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Physics Student Misconception: Relative Velocity, Time Dilation, and Length Contraction

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Abstract

This study aims to analyze senior high school students' misconceptions on the relativity topics of relative velocity, time dilation, and length contraction. The qualitative descriptive method was used in this study to explain student misconceptions from the student, documents, and observations during problem-solving. Six students take an extra course in an independent learning center to participate in this study. The student was classified as two high, middle, and low levels. The data was collected from student reports, interviews, and observations. The results show a considerable misconception of students' understanding of relativity topics. This study identifies that student misconceptions come from the learning process, resources, and teacher confirmation. Thus, there is a need for attention and remediation regarding the relativity material because it will affect the concept of students to the next level.

Keywords: Physics Concepts; Qualitative Study; Teaching Material; Curriculum

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INTRODUCTION

As a part of science learning, physics focuses on helping students understand the object by two topics: matter and energy. The Indonesian curriculum teaches physics from elementary to high school, while it depends on the chosen course at the university level. For example, at the elementary and junior high school levels, physics is taught as part of an integrated science course, while in high school, it is a separate physics course for the science department.

Physics proves to be quite challenging to learn and requires a relatively high level of intelligence to understand. The study results indicate that some basic skills needed to learn physics are counting skills (Munir, 2022), manipulating and observing (Kontro, 2019), problem-solving (Ince, 2018), and thinking skills (Akmam et al., 2019; Thonney & Montgomery, 2019;

Zakwandi & Istiyono, 2022). These basic skills are inseparable from the characteristics of physics subjects that focus on conditional problems, which in this case requires not relying on one concept to solve existing problems. Between concepts in physics have their respective roles in analyzing a problem. Therefore, when there is a profound misunderstanding on one main topic, it will have an impact on the following topic. However, the fact often encountered today is the emergence of alternative concepts owned by students and tend to be different from concepts accepted by experts or scientifically.

Many factors can cause misconceptions in physics learning (Febrianti et al., 2019; Hidayatulloh et al., 2015). For example, a topic that many misconceptions about in schools are relativity. The concepts in relativity material require a comprehensive understanding and have different characteristics from classical physics concepts that are widely studied at the elementary to the middle school level.

The misconceptions are student errors in understanding a concept. The misconception happens because students cannot relate the phenomena in everyday life with the knowledge gained at school (Treagust, 2006). Brown (1992) describes the misconception as a naive view and defines it as an idea not following the currently accepted scientific understanding. Sarwadi & Shahrill (2014) found misconceptions to be errors and incorrect relationships between concepts. Suparno (2013) describes misconceptions as an inaccurate understanding of concepts, using wrong concepts, wrong classification of examples, confusion of different concepts, and hierarchical relationships of incorrect concepts.

In studying physics, understanding concepts is an absolute requirement to achieve success. Fuentes et al. (2014) explain that concepts are essential for understanding all physical phenomena that occur so that they can solve physics problems that exist in everyday life and theoretical physics problems at school. The causes of misconceptions, according to Suparno (2013), are divided into five groups, and Nengah Mahara provides the same summary as shown in Table 1 (Mintzes et al., 2001; Suparno, 2013).

Table 1 The causes of misconception

Main reason	**Specific Reason**
Student	Preconception, associative thinking, humanistic thinking, incomplete reasoning, wrong intuition, student cognitive development stage, student ability, student interest in learning
Teacher	Does not master the material, is not a graduate from the field of physics, does not allow students to express ideas, teacher-student relations are not good
Text Book	Wrong explanations, misspellings, especially in formulas, book writing level, is too high for students, do not know how to read textbooks, science fiction books and cartoons often have misunderstandings
Context	Student experiences, different colloquialisms, wrong discussion partners, beliefs and religions, wrong explanations by parents/others, student life contexts (TV, radio, wrong movies, feelings of pleasure, freedom, or pressure)
Learning Process	The results contain lectures and writing directly into mathematical form, do not reveal misconceptions, do not correct homework, the analogy model used is inaccurate, and the demonstration model is narrow.

Several facts put forward by misconception researchers conclude that misconceptions are difficult to correct. Often, simple questions can be answered, but misconceptions arise on more complex questions without realizing it. Regression often occurs so that misconceptions cannot be eliminated (Jusniar et al., 2020). Although it is difficult to overcome this misconception, there are still many ways that can be done to overcome or at least reduce students' misconceptions. Effective and efficient ways of overcoming misconceptions are indeed challenging to find. However, several steps can be taken, as Brown (1992) proposed: The first step is to detect student preconceptions by knowing what is already in the student's head before the Teacher starts teaching. The second step is to design a learning experience that starts from these preconceptions and then refines the parts that are already good and corrects the parts of the wrong concept.

Based on several facts regarding misconceptions in physics concepts, this is what is interesting for researchers to identify physics misconceptions related to relativity in students. This study is expected to be an initial reference for optimizing physics learning on relativity topics in schools.

METHOD

In this study, the sample used was class XI students totaling six students with a female gender aged 15 years. Triangulation is used in qualitative research to check and establish validity by analyzing from various perspectives. Validity in quantitative research is seen based on the accuracy of a measuring instrument, namely an instrument. Validity in qualitative research refers to whether the findings accurately reflect the situation and are supported by evidence. Thurmond (2001) defines triangulation as a combination or combination of various methods to examine interrelated phenomena from different points of view and perspectives.

This research uses the descriptive qualitative method. According to Sugiono, qualitative Research is Research where the researcher is placed as the key instrument. The data collection technique is combined, and the data analysis is inductive (Creswell & Poth, 2016; Devers & Frankel, 2000). According to Holloway & Wheeler (1996), qualitative research produces and processes descriptive data, such as the transcription of interviews and observations.

An interview is a communication between two people involving someone who wants to get information from another person by asking questions based on a specific purpose. Interviews are divided into two, namely unstructured interviews and structured interviews. Unstructured interviews are often called in-depth, intensive, qualitative, and open-ended interviews. Meanwhile, structured interviews are often also called standardized interviews, in which the structure of the questions has been predetermined (usually written) with answer choices that have also been provided (Byrne, 2001)

Table 2 Question guided

No.	Question Guided
1.	Understanding Relativity
2	Definition of relative velocity
3	Definition of time dilation
4	Definition of length contraction
5	Problem-solving

Researchers conducted interviews with students related to understanding the concept of relativity material. Researchers used six samples of female students aged 15 years. The six students were grouped into three groups. The first group consisted of two students with high knowledge scores. The next group

consisted of two students with average knowledge scores. The last group consisted of students with low knowledge scores. All students were given the same open interview treatment regarding understanding the concept of relative velocity, time dilation, and length contraction. After conducting open interviews with all samples, the researchers could see the misconceptions that occur in relativity related to relative velocity, time dilation, and length contraction.

RESULT AND DISCUSSION

Based on the analysis of open interviews conducted by researchers with students, misconceptions about relativity material on relative velocity, time dilation, and length contraction are still found. The open interview conducted by the researcher was in the form of questions related to understanding the concepts of relative velocity, time dilation, and length contraction, along with questions related to these materials. An example of a question interview provides in Table 3.

Table 3 Sample of question

No	Question
1	Could you tell me what relativity is?
2	Could you tell me what the relativity velocity is?
3	Does the time dilation is a part of relativity? If yes, how does the time dilation happens? If not, what is caused the time dilation?
4	Can the length change while the object is moving?

This study shows there are still misconceptions about the relative velocity material, even in students with high knowledge scores. The analysis of student answers proves that students are still confused about the difference between the velocity of light and the relative velocity of objects when working on the researcher's questions. These students are still wrong in determining the direction of objects and the velocity. The wrong determination can be overcome by providing a firm and structured concept so students can distinguish between relative velocity and the velocity of light.

Efforts to try to overcome these misconceptions are by providing direct explanations to students. As a result, students realized that they had experienced misconceptions. However, after working on the new questions, the students again encountered errors in doing the work. This proves that misconceptions occur not only in the conceptual part but also in the mathematical aspect. It is proven by the responses given by students when doing mathematical calculations that do not lead to precise numerical operations, especially in solving time dilation problems. This finding proves that the problem of misconceptions cannot be solved at the end of the related concepts but must also be traced to the initial aspects that cause misconceptions. (Li, 2008; Master-Khodabakhsh, 2020).

Another factor that is indicated to cause misconceptions is the availability of textbooks. Researchers found many books that wrote different versions of the time dilation equation so that students were confused about how to use it. This is not wrong in principle, and it is just that students who are just learning about time dilation need to understand each form of equation fully. The role of the facilitator is very necessary in this case. The facilitator, i.e., the Teacher, is prepared to convey directed and solid material that needs to be through the unification of the formulas used. So that even though there are many versions of writing equations, students will not be confused about using these formulas.

The delivery of the material is attempted to show which time is on earth and which time is in outer space. After

that is done, the students' misconceptions are finally reduced. It is proven that when they are given treatment by working on the questions, they are correct in doing the questions. Students still have misconceptions regarding the actual length and relative length in the length contraction material, so errors are still found in doing the questions. In this case, students need to be given an accurate picture of what is meant by actual length and relative length (Chiriacescu et al., 2019; Prado et al., 2020). The Teacher's explanation should begin with explaining something that moves in relative terms, the beginning. Furthermore, students are given understanding and given examples in daily life. When students begin to understand, the Teacher can vary the stimulus in the form of new questions so that they can do the questions correctly.

Next on the sub-concept of relative speed. The study results show that there are still many misconceptions about the relative speed material in students whose knowledge scores are low. They still have not mastered the concept and still lack understanding of the material. For them, the relative speed is the same as the speed in uniform linear motion and acceleration linear motion, so when they are asked a question related to relative speed, it is still fatal in working on the problem. (Mabile, 2019; Moylan, 2022). Then in the time dilation material, students also found misconceptions about the concept. They speculated that the time everywhere, both on earth and in space, was the same.

Regarding working on problems related to relativity, there was no difference in ability between the three groups of students who showed the same error in working on time dilation questions. Then on the long contraction material, students with low knowledge scores still have misconceptions. They assume that the length is the same, both relative and actual, but an understanding of the concepts related to this is still lacking, so when given treatment, they work on questions related to this material, but they are still wrong in doing the questions.

Understanding the concept needs to be done gradually for students whose knowledge scores are low—giving different and gradual treatment based on the ability of different students. Some students take a long time to understand, so the Teacher takes a long time to explain to students. The complexity of the material presented can gradually increase from easy to complex. After being given this treatment, they could do the questions correctly. Moreover, given a book source that is easy to understand.

CONCLUSION

Based on the research results, it can be concluded that misconceptions still occur in class XII students regarding relativity related to relative velocity, time dilation, and length contraction. The students with high knowledge scores still found misconceptions about the relative material velocity, time dilation, and length contraction. Most of them occur in an immature understanding of the concept, a less than optimal teacher explanation, and a lack of understanding of the concept that causes this misconception to occur so that after being given conceptual consolidation, misconceptions can disappear, and students can work on questions related to the material correctly. In addition, books are needed that students can understand easily so that understanding concept can quickly enter their minds. There are still learning resource books that make students confused in learning them.

In the group of students with moderate knowledge values, there are still misconceptions about the relative material velocity, time dilation, and length contraction. This is also seen in understanding concepts related to poorly understood material. It still needs a more

intensive explanation from the Teacher. In addition, students need learning resources that students easily digest to help them understand the material described. In this group, misconceptions are resolved with intensive teacher explanations and mastery of concepts.

Students with low knowledge scores still found misconceptions about the relative material velocity, time dilation, and length contraction. This is due to a common understanding of concepts and a basic understanding of this material. These students have a reasonably weak understanding, so they still need to explain the material slowly and thoroughly and are given books that are easy to understand the concept. By being given intense treatment, students with low knowledge scores can conquer misconceptions about relative velocity, time dilation, and length contraction, even though it takes a long time because they still need a long time to understand concepts.

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