Journal of Science Education Research
Journal homepage: https://journal.uny.ac.id/index.php/jser/index

ISSN: 2597-9701

JSER

Evaluating Secondary School Students' Conception of Force and Motion Using a Four-Tier Diagnostic Test

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Keywords
Assessment, Force and Motion, Four-Tier Diagnostic Test, Misconceptions, Science Education, Middle School Students, Students' Conception

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Abstract

A major problem in education is misconceptions. The Four-Tier Diagnostic Test is one way to identify misconceptions. Since no research uses the Four-Tier Diagnostic Test to assess force and motion, the particular study aimed to investigate students' conceptions of force and motion topics by using a four-tier diagnostic test with secondary school students and to identify the concept of force and motion topics about which most students hold misconceptions. The instrument was developed through several steps, including a preliminary study, content validity with three experts, construct validity, and reliability, resulting in 17 questions from an initial 28 questions. This research evaluated 174 students using a cross-sectional survey design and convenience sampling. The research shows that the students' conceptions are 27.92% Scientific Knowledge, 27.92% False Positive, 6.76% False Negative, 18.59% Misconceptions, and 23.9% Lack of Knowledge. Most students have misconceptions about displacement, Newton's law, and vectors. Also, this research included a semi-structured interview with a teacher who revealed some reasons the students demonstrate these categories of conceptions. The findings implied that the scientific knowledge conceptions of students are important, especially in physics, and teachers find the effective teaching strategy for students to increase their scientific knowledge.

History
Received:
February 13, 2025

Revised:
July 12, 2025

Accepted:
September 1, 2025

How to cite:
Saputra, W. T & Rusyati, L. (2025). Evaluating Secondary School Students' Conception of Force and Motion Using a Four-Tier Diagnostic Test. *Journal of Science Education Research,* 9(2), 138-151. doi:https://doi.org/10.21831/jser.v9.i2.83165.

INTRODUCTION

Physics is an important course in school because it has contributed to the development of technology (Eraikhuemen et al., 2014). Some topics learned by students in physics are force and motion, which are fundamental concepts (Nie et al., 2019). The force and motion topics were learned by students up to the high school level. There are a lot of materials on force and motion, for example, gravity, friction, vectors, and mechanical energy. Students should have the correct concept in learning force and motion at school. Diagnosing misconceptions about force and motion at the secondary school level is important before they learn advanced physics.

A major issue in education is misconceptions, particularly in the study of physics, which places a strong emphasis on conceptual comprehension. (Diani, 2018). The school curriculum has an impact on misconceptions (Svandova, 2014). An explanation for reasons why students performs poorly in scientific classes is that many of them have incorrect or misguided ideas about science. Students at all levels of education are affected by the issue of science misconceptions, which have become widespread (Tompo et al., 2016). A student's misconception is the understanding that occurs when the student's conception of a topic is different from an expert's perception (Wijaya et al., 2016). One of the causes of misconceptions is that students have difficulties understanding the concept, which will affect the students' ability to apply the concept (Yuberti et al., 2020). It must be addressed before they start with either different or related topics (Suliyanah et al., 2018). Moreover, the textbooks may also be one of the causes of the misconceptions. The textbooks serve as the references for teachers and students in the teaching-learning process. Since the content of the textbooks is difficult, it leads to misconceptions (Kılıç, 2007). Misconceptions could be caused by the students' understanding before their formal learning, as well as their prior knowledge. A good educator should reduce the potential emergence of misconceptions in their students (Wijaya et al., 2016).

The misconception is not occurring in the students, but it was occurring in physics teachers at secondary school. They do not have an adequate conceptual understanding of force and motion at the secondary school level (Eraikhuemen et al., 2014). If the teacher does not understand the concept, the student will not understand the force and motion topic. It is either a misconception, partial understanding, or a lack of understanding of the concept. According to Istiyono and Colleagues (2023), teachers can use diagnostic tests to identify students' learning problems or difficulties. By identifying students' misunderstandings, diagnostic tests can also be used to organize subsequent attempts to correct them. Eryilmaz (2002) used an effective method to reduce misconceptions about force and motion through conceptual mapping and conceptual change discussions with physics teachers and high school physics students. The misconceptions assessed by the Force Concept Inventory served as a diagnostic tool for pre-service teachers on the topic of force and motion (Bayraktar, 2009). The Force Concept Inventory was used with the Force and Motion Conceptual evaluation, and applied the network analytic techniques to explore the structure of the incorrect answers to the Force Concept Inventory to reduce misconceptions (Wells et al., 2020).

Several diagnostic tests could recognize the misconception. The most common tests used are interviews, open-ended questions, multiple-choice questions, and multiple-tier tests. A tool that identifies the students' misconceptions is multiple-choice tests and interviews to find out the students' conceptual understanding, analyzing primary school students about the concept of force and motion (Sari et al., 2019). In the interview, the researchers reveal the students' misconceptions and identify them through content analysis, discussion with the teacher, and personal experience (Reshmi & Joseph, 2015). By open-ended conceptual questions in interviews, the result identifies the misconceptions, but not specifically (Montfort et al., 2007). Open-ended questions offer a more complete understanding of the learning process. For example, open-ended questions to determine the concept of the heart and its function, with a description and a drawing of the part of it.

The multiple-tier test not only assesses the conceptual understanding of the students but also assesses the confidence of the participant in answering the questions. The two-tier test only provides the ability to detect the conception of correct answer. However, incorrect reason (false positive) and incorrect answer, and correct reason (false negative) and a two-tier diagnostics test could not completely assess the students' misconceptions because of uncertainty in answering questions, resulting from the researcher's inability to determine whether a student's answer is guessing or real understanding (Gurel et al., 2015). Unlike two-tier tests, which merely indicate whether a wrong response is the result of misconceptions, the three-tier test can differentiate between a misconception and a lack of knowledge (Peşman & Eryilmaz, 2010). There was a convincing change in the students' understanding of the concept and in their confidence between the two-tier and the three-tier system (Yusrizal & Halim, 2017).

A multiple-choice test, like a four-tier diagnostic test, is convenient for diagnosing the misconception since it covers the confidence levels in both answers (Gurel et al., 2015). Also, it has four levels of multiple-choice questions for the students to answer. The Tier 1 has four options with one correct answer and three distractors. Tier 2 has two options, which indicate the level of confidence the student has in their answer in the first tier. The Tier 3 test is the reason for the student's answer. Then, Tier 4 has two options about the confidence level of students' answers in Tier 3. The Four-Tier Diagnostics test has more benefits than the three-tier test or the two-tier test because it could detect the lack of knowledge from the confidence in answering the question, and the reason (Kaltakci-Gurel et al., 2017).

Previous research has used several diagnostic tests to assess the students' conceptions. A two-tier diagnostic test that assesses students' misconceptions about science concepts, such as biology, chemistry, and physics, for high school students and prospective science teachers, identifying those with better conceptual understanding and fewer misconceptions (Soeharto & Csapó, 2022). The next multiple choice higher than a two-tier diagnostic test, is a three-tier diagnostic test. A three-tier diagnostic test was used to assess the students' misconceptions and investigate the correlation between confidence levels and misconception scores about force and motion at the high school level (Turker, 2005). Next, the multiple-tier test to assess the students is a four-tier diagnostic test, used in this study. The Four-Tier Diagnostic Test aims to test the conceptions of the prospective science teacher about the liquid pressure topics (Taban & Kiray, 2022). Also, it assesses the students at the university level by developing the test items from validity and reliability to find out the students' conception of the general concepts of biology (Prayitno & Hidayati, 2022). A four-tier diagnostic test embedded with a certainty of response index (CRI) to identify the misconceptions about fluid concepts. The CRI aims to identify the category of the confidence, rating scale from 0 to 5 (Diani et al., 2019). A four-tier diagnostic test categorizes the students' conception into misconceptions, concept understanding, not understanding the concept, and error (Sundaygara et al., 2021). However, there is no research about assessing students' conceptions about the force and motion topic at the secondary school level using a four-tier diagnostic test.

The particular research provides students a motivation and evaluation result of the concept, which aims they learn more about the force and motion topics. In addition, teachers they can find the best strategy to reduce misconceptions among students. Based on the background, the problem formulation was "How do Four-Tier Diagnostics Test Assess Students' Secondary School Conceptions of Force?" Based on the research problem, this study addresses the research questions, as follows: (1) What are students' conceptions about force and motion as assessed by a four-tier diagnostic test? (2) What concepts in force and motion have the most misconceptions?

RESEARCH METHOD

Many samples are needed to determine student misconceptions about force and motion topics using a four-tier diagnostic test. Therefore, the research used a survey design, specifically a cross-sectional survey design (Creswell, 2012). The survey method used a sample of a population by collecting information through surveys or interviews, designing data-collecting, obtaining lots of responses, and measuring the attitudes of the terms of attitudes, beliefs, opinions, or practices (Creswell, 2012).

The research assessed 174 secondary school students in 8th grade who had studied force and motion in two public middle schools (SMPN "X" Bandung and SMPN "Y" Padalarang) and consisting of 83 male students and 91 female students. The sample used convenience sampling. Convenience sampling is when a selected group of people who are (conveniently) available for research are included in the study sample (Fraenkel et al., 2017).

The instrument of this research included a preliminary study, content and construct validation, and reliability. The results are shown in the Appendix. Content validity is demonstrated by illustrating that the test items represent a sampling of the participants. The content validity used Aiken's Test index, which used raters or experts to examine the decision of the single items in terms of yes or no, agree or disagree, valid or invalid (Aiken, 1980). The Aiken Test formulation is shown below:

$$V = \sum S/[n(c-1)]$$

Note:
V = validity index (Valid, medium valid, invalid)
S = validator or the expert suggestion (agree/revise/rejected)
N = sum of the expert judgment
C = the sum of the validator

After the content validity measure, the value of the validity index is calculated by the equation. The result of the validity index is interpreted as summarized in Table 1.

Table 1. Aiken validity interpretation

Validity Index (V)	Interpretation
$0 \leq V \leq 0.4$	Invalid
$0.4 < V \leq 0.8$	Medium validity
$0.8 < V \leq 1$	Very valid

Construct validity is always involved when a test is interpreted as a quality that has no "operational definition" (Cronbach & Meehl, 1956). The construct validity decision is based on the number of the Corrected Item Total Correlation that is higher than the r Table. Then, it is valid. A measuring device's reliability is determined by how much it can be depended upon or trusted. Reliability can be used to ensure the consistency of measuring instrument, or whether the instrument is consistent in a repeated measurement. When measurements are consistent a measuring tool is considered dependable. The reliability index result is shown in Cronbach's Alpha number. Cronbach's alpha is a measure of reliability that compares the amount of shared variance, or covariance, between the items that make up an instrument with the amount of total variance (Collins, 2007). Guilford (1956) developed a way to interpret the reliability coefficient or reliability index, as presented in Table 2.

Table 2. The Categories of Reliability Index

Reliability index (r)	**Criteria**
0.80 – 1.00	Very High
0.60 – 0.79	High
0.40 – 0.59	Moderate
0.20 – 0.39	Low
-1.00 – 0.19	Very Low

After that, it continued to the questions in Tier 1 and Tier 3. In addition, the reliability test was conducted three times, just as the validity of the test items was assessed. The reliability index of Tier 1 and Tier 3 in pilot tests is presented in Table 3.

Table 3. The Reliability Result in the First Pilot Test

Test	**Tier**	**N of Item**	**Cronbach's Alpha**
I	1	28	0.518
	3	28	0.450
II	1	26	0.702
	3	26	0.710
III	1	22	0.721
	3	22	0.779

The result determined the students' conceptions. The conceptions are Scientific Knowledge (SK), False Positive (FP), False Negative (FN), Misconception (M), and Lack of Knowledge (LK). Specific answers will result in various concept decisions, so the data is analyzed easily. Table 4 shows the choices, depending on the four-tier diagnostic test (Kiray & Simsek, 2021).

Table 4. Comparison of Decisions of Four-Tier Test

Tier 1	Tier 2	Tier 3	Tier 4	Decision of four-tier test
True	Confident	True	Confident	SK
True	Confident	False	Confident	FP
False	Confident	True	Confident	FN
False	Confident	False	Confident	M
True	Confident	True	Not confident	LK 1
True	Not confident	True	Confident	LK 2
True	Not confident	True	Not confident	LK 3
True	Confident	False	Not confident	LK 4
True	Not confident	False	Confident	LK 5
True	Not confident	False	Not confident	LK 6
False	Confident	True	Not confident	LK 7
False	Not confident	True	Confident	LK 8
False	Not confident	True	Not confident	LK 9
False	Confident	False	Not confident	LK 10
False	Not confident	False	Confident	LK 11
False	Not confident	False	Not confident	LK 12

SK: Scientific knowledge; LK: Lack of knowledge; M: Misconception; FN: False negative; FP: False positive.

RESULT AND DISCUSSION

Students' Conceptions about Force and Motion

This part answers research question 1 and explains the conceptions about force and motion from the 174 students who have been assessed. The graph in Figure 1 shows the data from students in the same grade, who have learned about force and motion. The overall results are presented in Figure 1, categorizing the findings from each of the 17 questions into 5 conceptions.

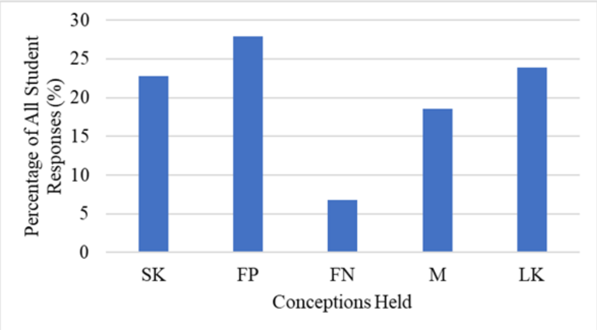

Figure 1. Students' Conceptions in Force and Motion

Based on Figure 1, the most (highest percentage of students' responses) students' conception in force and motion was False Positive. This means the students could answer correctly with a high confidence level, but their reason in Tier 3 is incorrect. The reason is that the students know the phenomenon, but they cannot explain the scientific explanation of the phenomenon. The False Positive conception is that students have the correct answer but for the wrong reasons (Gurel et al., 2015). The Scientific Knowledge and Lack of Knowledge have a similar percentage. It means some students can learn this science topic while others cannot. The finding supports the previous findings that the False Positive was the highest conception. In the conception category, the false positive rate is 28.6%, in one test item in assessing the wave concept as the highest (Krisdiana et al., 2018). In assessing the modern test theory, it was found that the False Positive is the highest conception in 13.16% rather than other conceptions (Istiyono et al., 2023). The findings of high false negative conceptions are rarely found. Students find it commonly difficult to explain the scientific basis behind the phenomenon rather than answer or predict the phenomenon without a scientific reason.

Additionally, some research found that the percentage of False Positives is commonly in line with the percentage of False Negatives. These findings are different from the average of False Negative conception being 4.72% and False Positive conception is not in line with the result of the False Positive being 9.01% in assessing the temperature and color topic (Maison et al., 2019). Other findings show both False Positives in 11% and False Negatives in 12% are a low conception in assessing the general biology concept (Prayitno & Hidayati, 2022). Assessment by a four-tier diagnostic test found that both False Positive and False Negative conceptions are under 10% in determining the concept of density (Kiray & Simsek, 2021). The finding in Ermawati and Colleagues (2019) in assessing the work and energy concept, the false positive conception is under 10% in the work sub-concept. The dynamic fluid concept also found the low false positives in 4.3% and false negatives in 3.8% (Kurniawati & Ermawati, 2019). The low false positive and false negative findings are occurring in assessing the chemical bonding concept, with the mean of false positive conception is 6.52% and false negative conception is 6.02% (Sen & Yilmaz, 2017).

The finding shows the result of the high Lack of Knowledge conception. The findings are in line with Kirbulut and Geban (2014) in assessing the States of Matter topic, which has the result of the Lack of Knowledge is 25.2% and also low in both False Positive (3.8%) and False Negative (8.9%). In assessing global warming by an FTDT, the pre-service science teachers assessed three categories, with content area 1 showing the highest Lack of Knowledge (40.1%), content area 2 showing a Lack of Knowledge of 26.3%, and content area 3 showing a Lack of Knowledge of 22.3% (Aksoy & Erten, 2022). The Lack of Knowledge conceptions is the highest by a number at 10.32% rather than False Positive conceptions at 9.01% and False Negative conceptions at 4.72% (Maison et al., 2019).

However, these findings of misconceptions are relatively low (18.59%). It is in line with the assessed FTDT in acid and base materials, with the misconception result being 11.50% among high school students (Lukman et al., 2022). Less than 10% of science teachers have misconceptions about density topics when assessed by FTDT (Kiray & Simsek, 2021). Those misconceptions are low because they are the smallest conceptions rather than scientific knowledge, as the majority of the conceptions are among those findings. The findings are different from previous work, which has shown high misconceptions of 48.08% and 61.54% for Newton's First and Second Law, respectively, by using a Four-Tier Diagnostic Test (FTDT) (Huda et al., 2022). Another study found that misconceptions on Newton's Second Law by FTDT are 54% of Misconceptions among senior high school students (Sundaygara et al., 2021). The FTDT has also been used to assess understanding of genetics, and 65.21% of the students' responses indicated misconceptions (Wulandari et al., 2021). 63.95% of high school students have misconceptions about thermodynamics topics by FTDT (Budi Bhakti et al., 2022). The majority of the students at the university-level have misconceptions, 39% assessed by FTDT on the topic of general biology (Prayitno & Hidayati, 2022). To get better clarity on the students' conception in force and motion topics in each question is presented in Table 5.

Table 5. Students' Conception of Each Test Item

Question	Student's Conceptions (%)				
	SK	**FP**	**FN**	**M**	**LK**
1	18.97	66.09	4.60	0.57	9.77
2	7.47	54.02	5.17	26.44	6.90
3	15.52	57.47	0.00	9.77	17.24
4	12.07	10.34	14.37	25.29	37.93
5	8.63	4.02	24.14	32.18	31.03
6	15.52	44.25	1.72	18.97	19.54
7	43.10	6.90	6.32	16.67	27.01
8	17.82	8.05	21.84	29.89	22.41
9	17.82	33.33	5.75	15.52	27.59
10	4.02	6.32	8.05	52.87	28.74
11	28.16	17.82	7.47	14.37	32.18
12	51.15	17.24	4.02	9.20	18.39
13	28.16	28.74	3.45	16.09	23.56
14	13.79	41.95	2.87	15.52	25.86
15	49.43	13.22	1.72	9.20	26.44
16	43.10	25.86	0.57	11.49	18.97
17	13.22	39.08	2.87	12.07	32.76

The result in table 5 shows that Scientific Knowledge has the biggest percentage in numbers 12, 15, and 16. On the other hand, the False Positive conception's biggest percentage is in numbers 1, 3, and 2. Moreover, the highest misconceptions of students are numbers 10, 5, and 8. And, the Lack of Knowledge percentage is in numbers 4, 17, and 11.

Interviews with the science teacher to gain insight into the learning processes of students in the science classroom and the various factors that influence the outcome of their learning were conducted as a follow-up to the FTDT. The interviews are recorded below.

Researcher: This is the result of the conception of the students in general about force and motion topics. The biggest concept in the force and motion topic is the False Positive concept. Do you know what the reasons and effects are that make the False Positive happen?

The science teachers: There are several factors, perhaps the most common of which can be used as the reason, because students do not / do not fully understand the material being taught, so they still cannot "connect" information with each other regarding the material. The second reason is that most students who study science lack interest or lack motivation. Whether it is in the morning or afternoon, if they lack motivation to learn, it is a bit difficult. Some of them, also, sometimes like to have someone who has "assessed" that science is difficult, even other students also like to say that science is more difficult than mathematics. Then, when they are brought to study, they become less interested/or less motivated for that reason.

Researcher: How many students are in the class?

The science teacher: There are different students in each class, but all of the class has more than 35 students.

Researcher: How do you feel when you teach a class that has more than 35 students?

The science teacher: When I teach the students and arrive at my home, I feel tired. And, I cannot make sure all of the students paid attention to the teacher and the curriculum demands that needed to be taught, all of the topics, without considering the understanding of the students.

This interview session with a teacher, reveals the reason for the students who have various conceptions that are assessed by the four-tier diagnostic test. It shows that the students lack motivation in learning science and have perception that the science subject is hard. Also, the teacher could not control all of the students' attention because there were a lot of students in a class. Similar findings about science teacher opinions on the responses to the conception of students argue that teachers' difficulties when explaining the concept by the conventional method and verbal explanation (Saputri & Rusyati, 2024). Other reasons that can cause the misconceptions are that teachers do not give feedback after students finish the final assignment and get their scores, and teachers continue to the next topic (Ambarita & Rusyati, 2025).

The Force and Motion Concept That Students Most Misconceptions

The particular part discussed Research Question 2, the most common misconception in force and motion. It offers valuable insights into the specific areas in which scientific concepts were not fully comprehended by students in each test item. Therefore, it makes it easy to identify the concept of the misconception and the students' knowledge that leads to the misconception. The list of misconceptions is what students thought about those test items based on the options.

The previous table provides insight into the misconceptions that students have about each question. By examining this table, this research obtain insight into how students view and consider the material they have studied. It draws attention to the particular areas of the subject matter where students frequently have misconceptions and offers a complete understanding of their cognitive processes and possible confusion. The list of the students' misconceptions answers is in line with the percentage of misconceptions in each test item. The students' responses demonstrating misconceptions in force and motion is presented in Figure 2.

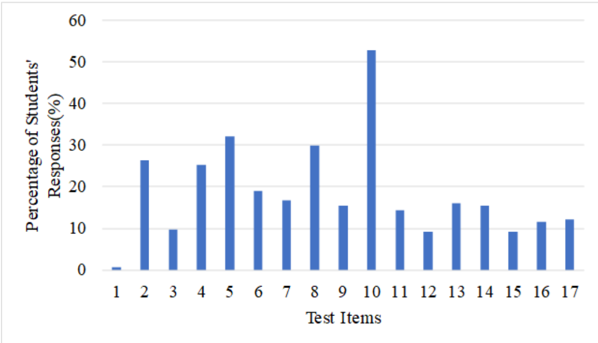

Figure 2. Percentages of Misconceptions in Each Test Item

Figure 2 shows the highest and lowest misconceptions in the 17 test items. The smallest misconception that students have is question number 1 about the frictional force. The question is related to applying oil on the surface of a plane and the effect. Most of the students answered correctly about the effect of applying the oil, but most of the students could not answer the scientific reason in tier 3. It can be seen in analyzing the results. FP is 66.09% in question number 1. The highest misconceptions are in question number 10 about displacement, question number 5 about Newton's Laws, and question number 8 about displacement.

There are a number of misconceptions that are among the three highest misconceptions. Test item number 10, which had the greatest level of student misconceptions about the vector, is presented in Table 6.

Table 6. Test Instrument Item number 10

Tier	Questions
1	Two balls move down from the top of the road to the bottom. Ball B reaches the road before Ball A. What is the vector value of the two balls? A. Ball A > Ball B B. Ball A < Ball B C. Ball A = Ball B D. Not enough information
2	Are you sure about your answer? A. Sure B. Not sure
3	What option best matches your reasoning? A. The vector value indicates the speed of the object B. The vector value indicates the displacement of the object C. The value of the vector affects the weight of the object D. The vector value affects the time
4	Are you sure about your answer? A. Sure B. Not sure
SK	CABA (4.02%)
M	AAAA (23.91%), AABA (1.09%), AACA (9.78%), AADA (1.09%), BAAA (36.96%), BACA (17.39%), BADA (4.35%), DAAA (1.09%), DACA (2.17%), DADA (2.17%)

In physics, a vector is a quantity with both magnitude and direction (Gregersen, 2020). The misconception, as stated, is the incorrect answer in Tier 1 and Tier 3, with high confidence levels in Tier 2 and Tier 4. As analyzed in students' answers. Most of the students' answers in Tier 1 are B, followed by answer A as the second highest. While in Tier 3, most students answer option A as the highest misconception because the student thought the vector indicates the speed of the object. Most students answered in Tier 1 B and Tier 3 A with a high confidence level in both answers. Most second students answered for misconceptions: the first tier is A and the third tier is A.

Poluakan and Runtuwene (2018) found that over 75% of students are unable to correctly draw vector diagrams for tension, friction, normal force, weight, and weight projections in inclined planes. Students show difficulties with vector component, especially in differentiating the trigonometry (Sirait et al., 2017). A lot of students struggled with qualitative reasoning when it came to vector addition and the relationship between vectors and their components. In particular, students frequently erred in their reasoning when it came to how the orientations of the various forces affected the resultant's magnitude (Flores et al., 2004). Flores-García and Colleagues (2008) found that when students were given the task of adding vectors without any context, many of the same challenges that the researcher saw then also surfaced when they were asked to add forces. The setting of force addition, however, led to other challenges. Even after receiving conventional training, a lot of students are still unable to understand that forces are vectors in circumstances where there is either no net force or a net force. In one-dimensional vectors, only 44% of students answered correctly, and in two-dimensional vectors, 27% of students answered correctly (Fauzi et al., 2017). When writing out mathematical expressions of vector fields, many students struggle with vector addition, misidentify field line density as a measure of field magnitude, mix up field line and equipotential line characteristics, and select the incorrect coordinate system (Bollen et al., 2017).

After the analyzed results, students thought the vector was indicated by the speed of the object. However, the speed of the object in physics concept should relate to acceleration and velocity. The vector representation topic has a sub-indicator, such as drawing a vector, calculating the magnitude, and finding the direction and vector operations (Pratama et al., 2018). According to Nguyen and Meltzer (2003), a vector has several categories. The categories are vector magnitude, vector direction, qualitative vector addition, one-dimensional vector addition, two-dimensional vector addition, two-dimensional vector subtraction, and comparison of resultant magnitude. The vector also represents the free-body diagram of the object. Those statements state the vectors do not have a connection with the speed, weight, and time as the incorrect answers provide.

The next test items that make students' second-highest misconceptions in number 5 are provided in Table 7. In question number 5, the concept is about Newton's second law, which relates to mass and acceleration.

Table 7. Test Instrument Item 5

Tier	Questions
1	Workers push two tables toward each other. Table A has a mass of 7 kg, and Table B has a mass of 12 kg. Which table will be harder to push? A. Table B B. Table A C. Both of the tables D. Not enough information
2	Are you sure about your answer? A. Sure

Tier	Questions
	B. Not sure
3	What option best matches your reasoning? A. Acceleration is inversely proportional to mass. B. Acceleration is directly proportional to mass. C. The acceleration has a value of 0. D. Acceleration has no relation to mass.
4	Are you sure about your answer? A. Sure B. Not sure
Answer key (SK)	BABA (8.62%)
Students answer	AABA (71.43%), AACA (7.14%), AADA (12.50%), CABA (5.36%), 3CACA (1.79%), DACA (1.79%)

The SK answer is B in Tier 1 with confidence in Tier 2 and B in Tier 3 with confidence in Tier 4. Most of the students' answers in Tier 1 are A, and the highest percentage of incorrect answers. The answer AADA is the second-highest misconception. The student taught that the heavier table is harder to push than the lighter table because students taught that the heavier table is harder to push. However, the student's state in Tier 3 is "acceleration has no relation to mass." The smallest misconception occurs when students who answer Tier 1 as D and Tier 3 as C with confidence in both Tier 2 and Tier 4. Students think this question is not a logical connection between different masses of the table that push each other. So, students choose the information about the test items is not enough. Therefore, the students' answer is that acceleration has no relation with the mass, as their answer in Tier 3. And, students thought it must be another factor that affected this phenomenon.

The findings, in line with previous research, show the students' weaknesses in understanding Newton's Law concept. The findings of the student's difficulties in learning Newton's law in the mastery of physics students are low due to several factors, such as individual students, the qualities of physical objects, and the teacher-created learning environments for the students (Putra & Heriyanto, 2020). Lack of Knowledge of conceptions is occurring to physics teachers in understanding Newton's Law concept, especially in representing the concept in a pictorial diagram, because physics teachers do not yet know about the pictorial diagram (Masrifah et al., 2020).

The current results add to several previous studies that have shown that middle school students struggle with the concepts of mass and acceleration. More students provide the wrong response to the conceptual physics challenge. The percentage of erroneous answers for the first, second, and third Newton's law problems is 69%, 71%, and 76%, respectively, because they are not learning the language of physics correctly and are being taught the wrong concepts (Setyani et al., 2017). In understanding Newton's Law of Motion, the poor performance of the pre-service teacher is attributed to teaching methods, student backgrounds, curriculum, and assessment (Cashata et al., 2022). The ability of students to understand Newton's law is influenced by the impressionable concepts of students from their experiences in the community and the educational setting (Meiliani et al., 2021).

There are still misconceptions besides Newton's Law conception. The next test item is the third-highest misconception among students. The test item and the students' answers, percentage of misconceptions, are presented in Table 8.

Table 8. Test Instrument Item 8

Tier	Questions
1	A car is seen changing places several times until finally it stops at its original place. What is the displacement value of the car? A. More than 1 B. 0 C. Less than -1 D. Not enough information
2	Are you sure about your answer? A. Sure B. Not sure
3	What option best matches your reasoning? A. Displacement indicates the movement of an object B. Displacement must have a clear direction C. Displacement indicates the difference between the beginning and the end of the object D. Displacement shows the speed of an object
4	Are you sure about your answer? A. Sure B. Not sure
Answer key (SK)	BACA (17.82%)
Students answer	AAAA (63.46%), AABA (11.54%), AADA (3.85%), DABA (19.23%), DADA (1.92%)

Test item 8 has several answers keys for misconceptions. Five answers lead the students to misconceptions. The highest misconceptions are answers AAAA. Most of the students thought that the displacement indicated the movement of the object. Therefore, wherever the object moves, it has a displacement value of more than 1 even though it moves back to its initial position. The smallest misconceptions are that students thought the displacement should be shown as the speed of the object. Therefore, the students' answers in Tier 1 are not enough because the questions do not contain the speed toward the displacement.

The findings show that the misconceptions about the displacement concept are among the first and third highest. As previous findings state, around 10% of students can differentiate between displacement and distance (Jufriadi, Ayu, et al., 2021). Numerous misconceptions on displacement and distance in straight-motion material are found as students rarely conduct laboratory activities, discussions, and presentations (Mufit et al., 2022). The concept of rectilinear motion, which includes displacement and distance as well as the movement of free fall, is easily understood despite common misconceptions because the concept that the students are taught by the teacher is limited (Sukariasih, 2016). Students also do not have the knowledge that displacement has magnitude and it is the same thing as distance. The reason is because the student's understanding of scalar and vector concepts is limited. However, the students only focus on the mathematical problem, and students do not know the magnitude of the displacement (Handhika et al., 2018). The misconceptions in motion, such as distance, position, and displacement, are 49.17%, caused by the students' friends while they are both still in the learning stage. Another cause is students not focusing on the teacher and their personal experience from the sourcebook or another media (Jannah et al., 2022). The cause of the misconception in the concept of distance and displacement is that students ignore other resources of the knowledge about problem-solving in test items. Only 42.8% of the students understand distance and displacement (Jufriadi, Kusairi, et al., 2021). The misconceptions in the concept of position, distance, displacement, velocity, and acceleration are 67.7%, caused by the majority of students' opinions as the result from their everyday experiences, in contrast with scientific ideas. Students get misconceptions when their expectations and scientific concepts do not match (Murdani & Sumarli, 2020). Therefore, future research has the opportunity to explore the teaching and learning strategies and identify the "scientific" reason for their conception as the new evidence. Another researcher also developed the instrument of the four-tier diagnostic test for another science topic. Therefore, this instrument could be used as an alternative assessment.

However, it is an urgent to find out the misconceptions between male and female students. Therefore, the independent sample t-test was conducted to reveal the differences in the misconceptions between male and female students. The results of the analysis are presented in Table 9, the group statistics.

Table 10. Independent Sample t-test

		Levene's Test for Equality of variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig (2-tailed)	Mean Difference	Std. error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Mis-Concept-ion	Equal Variances Assumed	0.65	0.799	-0.112	172	0.911	-0.03787	0.33690	-0.70286	0.62713
	Equal variances not assumed			-0.112	170.205	0.911	-0.03787	0.33706	-0.70322	0.62749

Table 9. Group statistics

	Gender	N	Mean	Std. deviation

Mis-conception	Male	83	3.1429	2.23140
	Female	91	3.1807	2.20893

The analysis of the group statistics in an independent sample t-test shows that the averages – either male or female students - are almost similar, but still show differences. However, to prove that the differences between male and female students are significant, this particular research conducted an independent sample t-test. Therefore, the result of the independent sample t-test is presented in Table 10.

Before interpreting the result of the independent sample t-test, it needs to determine the homogeneity of the result. Based on the output of the value in Sig. Levene's Test for Equality of Variance: the homogeneous value must be more than 0.05. However, the result has a value of 0.799 > 0.05. Therefore, the value is homogeneous. Then, the independent sample t-test can be conducted by identifying the Sig (2-tailed) in the t-test for Equality of Means. The results show the value is 0.911>0.05, which means that both male and female students are not significantly different.

The differences between male and female students on misconceptions contrast with previous findings. In the vibrations and waves concepts, students were assessed by FTDT and revealed that the differences between male and female students are not significant, with male students having 12.85% and female students having 17.75% (Kurniasih et al., 2023). Other findings reveal that the differences in misconceptions between male and female students significant different in the chemistry course. It shows that male students' misconceptions are higher in 31.9% than female students' misconceptions in 18.6% respectively (Kristyasari & Pongkendek, 2023). However, other finding shows the differences between male and female students are not significantly different, which happens in the chemistry course. The misconceptions about male students are 36%, which is not significantly different from the misconceptions about female students, about 35%; both fall into the medium (Utami et al., 2017).

CONCLUSION

The particular research aimed to find out the students' conceptions and misconceptions about force and motion in elementary science education by using a cross-sectional survey method with grade 8 secondary students. This study used a four-tier diagnostic test to assess students' conceptions of this topic. In addition, it conducted semi-structured interviews with teachers to reveal their learning process. The diagnostic test is a 17-item instrument that has been tested for content validity, construct validity, and reliability. The test items in force and motion consist of several concepts, such as friction force, gravitational force, Newton's Laws, pressure, vectors, and displacement.

The results found out several of students' conceptions in force and motion, with the order from highest to lowest being False Positive, Lack of Knowledge, Scientific Knowledge, Misconception, and False Negative. Analyzing the semi-structured interviews with the science teacher suggests a lack of motivation in students toward science and assumptions that science courses are hard as the primary reasons for the lack of understanding (high FP) observed. The result shows that the students' misconceptions occur in all of the test items, but most misconceptions relate to displacement, Newton's Laws, and vectors.

The findings have implications for science education and practice. Recognizing students' misconceptions in force and motion topics help teachers develop effective teaching strategies. The teacher could conduct the laboratory activity, demonstration, or other strategies to promote basic understanding and to advance understanding of a concept. The four-tier diagnostic test is intended for the assessment field to support teachers in distinguishing the understanding of students among genuine understanding, misconceptions, and guessing. By providing deeper insights into students' thought processes, the test allows teachers to connect their instructional strategies to address common misunderstandings effectively. For future research, it is intended as a foundation to design the interventions of misconceptions by any strategies and the sources of the literature review and comparison for future research that uses the FTDT.

ACKNOWLEDGMENTS

We would like to acknowledge Mary Margareth Thomas, Ph.D, as the supervisor to finalize the draft.

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