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Identification of Misconceptions with a Three-Tier Diagnostic Test on Elementary School Students' Force Topic

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Abstract: Misconceptions must be addressed immediately because they can cause failure to achieve learning objectives. The purpose of this study was to identify misconceptions, determine the level of misconception categories in the concept of force, such as friction, spring force, and muscle force, and determine the science learning process in the material of force. This study has a uniqueness in the form of subjects used, namely schools participating in the Kampus Mengajar 7 program, where the literacy and numeracy conditions of students are relatively low. This study uses a qualitative approach, with research subjects being students and teachers of grade IV at one of the elementary schools in Blitar City. The data collected include the results of the Three-Tier Diagnostic test to identify misconceptions, interviews with teachers, and documentation. Data analysis methods consist of data reduction, data presentation, and drawing conclusions. The results of the study showed that there were misconceptions in the material of force in science learning, especially in friction, spring force, and muscle force. Of the three concepts of force, there are still misconceptions in the material of force based on its type, such as spring force and friction having a high category and muscle force with a low category. These findings highlight the need for more hands-on experimentation and contextualized instruction in elementary science education to reduce misconceptions. Meanwhile, in the science learning process, teachers use a direct instruction model with a few experiments.

Keywords: Elementary School; Force Material; Misconception; Three-Tier Diagnostic test

Introduction

The main success factor in achieving a learning goal is understanding the concept. Therefore, teachers can conduct a diagnostic assessment to determine the extent of students' understanding of the concept. This diagnostic assessment is carried out to find out whether a concept held by students is wrong (misconception). This happened because misconceptions can occur in all situations, including learning. Misconceptions are also the formation of wrong concepts that occur when students connect one idea with another idea or when they combine new ideas with ideas that already exist in their minds (Suprapto, 2020).

Diagnostic assessment to measure the extent of misconceptions in students is very important to do. However, identifying and addressing misconceptions is not a priority for most teachers; they are too busy teaching (Rasul et al., 2019). This also happened in the preliminary study of this research, where teachers had never given diagnostic assessments to students. If this assessment is carried out, teachers can build better relationships with students because they know the problems experienced by students. If the

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communication relationship between teachers and students is less effective, it can cause misconceptions (Erman, 2017). There are many types of diagnostic assessments to measure misconceptions, such as two-tier tests, three-tier tests, four-tier tests, etc. This study used a three-tier test diagnostic assessment.

The three-tier test is a type of diagnostic test that is used to differentiate between students who lack knowledge (do not understand the concept) and students who experience misconceptions (Haryono & Aini, 2021). A three-tier test has three levels; the first asks students' knowledge of the concept in the form of multiple-choice questions. The second level is the students' reasoning from the answering process at the first level in the form of reasons for choosing the answer. The third level is a question about students' confidence in the answers at the first and second levels (Natalia & Sudrajat, 2023). Three-tier tests can help students find the truth and reasons behind the information presented so that students can solve problems using the information accompanied by appropriate reasons (Sari et al., 2024). The results of the three-tier test can be used as a basis for planning further action for students.

One of the science materials that can be tested for misconceptions is force material, such as muscle force, friction force, and spring force, because this material is very close to students' daily lives. Based on the results of interviews with the homeroom teacher of grade 4 of an elementary school in Blitar, students have been taught force material but have not had the opportunity to practice. In addition, in learning force material, teachers have not had the opportunity to conduct diagnostic tests, so teachers do not know the level of students' understanding of the concept of force.

Previous research has discussed many misconceptions on force material, but this research has its own uniqueness. In previous research, the first uniqueness is the use of an instrument (Two-Tier Multiple Choice) to detect misconceptions on force material, such as in the study Ngazizah (2024). While in this study using a three-tier test. The three-tier test is considered more accurate than the two-tier test because it has more complex stages of misconception. In addition, the study Fabilla, Wijayanti, and Cahyadi (2023) also used an instrument (Three-Tier Test) implemented in elementary schools, where a higher percentage of misconceptions was found compared to students who understood the concept well. This finding is also the same as one of the results in this study. However, this study also identified the science learning process in the material of force. This is one of the unique things in this study.

Meanwhile, the study Danil et al., (2023) analyzed misconceptions through essay questions, while this study used multiple choices with a tree-tier diagnostic test. The diagnostic techniques used in detecting misconceptions are different; this could be a novelty in this study. Of the three studies, the samples used have their own differences in this study.

Previous studies tend to pay less attention to the characteristics or specific criteria of elementary schools as research subjects. In this study, the subjects selected were elementary schools that were targeted by the Kampus Mengajar Program, a program aimed at schools with low literacy and numeracy levels. The school sample in this study was selected because in the same year as the research was conducted, the school participated in the 7th batch of the Kampus Mengajar Program. Therefore, this study applies a three-tier diagnostic test rather than a four-tier test or a more complex misconception diagnostic test in identifying elementary school students' misconceptions on force material because the sample conditions in this study have a low literacy level. This certainly makes students understand the test given better, and the results of this test are better than the two-tier test. Based on the background that has been described above, this study clearly aims to answer the following research problem formulations: identifying misconceptions that occur in students in understanding the concept of force such as friction, spring force, and muscle force; to what extent these misconceptions occur in students; and how the science learning process on force material is currently applied in the classroom.

Method

This study uses a qualitative approach that aims to identify misconceptions in each number and to determine the level of misconception categories for each force concept, such as friction force, spring force, and muscle force. This study was conducted in one of the public elementary schools in Blitar City, which is a school in the Kampus Mengajar Batch 7 program. The subjects of this study were grade IV students who were selected purposefully, as well as grade IV teachers who would be interviewed to obtain more in-depth information related to the learning of force material in the class.

The data collection techniques used were written tests, interviews, and documentation. Snippets of interview transcripts conducted with teachers have been translated into English. The main instrument in data collection was in the form of three-tier multiple-choice questions (a three-tier diagnostic test) and had been tested for validity, reliability, discriminating power, and difficulty level. Validity and reliability are carried out non-empirically and empirically.

Non-empirical validity is carried out by content validation. Content validation is carried out in a manner similar to that adopted by Widoyoko in 2009 in the article Lestari et al., (2024). Validation was conducted by two science experts with a focus on elementary school teacher education. The validation results obtained were 5 yaks in the "very good" category. Then the reliability was tested using the percentage of agreement. According to Borich in 1994, the percentage of agreement was said to be reliable if it was obtained ≥ 75% (Wicaksono et al., 2020). This research has a value of 100%. This is a question that is worthy of being tested on students by means of empirical validation.

Empirical validity is carried out by testing validity, reliability, discrimination power, and level of difficulty. All of these tests were conducted using SPSS 26. In the validity test, the researcher used a significance value of ≤ 0.05 and had been valid for 20 questions. Then, the questions were tested for reliability using the r value (cronbach's alpha). The reliability value was also above 0.7. This means that the questions are reliable (Sajidan et al., 2024). Then, the 20 questions were tested for their discriminatory power to obtain the questions used in this study.

This instrument consists of three levels: the first level contains multiple-choice questions related to style material, the second level asks students to choose the reasons for the answers they choose, and the third level measures the level of students' confidence in their answers (Permadani et al., 2022). The instruments in this study have been tested for validity, reliability, difficulty, and discriminatory power. The data obtained from the written test were then analyzed and categorized based on Table 1. Table 1 explains the steps to categorize students' answers so that their level of misconceptions can be identified.

Table 1. Categorize of Misconceptions

Answer	Reason	CRI Value	Category
True	True	>2.5	UC
True	True	<2.5	UCBS
True	False	>2.5	M
True	False	<2.5	DUC
False	True	>2.5	M
False	True	<2.5	DUC
False	False	>2.5	M
False	False	<2.5	DUC

Source: adopted from Dewi & Wulandari (2021)

Information:

UC : Understand the Concept
UCBS : Understand the Concept But Not Sure
DUC : Don't Understand the Concept
M : Misconception

$$P = \frac{F}{N} X\ 100\% \quad (1)$$

Information:

P : Percentage of student answers for each question item
F : Frequency of student answers for each question item
N : Number of students
100% : Constant number

The results of the percentage calculation are then described in the form of a description. Analysis is carried out on each question item to identify misconceptions in students and to group the level of misconception according to the percentage obtained. The category of the level of student misconception is explained based on the percentage obtained. Table 2 shows the category of the level of student misconception.

Table 2. Category Percentage Level of Misconception

Percentage	Category
0-30%	Low
31-60%	Currently
61-100%	High

Source: Wilantika et al., (2018)

Result and Discussion

Result

The first aim of this research is to identify misconceptions about each number. This identity is written in Table 3.

Table 3. Results of Identifying Criteria for Each Question

Sub Concept	Question Number	UC	UCBS	DUC	Criteria M
Muscle Force	1	70%	0%	0%	30%
	2	70%	0%	0%	30%
Frictional Force	3	40%	0%	0%	60%
	4	20%	0%	0%	80%
	5	30%	0%	10%	60%
Spring Force	6	10%	0%	20%	70%
	7	20%	0%	10%	70%
Average		37,14%	0%	5,72%	57,14%

In Table 3, the majority of students experience misconceptions. Almost all the questions were tested. Question number 4 has the greatest percentage of misconceptions. Meanwhile, there are no students who understand the concept but are not sure. So, there are still misconceptions about the force material in each number tested.

Researchers divide this research into three sub-concepts. Then, researchers chose several numbers that had the highest percentage of misconceptions. The first sub-concept in numbers 1 and 2 has the same degree of misconception. In the second sub-concept, number 4 has

a high degree of misconception. In the last sub-concept, numbers 5 and 6 have the same percentage of misconceptions. The following is an explanation of the misconceptions about each concept with the same or largest percentage of misconceptions.

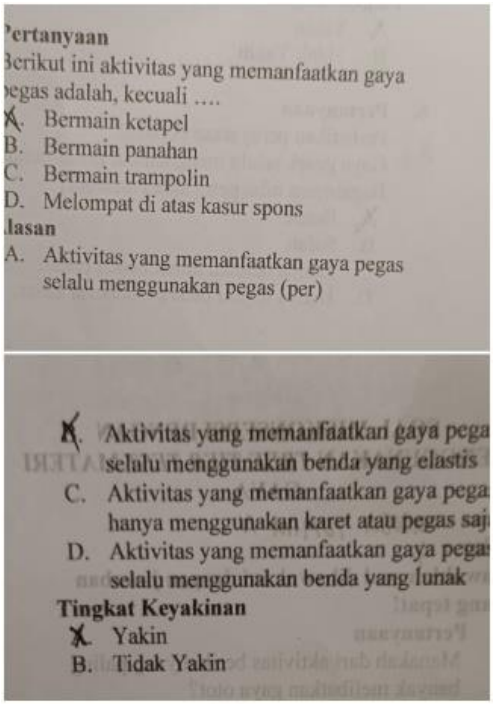

Figure 1. Question number 6

Most misconceptions regarding the sub-concept of spring force occur in questions number 6 and 7. Question 6 is that students are asked to determine activities that utilize spring force. Many students answered activities that utilize spring force. This is because students ignore the word "except" in the question. This can be seen from the reason chosen by the students is the correct reason, namely the spring force occurs in elastic objects. Therefore, it can be said that students already understand the concept of spring force but have not read the questions carefully. Apart from that, the reason students experience misconceptions could be because students have difficulty understanding spring forces in the context of activities. Students assume that the spring force is only used on objects that have a large spring system, such as archery and trampolines where the objects are large. Thus, students experience misconceptions because they are not careful in reading the questions and have difficulty understanding spring forces on small objects.

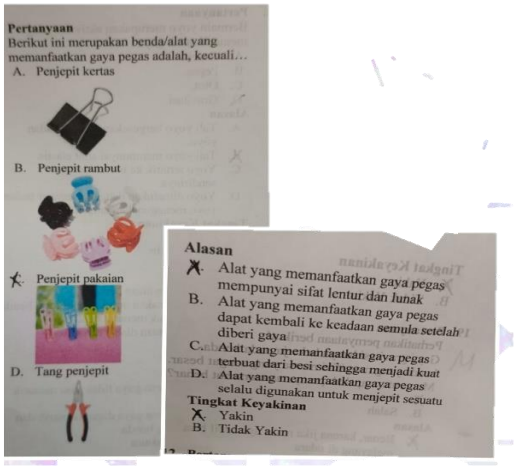

Figure 2. Question number 7

Question number 7 is that students are asked to determine a tool that utilizes spring force. Most students answered that the tool that uses spring force is a clothes peg. This can happen because students focus on the shape of the object. In the answer choices, all tools have almost the same mechanism, namely clamping an object. The difference is that in a paperclip, the part that can bend is thin black metal. This indicates that objects that utilize spring force have flexible and soft properties. This is in accordance with the reasons chosen by students. Students assume that tools that utilize spring force are tools that are flexible and soft. On clothes pegs, students see that the tool does not have flexible and soft parts. Students misjudge the function of the spring force, which depends not only on how flexible and soft the object is but also how the object must return to its original shape after being applied force. Thus, students experience errors in understanding the concept of spring force, namely that spring force occurs in elastic objects and can return to its original shape after being applied force.

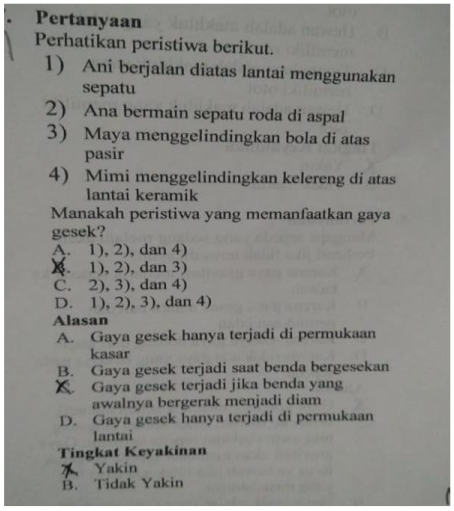

Figure 3. Question number 4

The most common misconceptions regarding the sub-concept of friction force occur in question number 4. Question number 4 is that students are asked to choose an event that uses friction force. Many students exclude that the event of rolling marbles on ceramics is an example of friction. They think that friction is the force that prevents an object from moving to rest, such as when braking a bicycle. So in the concept that is built, the surface of an object that uses friction is a rough surface, and the event being exemplified must end with the object becoming stationary.

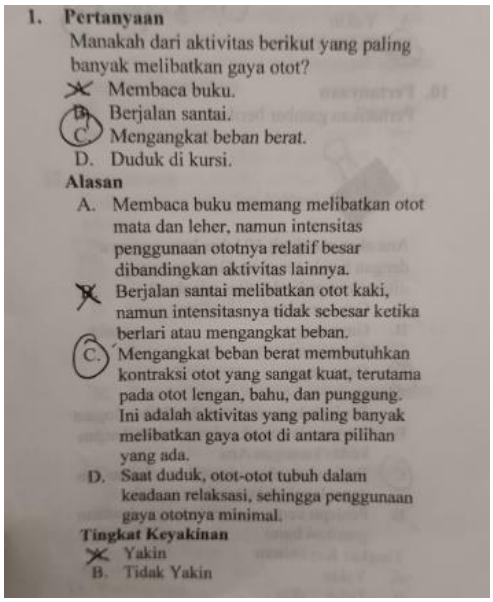
1. **Pertanyaan**
Manakah dari aktivitas berikut yang paling banyak melibatkan gaya otot?
A. Membaca buku.
B. Berjalan santai.
C. Mengangkat beban berat.
D. Duduk di kursi.
Alasan
A. Membaca buku memang melibatkan otot mata dan leher, namun intensitas penggunaan ototnya relatif besar dibandingkan aktivitas lainnya.
B. Berjalan santai melibatkan otot kaki, namun intensitasnya tidak sebesar ketika berlari atau mengangkat beban.
C. Mengangkat beban berat membutuhkan kontraksi otot yang sangat kuat, terutama pada otot lengan, bahu, dan punggung. Ini adalah aktivitas yang paling banyak melibatkan gaya otot di antara pilihan yang ada.
D. Saat duduk, otot-otot tubuh dalam keadaan relaksasi, sehingga penggunaan gaya ototnya minimal.
Tingkat Keyakinan
A. Yakin
B. Tidak Yakin

Figure 4. Question number 1

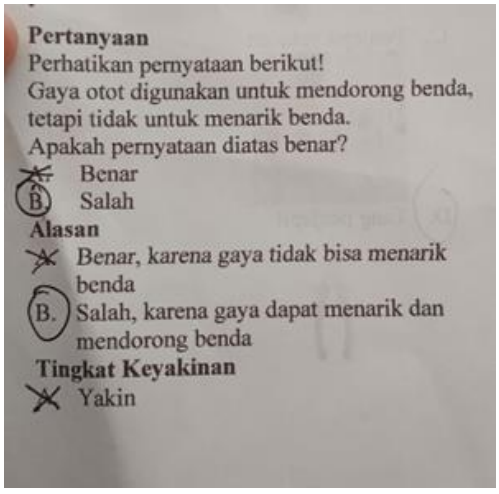
Pertanyaan
Perhatikan pernyataan berikut!
Gaya otot digunakan untuk mendorong benda, tetapi tidak untuk menarik benda.
Apakah pernyataan diatas benar?
A. Benar
B. Salah
Alasan
A. Benar, karena gaya tidak bisa menarik benda
B. Salah, karena gaya dapat menarik dan mendorong benda
Tingkat Keyakinan
A. Yakin

Figure 5. Question number 2

Questions 1 and 2 have the same percentage of misconceptions, namely 30%. In this number, students who understand the concept also have the same percentage, namely 70%. Meanwhile, 0% of students understand the concept but are not sure, and 0% do not understand the concept. In question number 1, students are asked to identify several activities that involve muscle force in everyday life. Meanwhile, in question number 2, students are able to judge whether a statement is true or false regarding the concept of muscle force. The concept of muscle force is indeed easier than other force concepts such as spring or friction. Muscular force involves muscle movements that make the human body do something. So muscle force always involves humans in changing shape, direction, etc. an object. For example, in questions numbers 1 and 2. Meanwhile, friction and spring forces have different characteristics for each object.

Then the second aim of this research is to determine the level of misconception categories for each force concept, such as friction force, spring force, and muscle force. The results are written in Table 4 as follows.

Table 4. Percentage of Misconceptions for Each Style Sub-Concept

Sub Concept	Criteria				Categories of Misconception Levels
	UC %	UCBS %	DUC %	M %	
Muscle Force	70	0	0	30	Low
Frictional Force	30	0	3.33	66.67	High
Spring Force	15	0	15	70	High

In Table 4, most students also experience misconceptions. In general, many students experience misconceptions about spring force, even though they have the same level of misconception about friction force. Meanwhile, muscular style has the lowest percentage of misconceptions, and all students do not have the criteria for understanding the concept but are not sure and do not understand the concept. So there are still misconceptions regarding force based on its type, such as spring and friction forces in the high category and muscle forces in the low category.

The third aim of this research is the process of learning science on stylistic material. This third result was obtained by conducting interviews with teachers regarding the science learning process carried out. The teacher explains style material using direct instruction using a few small experiments. Small experiments that have been carried out include pushing and pulling a table. Apart from that, the teacher also hasn't done any other experiments. This was obtained from the results of interviews with class teachers who stated that.

Teacher: "*... style is the most pushing table*"
Researcher: "*Yes*"
Teacher: "*Interesting that. For example, the simple one is just that. If it's a spring, it's not*"
Researcher: "*ooo, just up to the muscle force*"

Teacher: "*Yes, muscle force, spring force, gravitational force. But I have explained everything. It's just that the practice only encourages the same interesting, that's it.*"
Researcher: "*If that's the case. It means that the media is a concrete object, sir, yes. With desks in the classrooms*"
Teacher: "*yes…*"

Discussion

This research has three main purposes. The first purpose of this research is to identify misconceptions about each number. The results of this research are that misconceptions are still found regarding the topic of force in each number. The second purpose of this research is to determine the level of misconception categories for each force concept such as friction force, spring force and muscle force. The results of this research are that there are still misconceptions regarding the topic of force. The highest to lowest misconceptions start from spring force, friction and muscles. Spring and muscle forces have a high misconception category. Meanwhile, muscle force has a low misconception category. These results are also in accordance with several previous research findings.

In previous research, there were still misconceptions about force (Danil et al., 2023; Nasution et al., 2021; Ngazizah 2024). In fact, in two of the three previous studies, spring force also occupied the highest misconception category (Nasution et al., 2021; Ngazizah 2024). Where this result is also the same as this research. Apart from similarities, there are several other differences. Some of the main differences between this research and the three studies are the data analysis used to determine student misconceptions. Even though the data analysis techniques used are different, the results can still show that misconceptions about force are still found in the elementary school domain. Apart from that, this research also understands the process of learning science in the topic of force.

The third research purpose is to find out the science learning process in the topic of force. The teacher uses a direct instruction model in the topic of force. The rise of misconceptions regarding the main force of the spring force is very natural, because teachers only use direct instruction when providing lessons on frictional force. Several studies show that direct learning can indeed improve learning outcomes (Aliyah, 2022; HR, 2024; Priyanto, 2020; Suryadi, 2022; Tari & Sari, 2024). However, this is certainly not good for use, especially for children aged 10 years, who still need concrete objects to make it easier to understand the topic (Babakr et al., 2019). Therefore, the help of concrete objects can help students understand concepts and complete learning outcomes. The teacher provides information that he has carried out practice in the form of pulling and pushing the table. This is proof that providing direct examples can minimize misconceptions. Pushing and pulling involve muscle forces, where misconceptions about this topic are the smallest compared to other sub-forces. As a result, students experience misconceptions about force.

This research is unique in the subjects used. Researchers used one of the schools that had been part of the Kampus Mengajar Batch 7 program. Schools participating in this program are those identified as having low literacy and numeracy skills. Literacy and numeracy are one of the main keys to understanding concepts. This certainly influences the magnitude of misconceptions among students. The results of this research also show that each number has misconceptions. Apart from that, every student also experiences misconceptions.

Misconceptions among students must be handled properly. If this is not handled properly, it will affect students' acceptance of new concepts related to force. Often, misconceptions are very difficult to change because concepts have remained firmly entrenched based on the construction of knowledge through experience. For this reason, an alternative way that can be used to change misconceptions is to construct new concepts that are more suitable for explaining experiences. Based on this, there is a need for diagnostic tests and justification of inappropriate concepts (Jumini et al., 2017). When giving diagnostic tests, it should be adjusted to the student's condition. For instance, international schools can use a minimum of four tier tests. Several diagnostic tests, such as the four-tier test, five-tier test, six-tier test, and others, are effective in detecting misconceptions (Azizah et al., 2022; Kiray & Simsek, 2021; Putra et al., 2020; Utari et al., 2021).

Conclusion

The purposes of this research is to identify misconceptions, determine the level of misconception categories in the concept of force, such as friction force, spring force, and muscle force, and determine the science learning process on the topic of force. In the identification process, there are still misconceptions about the concept of force. Meanwhile, there are still misconceptions regarding force based on its type, such as spring and friction forces in the high category and muscle forces in the low category. Lastly, in the science learning process, the teacher uses a direct instruction model with a few small experiments.

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The authors declare no conflict of interest.

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