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# CoSiReT: Innovation of ReT (Refutation Texts) to Reduce Students' Misconceptions Concerning Transverse Waves

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**Abstract:** The research goal was to develop innovative learning media on refutation texts (ReT), scilicet integrating Computer Simulations on Refutation Texts (CoSiReT). CoSiReT's role is to reduce students' misconceptions concerning the basic concept of transverse waves. This research design used 4D (Define, Design, Develop, and Disseminate). Participants include 64 students aged 16-18 years in the Tuban region, East Java, Indonesia (37 male were called *Mas*, and 27 female were called *Mbak*). The research instrument used a media validation sheet (15 assessment indicators). The pre-post test instrument used the Multi-representation of a Four-tier Instrument on Transverse Wave (MOFI-OTW). Analysis of data validation results was using a rater test assisted by Rasch's Mini-Facets software. According to the seven validators, the results of CoSiReT fulfill aspects of instructions for use, language, content presentation, and appearance. The percentage of students' misconception reduction was analyzed using the Reduction Misconceptions (RM) adapted from Hake's n-gain equation. Overall, the reduction of misconceptions is in the high category. Thus, it can be concluded that CoSiReT can be developed and used a role in reducing student misconceptions. Researchers or practitioners are expected to implement CoSiReT as a learning innovation that aims to reduce basic misconceptions of transverse waves.

**Keywords:** Computer simulation; CoSiReT; Mini-facets rasch; Misconception; Refutation text; Transverse waves

## Introduction

Understanding of physics concepts is an essential concept that high school students must have in Indonesia. Nevertheless, it is undeniable that students' misinterpretations about concepts while following learning instructions still occur repeatedly (Fan et al., 2018; Samsudin et al., 2021; Suhandi et al., 2020). This case, experts called it a misconception (Gurel et al., 2015; Will et al., 2019; Yürük et al., 2016). Conceptions are different from what the teacher or experts instruct will affect students' reasoning patterns in the future (Samsudin et al., 2021; Schroeder et al., 2022). Hence, physics education needs serious handling of this case. Physics learning needs to involve methods of changing conceptions. Thus, misconceptions can be reduced.

One method of changing conceptions that has phenomenal among researchers is Refutation texts (ReT). ReT is an arrangement of instructional texts that refute and replace students' misconceptions which inconsistent with scientific conceptions (Asterhan et al., 2020; Hoof et al., 2021; Tippett, 2010). The role of ReT has been shown to be effective in achieving its function, namely to change students' conceptions from misconceptions (Guzzetti et al., 1993; Will et al., 2019). This effectiveness was supported by the text covering four conditions of changing conceptions, namely dissatisfaction, intelligibility, plausibility, and fruitfulness (Posner et al., 1982). The four states of altered conception are not found in explanations of conventional texts or ordinary books.

The ReT structure is different from the text found in ordinary books. In the first stage, students are asked explicit questions to make predictions about a situation in daily life that can lead to misconceptions, then students provide answers involving their level of

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confidence (Mason et al., 2017; Tippett, 2010). In the second stage, the text presents refute concerning student misconceptions contradicted by scientific conceptions (Danielson et al., 2016; Mason et al., 2017). The third stage is followed by relevant scientific explanations (Adesope et al., 2017; Mason et al., 2020; Sinatra et al., 2011; Tippett, 2010). The existence of a changing conception process at each stage can reduce misconceptions in students.

Recently, several studies have stated the weaknesses of ReT. Instead of understanding scientific conceptions, students who do not like reading will be more unmotivated to read the scientific explanations given. Correspondingly, not all students can understand the meaning of the text, because each student has a different level of understanding of the text (Djudin, 2021). This indicates that physics concepts not always be understood in the form of verbal explanations.

Not all physics concepts can be apprehended by students directly without any scientific evidence that can be seen by the eye, such as the basic concept of transverse waves. In Indonesia, the basic concepts of transverse waves for high school students include the definition and characteristics of transverse waves, and the relationship between wavelength, frequency, period, and wave amplitude. Simple from this basic concept, students still experience misconceptions. For example, an understanding concerning the definition of the transverse wave, namely "Based on the direction of propagation and the direction of vibration, the definition of a transverse wave is a wave that has a direction of vibration perpendicular to the direction of propagation". In this case, an example of identifying misconceptions is shown the phenomena in Figure 1.

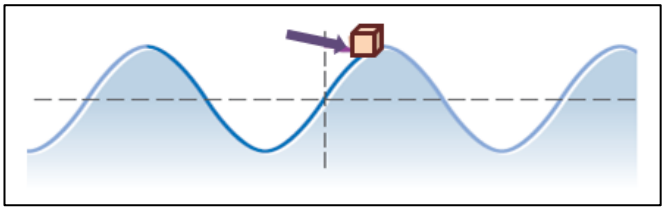

**Figure 1.** Cork box phenomenon above the water surface

Students are asked to predict the direction of the cork box on the water wave's surface. As many as 43% of all students stated that the direction of the cork box was moving to the right or left. Students were sure of their answers. In this case, students are identified as having misconceptions.

Supported by the findings of misconceptions from previous researchs for this case are; 1) when the frequency of the wave increases, the wavelength becomes longer (Barniol et al., 2017; Caleon et al., 2010, 2013; Mufida et al., 2022), 2) a change in amplitude causes the wavelength to change, and so does otherwise (Aykutlu et al., 2021; Barniol et al., 2017; Caleon et al., 2010, 2013; Mufida et al., 2022; Tongchai et al., 2009), 3) direction the vibration of particles in transverse waves is in the direction of their propagation (Caleon et al., 2013; Sutopo, 2016; Tumanggor et al., 2020). Based on this literature, cases of misconceptions about the basic concept of transverse waves are still common.

Overcoming the case and the weakness of previous research, the literature review by Schroeder et al. (2022) stated that additional research on ReT features is needed, such as more images or graphics because there is still very little research related to this. As a result, it is worth researching. Furthermore, in sequence with this case, researchers suggest the use of technology, such as computer simulation or virtual simulation that allows students to conduct scientific investigations (Çalik et al., 2015; Wibowo et al., 2019). Scientific investigation can support to change students' conceptions (Kaniawati et al., 2021; Suhandi et al., 2020; Surtiana et al., 2020). In addition, several studies state that the use of computer simulations can reduce misconceptions in the field of physics education (Fratiwi et al., 2018; Hermita et al., 2017; Putri et al., 2021; Samsudin, 2022; Wibowo et al., 2017). This advantage can be concluded that simulation recreates an active and effective role in reducing student misconceptions, especially in the field of physics education.

Therefore, this research innovates ReT by integrating a computer simulation of the ReT feature called CoSiReT (Computer Simulation on Refutation-Texts). CoSiReT was developed in interactive media, which is displayed in web form. The usefulness of simple computer simulations is integrated into ReT activities. To be more structured, the steps of CoSiReT are designed as shown in Figure 2.

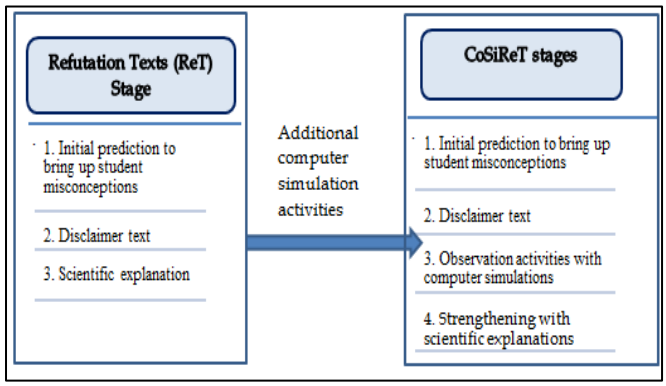


**Figure 2.** Transformation of learning activity stage from ReT to CoSiReT

Several studies have initiated research related to the integration of computer simulations with electronically presented ReT, such as Fratiwi et al. (2020) making ERIC

text to change high school students' conceptions of Newton's laws. Samsudin (2023) developed CC-VM, in which this media is a combination of CCT and virtual CCLab to improve students' mental models of light waves. Nurhasanah et al. (2022) implemented SiPOERT (Simulation in Predict Observe Explain with Refutational Text) so that it succeeded in reducing the percentage of students misconceptions about simple harmonic motion. Nonetheless, the innovation of computer simulations on refutation texts to reduce misconceptions about transverse waves is still rare.

Thus, the development of CoSiReT to reduce students' misconceptions concerning the basic concept of transverse waves is the aim of this research. The CoSiReT development research needs to be carried out because misconceptions still commonly occur in students while the shortage of learning media used to reduce misconceptions. The CoSiReT development was analyzed based on a judgment assessment using a rater test with the Mini-Facet Rasch software, which is rarely done by other researchers. The integration of computer simulations on refutation texts which was developed is a novelty in this research. The CoSiReT feature is simple and easy to use, the user does not make it difficult to operate. This research has implications for the world of education, especially in the study of physics learning media. Hence, the use of CoSiReT in learning is expected to assist practitioners or researchers in the field in conveying a concept, especially in learning the basic concept of transverse waves.

## Method

*Research Design*

Design 4D (Define, Design, Develop, and Disseminate) is used as the design of this study. Each stage is explained in detail in Figure 3.

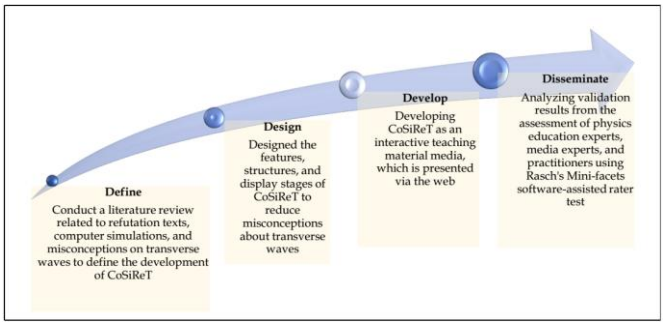


**Figure 3.** Steps from 4D research design to CoSiReT development

*Participants*

The participants in this study were 64 high school students in Tuban, East Java, aged 16-18 years. Student demographics are shown in Figure 4. The boy student are called *Mas* and the girl student are called *Mbak*. The location of the school is in the middle of Tuban region.


**Figure 4.** Tuban district map and demographics of the participants

*Research Instruments*

The validation sheet was used as the research instrument to develop CoSiReT. Validation sheets were given to physics education experts, media experts, and practitioners (teachers). The validation aspect includes aspects 1) instructions for use, 2) language, 3) content presentation, and 4) appearance, which is a total of 15 assessment indicators. Validation indicators are assessed based on assessment criteria, namely valid without revision, valid with revision, and invalid.

The pre-post-test questions were used to diagnose misconceptions before and after the implementation of CoSiReT. The pre-post test instruments used the instruments developed by Mufida et al. (2022), namely the Multi-representation of a Four-tier Instrument on Transverse Wave (MOFI-OTW).

*Data Analysis Procedures*

After being assessed by the validator, the assessment data is subjected to a process of content validity or expert judgment. The CoSiReT media assessors consisted of 3 physics education experts, 2 media experts, and 2 practitioners (7 validators). The validator's assessment data is tested by the rater by utilizing Rasch's Mini-Facets, which analyzes more on Wright maps. The results of the students' pre-post test were categorized into several conception categories by Mufida et al. (2022). This conception category was adapted from Aminudin et al. (2019). The categories of conception are presented in Table 1.

The percentage of students' misconception reduction was analyzed using the misconception reduction equation (RM) as in equation (1) which was adapted from Hake's n-gain equation (Hake, 1999).

$$\text{RM} = \frac{(\%\langle \text{Si} \rangle - \%\langle \text{Sf} \rangle)}{(\%\langle \text{Si} \rangle - 0)} \quad (1)$$

Where RM is the average reduced misconceptions (MC), $\langle Sf \rangle$ is the average percentage of misconceptions post-test scores, and $\langle Sf \rangle$ is the average percentage of misconceptions pre-test scores. The RM values obtained are interpreted as 1) high (RM>70), moderate (70≥RM>30), or low (RM ≤ 30) (Samsudin, 2022).

**Tabel 1**. Conception Category for Students

| Tier | Categories of Students' Conception | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SU | PUP | | | PUN | | | | NU | | | | MC | | | | NC |
| 1 (Option) | C | C | C | C | C | C | C | C | IC | IC | IC | IC | IC | IC | IC | IC | IA |
| 2 (Level Confidence) | S | S | NS | NS | S | S | NS | NS | S | S | NS | NS | S | NS | NS | S | |
| 3 (Reason) | C | C | C | C | IC | IC | IC | IC | C | C | C | C | IC | IC | IC | IC | |
| 4 (Level Confidence) | S | NS | S | NS | S | NS | S | NS | S | NS | S | NS | NS | S | NS | S | |

Description: Sound Understanding (SU), Partial Understanding Positive (PUP), Partial Understanding Negative (PUN), No Understanding (NC), Misconception (MC), and No Coding (NC). Correct (C), Incorrect (IC), Sure (S), Not Sure (NS), and Incomplete Answer (IA)

## Result and Discussion

The results and discussion for this research are explained based on the steps of the 4D research and development design (Define, Design, Develop, and Disseminate).

*Define*

CoSiReT is the development of refutation texts (ReT) teaching materials, which is a form of media innovation for teaching materials. The innovation is integrating simple computer simulations into the refutation texts feature. Originally, ReT contains refutations of misconceptions and scientific explanations (Adesope et al., 2017; Mason et al., 2017, 2020). Supported by simulations, ReT does not only contain text but can also conduct investigations interactively. This can facilitate the reduction of students' misconceptions about the basic concept of transverse waves. In addition, simulations can visualize abstract concepts clearer, motivate learning, and expedite the learning process (Kaniawati et al., 2021; Ouahi et al., 2022; Samsudin, 2022). Interactive features that are not monotonous can motivate students to learn.

*Design*

CoSiReT was designed on a storyboard by following the steps in Figure 2. Based on the findings of misconceptions from previous research from Caleon et al. (2010), Caleon et al. (2013), Barniol et al. (2016), Mufida et al. (2022), Thongchai et al. (2009), Aykutlu et al. (2021), Sutopo, (2016), Tumanggor et al. (2020) and the results of identifying misconceptions in schools, the physics content in CoSiReT was developed into four conceptual contents related to the basic concept of transverse waves. CoSiReT content namely 1) basic characteristics of transverse waves, 2) compare the graphs of the relationship of deviation with time and the graph of the relationship of deviation with distance, 3) the relationship between frequency and wavelength, and 4) the relationship between period and wavelength.

First, students are asked to analyze the phenomena presented in the condition of pictures or videos. Student answers aim to bring up misconceptions (Mason et al., 2017). Subsequently, students read the refutation text, in which the text will refute answers that are not following scientific conceptions. Second, students make virtual observations and investigations through simulations. Based on the results of observations using simulations, students compare the initial predictions with the results of observations. Third, CoSiReT reinforces student conceptions with scientific explanations.

*Develop*

Usually, refutation texts (ReT) are displayed in written form on paper. The CoSiReT development stage is presented in the form of interactive teaching materials that can be accessed via laptops or smartphones. An example of the CoSiReT feature can be displayed in Figure 5.

CoSiReT is in the form of a web, which students can access after getting a link and filling in their identity. Students fill in the initial predictions in the column provided along with their level of confidence. There is a check button to find out students' conceptions, if students experience misconceptions there is a refutation text. Subsequently, students bring out virtual observations according to Figure 6. A feature of CoSiReT integrates existing simple computer simulations with refutation (ReT) that is made. Simulation computer integration to provide facts through scientific observations (Wibowo et al., 2019; Çalik et al., 2015;

Suhandi et al., 2020; Surtiana et al., 2020). Students can complete until the last stage, namely reading a scientific explanation.

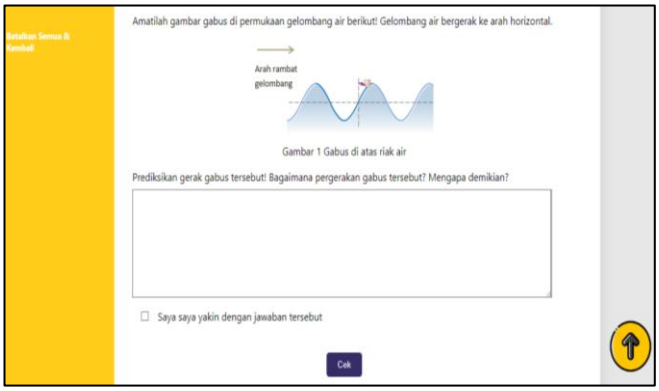


**Figure 5.** The examples of CoSiReT features on the web

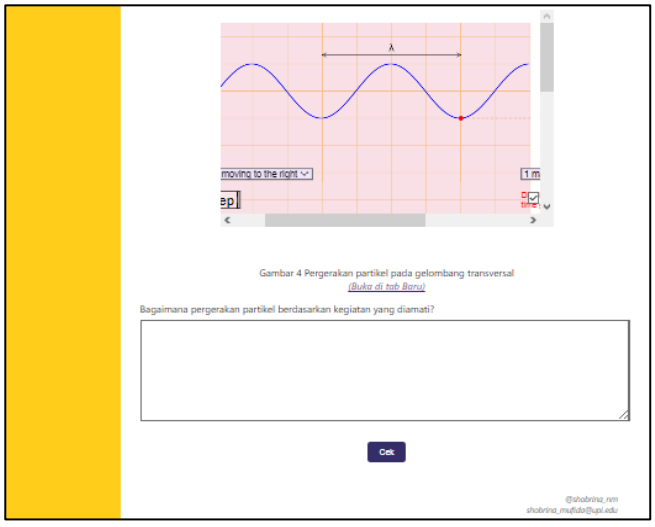


**Figure 6.** The example of the CoSiReT feature for bringing out scientific observations virtually

After being developed, CoSiReT was assessed by 3 physics education expert validators, 2 physics learning media experts, and 2 practitioners (teachers). The validator assessment analysis used the rater test presented in the Wright maps of the Mini-Facets Rasch software, according to Figure 7.

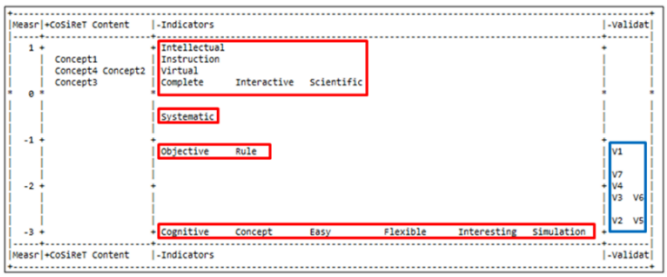


**Figure 7.** The results of the expert assessment using Rasch's Mini-Facets were reviewed from the Wright-maps

Based on Figure 7, the right side is seven validators, namely V1, V2, V3, V4, V5, V6, and V7 (3 physics education experts, 2 media experts, and 2 practitioners). The left is the content of CoSiReT which consists of four concepts. This CoSiReT content is adapted to the findings of misconceptions (already explained at the design stage). The middle part is an indicator of assessment coded with keywords. A total of 15 assessment indicators were coded with keywords.

Aspects of the instructions for use, namely the instructions for the media are clearly stated coded with "Instruction" and learning objectives are clearly stated coded with "Objective". The aspect of language is using language that is following the rules of Indonesian coded with "Rule", conformity with the intellectual and psychological development of "Intellectual" students. The aspect of content presentation, namely CoSiReT includes the completeness and depth of the transverse wave concept coded "Complete", the use of simulations to build student concepts is coded "Simulation", Simulations are useful for making virtual observations coded "Virtual", CoSiReT can change conceptions through scientific explanations coded "Scientific", the process of cognitive learning (oriented towards the construction of students' knowledge) is coded as "Cognitive", coherent and systematic activities are coded as "Systematic", the relevance between the concepts of transverse waves includes four conditions for changing the concept of "Concept". Aspects of appearance include CoSiReT having an attractive appearance and motivating to learn coded as "Interesting", CoSiReT being easy for users to use code as "Easy", CoSiReT being flexible which can be used via laptops and smartphones coded as "Flexible", and CoSiReT is interactive to refute misconceptions students are directly coded "Interactive".

Overall the contents of concept1, concept2, concept3, and concept4 fulfill the assessment of all validators. However, it is necessary to revise concepts1 for intellectually coded indicators, concepts2 and concepts4 for indicators coded intellectually and instructional, and concepts3 for intellectually coded, instructional, and virtual indicators. Improvement of intellectually coded indicators where the content of concepts1, concepts2, concepts3, and concepts4 needs improvement related to suitability with students' intellectual and psychological development. According to validator notes V1 and V7, the content developed is too high-level for high school students, so it needs to be revised. Improvements to coded instruction indicators for concepts2, concepts3, and concepts4, meaning that the V4 and V7 validators ask to clarify the instructions for using CoSiReT. Improved virtual coded indicators for concept3, meaning that validators V1, V2, and V7 ask

to add questions when making observations using simulations. In addition to the indicators mentioned earlier, all CoSiReT content meets the validation indicators.

*Diseminatte*

The CoSiReT trial was implemented in schools. Students are given a pre-post test. The pre-post-test questions used from the MOFI-OTW are four questions (Q1, Q2, Q3, and Q4), which are questions adapted to the misconceptions found in content of CoSiReT. In reducing misconceptions, the categories of conceptions for students analyzed are only the categories of misconceptions. Reducing misconceptions (RM) for each question on the transverse wave is shown in Figure 8.

Based on Figure 8, the percentage of misconception reduction is highly categorized. These results are based on the interpretation of Hake (1999). Overall, the role of CoSiReT reduce misconceptions. This is because the CoSiReT refutation text given can put students in cognitive conflict. It can be concluded that the role of CoSIReT reduces misconceptions concerning the basic concept of transverse waves.

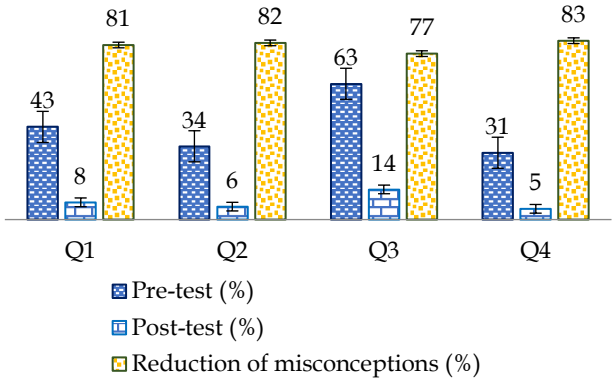


**Figure 8.** The results of reducing student misconceptions for each basic concept of transverse waves after implementing CoSiReT

According to Caleon et al. (2013), refutational text reduces students' alternative conceptions regarding the propagation of wave periods. In obtainment, the addition of computer simulations requires students to make scientific observations (Samsudin et al., 2022; Putri et al., 2021; Samsudin et al., 2020; Wibowo et al., 2017; Surtiana, 2021; Fratiwi et al., 2018). Thus, the process of changing students' conceptions becomes more optimal. Showing virtual scientific investigation can also improve students' understanding of concepts (Lähdesmäki et al., 2022; Paje et al., 2021). Hence, misconceptions are reduced. Students are immediately contradicted by facts when making virtual observations. Furthermore, students are reinforced with scientific explanations. This finding is in concert with Fratiwi et al. (2020) where the combination of conceptual change text (CCT) and computer simulation is changing students' conceptions about Newton's second law.

Regardless, it is unavoidable that students still experience misconceptions, especially regarding the concept in Q3 (relationship of frequency and wavelength). As many as 17% of students still convey that if the frequency increases, the wavelength also increases. Even though this concept is the basic concept of waves. It is possible that misconceptions can be caused by several factors, such as books read, everyday phenomena seen, or intuitive thoughts that are still very attached to students (Mufida et al., 2022). This case needs to be resolved further because understanding the basic concepts is very important in physics (Aminudin et al., 2019). Overall, misconceptions can be reduced to a high category through the role of CoSiReT. These positive findings can be recommended to researchers or practitioners to facilitate learning in reducing misconceptions anywhere and anytime, especially post-Covid-19 pandemic learning where physics learning is less stable.

## Conclusion

In this research, it can be concluded that CoSiReT can be developed and used founded on the 4D research design. In its development, innovation in ReT becomes an interactive teaching material CoSiReT can be used to reduce misconceptions about the basic concept of transverse waves. Based on the results of the Wright-maps analysis assisted by Mini-Facets Rasch software, the judgment's assessment stated that CoSiReT fulfilled twelve assessment indicators. There is a little improvement in the three assessment indicators with the code "Intellectual", "Instruction", and "Virtual". The results of the CoSiReT implementation stated that there was a reduction in misconceptions in the high category. Accordingly, overall, CoSiReT is said to have the maximum role in reducing students' misconceptions concerning the basic concept of transverse waves. This is supported by the integration of computer simulations into refutation texts which requires students to carry out virtual scientific observations. Therefore, researchers and other practitioners are expected to be able to implement CoSiReT in different school areas.

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**Author Contributions**

Research contributions related to "Conceptualization, S.N.M., A.S., I.K., and E.S.; methodology, S.N.M., A.S.; software, S.N.M.; validation, A.S., E.S., I.K., and H.N.; formal analysis, S.N.M., A.S., and E.S.; investigation, S.N.M.; resources, S.N.M., A.S., I.K., and E.S.; data curation, S.N.M, A.S., I.K., and E.S.; writing—original draft preparation, S.N.M.; writing—review and editing, S.N.M, A.S., I.K., E.S., and H.N.; visualization, S.N.M., A.S., and E.S.; supervision, A.S., E.S., I.K., and H.N.; project administration, S.N.M, A.S., and E.S.; funding acquisition, A.S., E.S., I.K., and H.N.". All authors have read and agreed to the published version of the manuscript.

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**Conflicts of Interest**

"The authors declare no conflict of interest."

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