S06, S15, S16, S19, S28, S29 **(26%)**	S04, S09, S13, S19, S30 **(16%)**	S30 **(3%)**	S05, S06, S07, S08, S12, S14, S15, S17, S18, S20, S22, S24 **(39%)**	S07, S10, S14, S17, S25, S26, S27 **(23%)**	S28 **(3%)**	-
N10	S23 **(3%)**	S02, S09, S11, S18, S21, S22, S23, S24, S31 **(29%)**	S01, S09, S11, S12, S15, S26 **(19%)**	S03, S05, S06, S08, S10, S13, S14, S15, S17, S20, S25, S27, S28, S30 **(45%)**	S03, S27, S30 **(10%)**	-	S02, S04, S05, S06, S07, S08, S10, S13, S14, S16, S17, S18, S19, S20, S21, S22, S24, S25, S28, S29, S31 **(68%)**	S01, S04, S07, S12, S16, S19, S26, S29 **(26%)**	-	-
N11	-	S01, S02, S18, S20, S22, S23, S31 **(23%)**	S01, S06, S09, S10, S18, S23, S25, S30 **(26%)**	S03, S04, S05, S06, S07, S08, S09, S11, S13, S15, S21, S24, S25, S27, S28, S30 **(51%)**	S02, S04, S05, S13, S20 **(16%)**	-	S03, S07, S08, S11, S12, S14, S16, S17, S19, S21, S22, S24, S26, S27, S28, S29, S31 **(55%)**	S10, S12, S14, S16, S17, S19, S26, S29 **(26%)**	S15 **(3%)**	-
N12	-	S18 **(3%)**	S02, S07, S09, S13, S14, S19, S23, S27, S28 **(29%)**	S01, S02, S05, S06, S09, S11, S19, S20, S23, S27, S28, S31 **(39%)**	S01, S20, S30, S31 **(13%)**	S30 **(3%)**	S03, S04, S05, S06, S08, S10, S11, S12, S15, S16, S17, S18, S21, S22, S24, S25, S26, S29 **(58%)**	S03, S04, S07, S08, S10, S12, S13, S14, S15, S16, S17, S21, S22, S24, S25, S26, S29 **(55%)**	-	-
Average	**6%**	**32%**	**28%**	**38%**	**14%**	**1%**	**49%**	**28%**	**3%**	**2%**

Bold values indicate the percentage of students in each conception category.

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(2021) there are many physical terms that have different meanings from everyday terms such as the terms force, power and work. In addition, in line with the research of Fithrathy (2019), after the application of physics learning with multimedia, students' verbal representation abilities had a smaller increase than pictorial representation (graphics).

The process of correcting students' mental models in Newton's Second Law sub-material is shown in Figure 8. Based on Figure 8, the highest total correction in students' mental models occurred in the Acceptable Correction (ACo) category of 55%. That is, after the implementation of e-rebuttal texts, students' mental models experienced acceptable corrections.

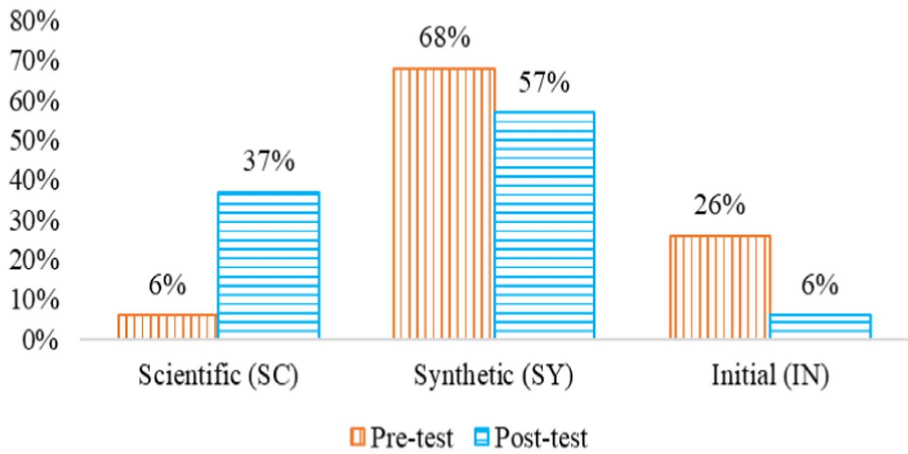
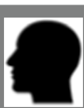
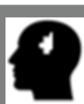


FIGURE 5
Comparison of the percentage of students' mental models at pre-test and post-test.

TABLE 4 Students' mental models for pre-test and post-test.

Sub-material	 Scientific (SC)		 Synthetic (SY)		 Initial (IN)	
	Pre-	Post-	Pre-	Post-	Pre-	Post-
Newton's first law	S06, S19, S23 **(10%)**	S12, S17, S18, S20, S21, S23, S25, S27, S30 **(29%)**	S01, S02, S05, S07, S08, S12, S13, S15, S16, S17, S18, S20, S21, S22, S24, S27, S28, S31 **(58%)**	S01, S02, S03, S04, S05, S06, S07, S08, S09, S10, S11, S13, S14, S15, S16, S19, S22, S24, S26, S28, S29, S31 **(71%)**	S03, S04, S09, S10, S11, S14, S25, S26, S29, S30 **(32%)**	-
Newton's second law	-	S02, S05, S08, S10, S11, S14, S20, S22, S23, S24, S25, S29, S31 **(42%)**	S01, S02, S04, S05, S06, S07, S08, S09, S10, S11, S12, S14, S15, S16, S17, S18, S19, S20, S22, S23, S24, S26, S29, S30, S31 **(81%)**	S01, S03, S04, S06, S07, S12, S13, S15, S16, S17, S18, S19, S21, S27, S30 **(48%)**	S03, S13, S21, S25, S27, S28 **(19%)**	S09, S26, S28 **(10%)**
Type of forces	S25, S27 **(6%)**	S01, S02, S06, S08, S09, S11, S13, S16, S18, S19, S20, S21, S22, S24, S31 **(48%)**	S01, S02, S03, S04, S05, S07, S08, S10, S11, S13, S15, S16, S17, S18, S19, S21, S22, S23, S26, S29, S30, S31 **(71%)**	S03, S04, S05, S07, S10, S12, S14, S15, S17, S23, S25, S26, S27, S28, S29, S30 **(52%)**	S06, S09, S12, S14, S20, S24, S28 **(23%)**	-
Newton's Third Law	S09, S23 **(7%)**	S05, S06, S09, S11, S18, S23, S27, S28, S31 **(29%)**	S01, S02, S06, S07, S10, S11, S12, S13, S14, S15, S18, S19, S20, S25, S26, S27, S28, S30, S31 **(61%)**	S01, S02, S03, S04, S07, S08, S10, S13, S14, S15, S17, S19, S20, S21, S22, S24, S25, S30 **(58%)**	S03, S04, S05, S08, S16, S17, S21, S22, S24, S29 **(32%)**	S12, S16, S26, S29 **(13%)**
Average	**6%**	**37%**	**68%**	**57%**	**26%**	**6%**

*S1-S31 are students number 1 until 31.

TABLE 5 The process of correcting the overall mental model of students from pre-test to post-test.

Correction category	Pre-	→	Post-	Sub-material (students code)	f	Example of students' mental model correction
Acceptable correction (ACo)		→		Law I (S12, S17, S18, S20, S21, S27); Law II (S02, S05, S08, S10, S11, S14, S20, S22, S23, S24, S29, S31); TF (S01, S02, S08, S11, S13, S16, S18, S19, S21, S22, S31); Law III (S06, S11, S18, S27, S28, S31)	35	Newton's First Law sub-material for S17: At pre-test, S17 had AC on the concept of inertia, SU on the concept of force balance for a stationary object and PU for the concept of force balance on an object moving in a straight line so that it has a Synthetic (SY) mental model. At the post-test, S17 had SU on the concept of inertia and force balance on an object moving in a straight line and PU on the concept of force balance for a stationary object so that it had a Scientific (SC) mental model.
		→		Law I (S25, S30); Law II (S25); TF (S06, S09, S20, S24); Law III (S05)	8	Newton's Second Law sub-material for S25: At pre-test, S25 has AC on the concept of the effect of force on velocity, the effect of mass on acceleration in free fall motion and inclined plane so that it has an Initial (IN) mental model. At post-test, S25 had SU on the concept of the effect of force on velocity and the influence of mass on acceleration on an inclined plane, and SU on the concept of mass influence on acceleration in free fall so that it has a mental model of SC.
		→		Law I (S03, S04, S09, S10, S11, S14, S26, S29); Law II (S03, S13, S21, S27); TF (S12, S14, S28); Law III (S03, S04, S08, S17, S21, S22, S24)	22	Sub material types of forces for S12: At pre-test, S12 had AC on the concepts of normal force, frictional force and gravitational force so that it had an IN mental model. At post-test, S12 had SU on the concept of normal force and gravity, and AC on the concept of frictional force so that it had a mental model of SY.
No acceptable correction (NAC)		→		Law I (S06, S19); TF (S25, S27)	4	Newton's First Law sub-material for S06: At pre-test, S06 had PU on the concept of inertia, balance of forces for stationary objects, and balance of forces on objects that move in a straight line so that S06 have a mental model of SC. At post-test, S06 had SU on the concept of inertia and AC on the concept of force balance on a stationary object and an object moving in a straight line so that it has a mental model of SY.
		→		Law II (S09, S26); Law III (S12, S26)	4	Newton's Third Law sub-material for S26: At pre-test, S26 had PU on the concept of action-reaction force for colliding objects, and AC on the concept of action-reaction force on objects that push other objects and colliding objects so that they have a mental model of SY. At post-test, S26 has AC on all the concepts of action-reaction force so that it has a mental model of IN.
No correction (NCo)		→		Law I (S23); LAW III (S09, S23)	3	Newton's First Law sub-material for S23: At pre-test, S23 had PU on the concept of inertia and force balance on an object moving in a straight line, and SU on the concept of force balance for a stationary object so that it has a mental model of SC. At post-test, S23 had the same conception so S23 had the same mental model.
		→		Law I (S01, S02, S05, S07, S08, S13, S15, S16, S22, S24, S28, S31); Law II (S01, S04, S06, S07, S12, S15, S16, S17, S18, S19, S30); TF (S03, S04, S05, S07, S10, S15, S17, S23, S26, S29, S30); Law III (S01, S02, S07, S10, S13, S14, S15, S19, S20, S25, S30)	45	Newton's Second Law sub-material for S01: At pre-test, S01 had NU on the concept of the effect of force on velocity and the effect of force on acceleration on an inclined plane, and PU on the concept of mass influence on acceleration in free fall so that it has a mental model of SY. At post-test, S01 had PU on the concept of the effect of force on velocity and mass effect on acceleration on an inclined plane, and AC on the concept of mass influence on acceleration in free fall so that it has a mental model of SY.
		→		Law II (S28); Law III (S16, S29)	3	Newton's Third Law sub-material for S16: At pre-test, S16 has AC on all concepts of action-reaction force so that it has an IN mental model. At post-test, S16 has AC on all concepts of action-reaction force so that it has an IN mental model.

Bold values indicate the percentage of students in each conception category.

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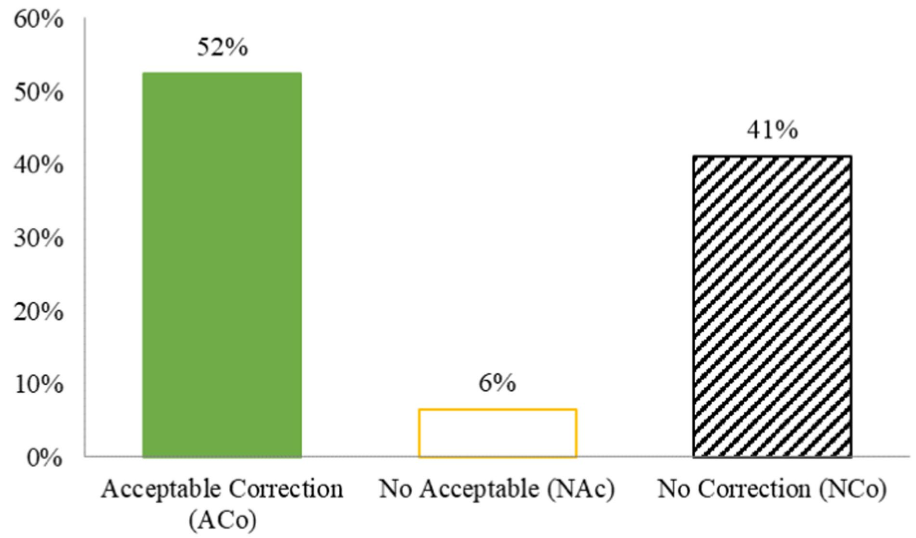

FIGURE 6
Percentage of correction categories of students' mental model from pre-test to post-test.

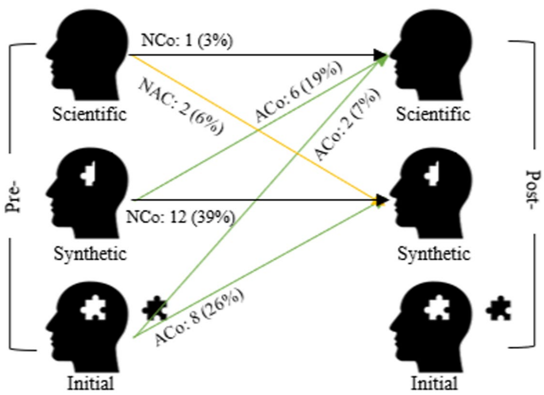

FIGURE 7
Correction of students' mental model on Newton's first law sub-material from pre-test to post-test.

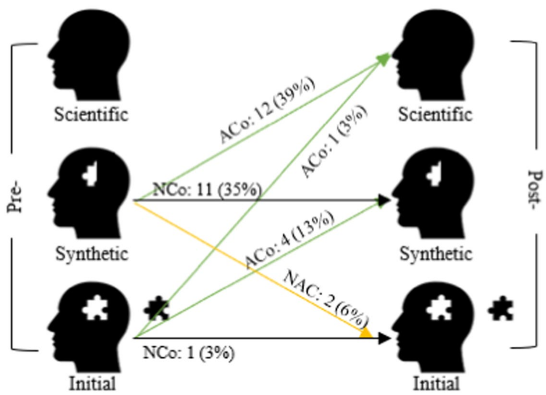

FIGURE 8
Correction of students' mental model in Newton's second law sub-material from pre-test to post-test.

Corrections from SY to SC are the most common corrections. In the No Acceptable Correction (NAC) category, 7% occurred. In the No Correction (NCo) category, most occurred in SY at 35%.

The process of correcting students' mental models in the types of forces is shown in Figure 9. Based on Figure 9, the highest total corrections in students' mental models occurred in the Acceptable Correction (ACo) category of 58%. That is, after the implementation of e-rebuttal texts, students' mental models experienced acceptable corrections. Corrections from SY to SC are the most common corrections. In the No Acceptable Correction (NAC) category, 7% occurred. In the No Correction (NCo) category, most occurred in SY at 35%.

The process of correcting students' mental models in Newton's Third Law sub-material is shown in Figure 10. Based on Figure 10, the highest total correction in students' mental models occurred in the NCo category of 49%. Most mental models occur in SY. This means

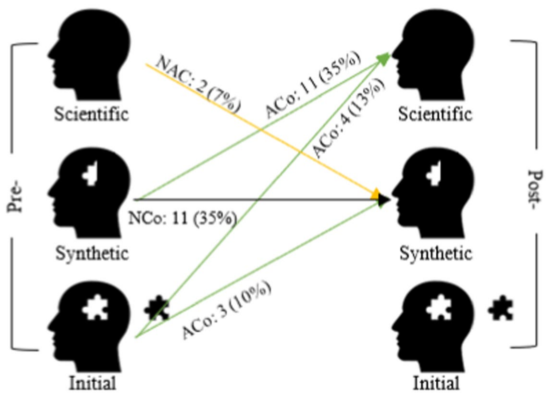

FIGURE 9
Correction of students' mental model in sub-material types of forces from pre-test to post-test.

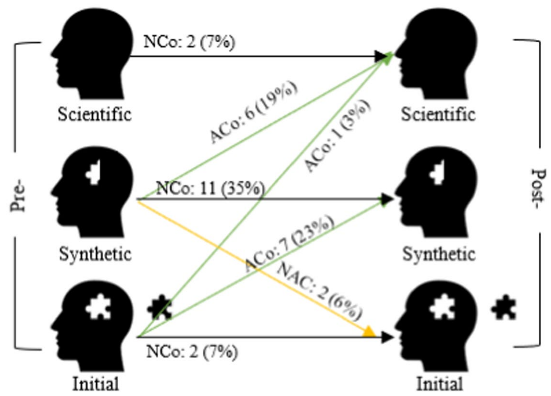

FIGURE 10
Correction of students' mental model in Newton's third law sub-material from pre-test to post-test.

that students' mental models remain in SY after the application of e-rebuttal texts. In the ACo category, the correction from IN to SY occurred the most. That is, the mental model of students is not complete after the learning process. In the No Acceptable Correction (NAC) category, 6% occurred.

4 Conclusion

Based on research conducted to reconstruct students' mental model in conceptual change through e-rebuttal texts on Newton's Laws, it was concluded that e-rebuttal texts can be used to reconstruct students' mental models in conceptual change to become Scientific (SC). Overall, positive changes were seen from pre-test to post-test on each mental model. The rate of correction in students' mental models from pre-test to post-test occurred primarily in the Acceptable Correction (ACo) category. Insertion of prediction and observation sections into rebuttal texts creating new structures in e-rebuttal texts: predictions, presenting current misconceptions, sentence of refute, observations and scientific explanations.

Moreover, there are some recommendations made by researchers based on the studies that have been conducted. Before using e-rebuttal texts, the teacher or researcher should check device and internet connectivity availability, as the media used is web-based. Other researchers may add parts of the text, such as animated force diagrams on inclined planes, motion during free fall, simulated action and reaction forces on nearby objects, etc. Additionally, the learning process used does not involve students participating in groups. Therefore, researchers may also use learning models and strategies to involve students in groups to facilitate the discussion process.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Universitas Pendidikan Indonesia. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

AnS: Conceptualization, Funding acquisition, Supervision, Writing – review & editing. AcS: Conceptualization, Methodology, Supervision, Writing – review & editing. NF: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft. NN: Project administration, Visualization, Writing – review & editing. SF: Writing – review & editing. MP: Writing – review & editing. SL: Supervision, Writing – review & editing. BC: Conceptualization, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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