



## Development of Three Tier Static Electricity Diagnostic Test to Identify Student Conceptions about Static Electricity



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### Abstract

The purpose of this research was to develop and validate *Three Tier Static Electricity Diagnostic Test (TTSEDT)*. The development procedure consists of four stages: define, design, develop, and validation. The subjects of this study consist of 2 physics education experts and 120 high school students, in 12th grade. The response of two experts was used to determine the content validity of TTSEDT. Meanwhile, the students' responses were used to determine the items internal consistency, discrimination index, difficulty index, and reliability index. The reliability of TTSEDT was determined by KR-20. The results showed that: (1) TTSEDT meet content validity which means that TTSEDT items are really measures the students' conceptions and misconceptions about static electricity; (2) the items internal consistency index is in the interval 0.20-0.47; (3) the items discrimination index is higher than 0.20; (4) the difficulty index of test items is in the interval of 0.25 - 0.75; (5) the reliability index of TTSEDT is 0.73 ( $p < 0.05$ ). TTSEDT is a valid, reliable, and effective instrument for identifying students' conceptions of static electricity.

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## 1. Introduction

Studies (Gonen & Kopckay: 2010; Dud, *et al.*:2015; Blas, Seidel, & Fernandez: 2010) show that before learning science in a class, learners have had a conception that most inconsistent with the scientific concept. Student conceptions that are inconsistent to the scientific concepts are given various labels such as preconceptions (Turgut & Turgut: 2011), Children science (Bell: 1993; Osborne, *et al.*: 1985); alternative conceptions (Peterson: 2002),

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conception naïve (Alwan: 2010), and misconception (Brown & Clement: 1989; Onder: 2017). It has been widely accepted that misconceptions are stable, difficult to change (Sencar & Eryilmaz: 2004; Kaltakci & Didis: 2007), and contribute negatively to learning (Blas, Seidel, & Fernandez: 2010; Ozkan & Selcuk: 2012). Therefore, the identification of student misconceptions becomes essential for the effective teaching of physics. Misconceptions can be detected by testing students. This test can be done at the beginning or the end of the lesson. To reveal the existence of misconception then required a type of test that is able to analyze students' difficulties and weaknesses. The type of test is a diagnostic test. The Diagnostic test is a test used to know the weaknesses of students so that the weaknesses can be given appropriate treatment (Arikunto: 2009). Diagnostic tests are useful for learning difficulties encountered by students, including misconceptions. By knowing the students' misconception, the teacher can immediately find a solution to solve the problem. Through diagnostic tests can be known about concepts that have been understood and that have not been understood by students.

In physics education, student misconceptions have been measured in various ways such as interviews (Osborne & Gilbert: 197; Osborne & Gilbert: 1980; Eshach: 2003), open questions (Palacios, Cazorla, and Cervantes, in Gurel, Eryimaz, & McDermott: 2015; Colin, Chauvet & Viennot: 2002; Taslidere: 2016), and ordinary multiple choice test (Treagust: 1998; Cataloglu & Robinett: 2002; Engelhardt & Beichner: 2004; Maloney, *et al.*:2001; Libarkin: 2008; Bardar, *et al.*: 2007). Interviews were conducted with the aim of discovering what students think and how they feel about something. Interview techniques are a flexible technique and allow for more in-depth student information. However, this technique requires the training of the interviewer, it takes a long time for a large number of subjects if it is to obtain broader generalize, the interviewer may contaminate the findings of the researcher (Gurel, Eryimaz, & McDermott: 2015).

Ordinary multiple choice test is one alternative that is used to overcome difficulties encountered in the interview process and open test. This multiple-choice test can be directly assessed and applied to a large number of students. The development of multiple-choice tests on students' misconceptions has the potential to make a valuable contribution to the body of work in the area of misconceptions and to assist in the process of helping science teachers to more readily use the findings of research in their classrooms (Treagust: 1998). From a usage point of view, multiple-choice tests are valid and reliable, easy to calculate, manageable, allowing teachers to effectively assess students' understanding (Gurel, Eryimaz, & McDermott: 2015).

Like interview techniques and open questions, ordinary multiple choice tests are also not spared from the weaknesses. Some of the disadvantages of an ordinary multiple-choice test include: (1) student's guess contributes to error variance and reduces test reliability, (2) selected choice does not provide in-depth insights about student ideas or conceptual understanding, (3) students are forced to choose each answer from a very limited list of choices, which prevents them from building, organizing and presenting their own answers, (4) It is very difficult to write a good multiple-choice question. In addition to the above deficiencies, the ordinary multiple-choice test cannot demonstrate students' deep understanding of the correct answers (Chang, Yeh, & Barufaldi : 2010). In other words, the ordinary multiple-choice test cannot distinguish whether the student's correct answer is supported by correct reasoning or improper reasoning (Bento: 2018).

Referring to the weaknesses of the ordinary multiple choice test, researchers like Treagust (1998), Chandrasegaran, *et al.* (2007), Bilal & Erol (2009), and Kilic & Saglam (2009) developing the two-tier test. In general, two-tier tests are a diagnostic instrument in which the first tier contains questions with alternative answers such as the ordinary multiple choice test, and the second tier contains the choice of reason for the answer of the first tier. This two-tier diagnostic test allows researchers to identify students' wrong answers caused by misconception, and whether the true answer is caused by a scientific understanding (Taslidere: 2016). Two-tier tests are more efficient than ordinary multiple choice tests, although these tests have some disadvantages in distinguishing the lack of knowledge from misconceptions, mistakes, or scientific knowledge (Gurel, Eryimaz, & McDermott: 2015). This happens because there was always a chance for students to guess the answers. Thus, the students' correct answers may come from a scientific understanding or guess, as well as a student's wrong answer may be due to a lack of knowledge or misconception (Taslidere: 2016)

Departing from the limitations of two-tier diagnostic tests, the researchers developed a three-tier diagnostic test by adding a third tier to each test item that asked students' beliefs about the answers given to the first and second tiers. In a three-tier diagnostic test, the researcher constructs a multiple-choice test in which the first tier is an ordinary multiple choice test, the second tier is a multiple choice test that asks the reasoning of the first student's answer, and the third tier asks students' level of confidence in the first and second tier answers (Gurel, Eryimaz, & McDermott: 2015). In the field of physics teaching the development of three-tier diagnostic test has been done on various topics such as : geometric optic (Kutluay: 2005); force and motion (Turker: 2005); gravity concepts

(Kaltakci & Didis: 2007); the nature and propagation of some common wave phenomena (Caleon & Subramaniam: 2008), waves (Caleon & Subramaniam: 2010), simple electric circuit (Pesman & Eryilmaz: 2010), momentum and collision (Pacala: 2018). This research is focused on developing the three-tier diagnostic test for static electricity called Three Tier Static Electricity Diagnostic Test (TTSEDT). This research is conducted to answer the problems as follows.

- a) How is the content validity of TTSEDT?
- b) How are the items internal consistency of TTSEDT?
- c) How are the items discrimination Index of TTSEDT?
- d) How is the reliability of TTSEDT?
- e) Is the TTSEDT effective to identify students' conception about static electricity?

## 2. Materials and Methods

The development of TTSEDT consists of four stages: Define, Design, and Develop, and Validation (modified from (Thiagarajan: 1974).

### *Define*

This stage defines the TTSEDT needs related to the conception and misconceptions that occur in static electricity. Scientific concepts are identified from the Basic Competencies of High School Curriculum. Meanwhile, various misconceptions on static electricity are identified from the various literature and research results using ordinary multiple choice tests and two-tier multiple-choice tests such as (Maloney, *et al.*:2001; Bilal & Erol: 2009; Koudelkova & Dvorak: 2014).

### *Design*

This stage begins with the preparation of a test grid to ensure compatibility between test items and the concepts to be measured. The first tier of TTSEDT is designed in multiple-choice form with four alternative choices. The alternative correct answer is a scientific concept, while alternative wrong answers are misconceptions related to certain concepts. The second tier of TTSEDT is designed in multiple-choice form, with alternative answers in the form of reasons for alternative answers in the first tier. An alternative reason for the correct answer in the second tier is the scientific explanation of the concept, while the alternative wrong answer is a non-scientific explanation. The third tier of TTSEDT is designed in the form of a choice of confidence in the answers in the first and second tiers which are avoided by two alternatives, namely sure and not sure.

### *Develop*

Developed the Three-Tier Multiple Choice Test items in accordance with the identified concepts of the high school curriculum, findings with ordinary multiple choice tests and two-tier tests. Some items are developed from an ordinary multiple choice test from (Maloney, *et al.*: 2001; Bilal & Erol: 2009; Koudelkova & Dvorak: 2014), and partly developed by the author himself.

### *Validation*

The content validity of the TTSEDT is obtained by analyzing whether the test items really measure key concepts and misconceptions of students about static electricity. Content validation was carried out by two physics education experts. These experts are asked to analyze the items that include item statements, alternative choices, answer keys, and distractors. In the first tier, the experts analyze whether the item statement is easy to understand? Is the answer key a scientific concept? Is the distractors are the variety of students' misconceptions about certain concepts. In the second tier, experts are asked to analyze whether the answer key for student reasons is a scientific explanation and whether distracter is a non-scientific explanation of the concepts asked in the first tier. They made some corrections, comments, and suggestion on some of the items that were used to revise the item. At this stage, pilot testing was performed for internal consistency analysis, discrimination index, difficulty index, and test reliability. Pilot testing

was conducted in SMA Negeri 1 Kediri in the odd semester of the academic year 2017/2018. The number of students participating in this pilot testing is 102 people. The study begins in October to November 2017.

### Data Analysis

Data analysis was carried out in a descriptive quantitative and qualitative manner. The content validity is expressed qualitatively based on the expert responses. Calculation of internal consistency index, discrimination index, difficulty index, and reliability of the test is assisted by SPSS for Window. Internal consistency index, discrimination index, difficulty index, and reliability were determined from the third tier score. In the third tier score of 1 is given if the student's answer in the first tier is right, the reason in the second tier is right and the third tier answer is "sure". The score of 0 is given for the other answers. Reliability index is calculated by KR-20 formula (Arikunto: 2009). Variety of students' conceptions are categorized into the scientific concept, lack of confidence, misconception, and lack of knowledge based on a combination of students' answers in the first, second and third tiers with criteria as in Table 1.

Table 1  
Categories of student knowledge on each test item

1 <sup>st</sup> tier response	2 <sup>nd</sup> tier response	3 <sup>rd</sup> tier response	Category of students conception
True	True	Sure	Scientific Concept
Correct	Correct	not sure	Lack of Confidence
Corect	Incorrect	Sure	Misconception
Incortect	Correct	Sure	Misconception
Incorrect	Incorrect	Sure	Misconception
Incorrect	Correct	Not sure	Lack of Knowledge
Correct	Incorrect	Not sure	Lack of knowledge
Incorrect	Incorrect	Not sure	Lack of Knowledge

Adapted from Arslan, Cigdemoglu, & Mosely (2013).

## 3. Results and Discussions

### 3.1 Content Validity

According to experts, the TTSEDT developed meet content validity. This means that TTSEDT items are really measuring the students' conceptions and misconceptions about static electricity. In the first tier, the answer keys are scientific concepts and the distracters are the non-scientific concepts. In the second tier, answer keys are the scientific explanations of the concept and the distracters are the nonscientific explanation. In this study, the test material includes concepts of charge, electrostatic force, electric field, potential energy, electrical potential, and capacitors. This material was derived from the 12<sup>th</sup>-grade high school curriculum.

### 3.2 Items Internal Validity

Of the 30 items tested, there are 29 items that have an internal validity index in the range of 0.20-0.49 as shown in table 3. These values are greater than the table values ( $r_{table}=0.195$ ) at the 5% significance level. This means that TTSEDT items are consistent with the entire item.

Table 2  
Items internal validity index

Items number	Internal validity (r)	Items number	Internal validity (r)
1	0.39	16	0.45
2	0.42	17	0.28
3	0.34	18	0.45

4	0.43	19	0.34
5	0.38	20	0.32
6	0.25	21	0.20
7	0.34	22	0.35
8	0.36	23	0.36
9	0.23	24	0.47
10	0.47	25	0.28
11	0.35	26	0.29
12	0.31	27	0.30
13	0.21	28	0.24
14	0.33	29	0.39
15	0.32		

Note:  $r_{table} = 0.195$ .

### 3.3 Items Discrimination Index

Table 3 shows a summary of the results of items discrimination index analysis of TTSEDT. There are 21 items (72,4%) which have discrimination index in the medium category, 7 items (24,1%) have discrimination index in the good category, and 1 item ( 3.4%) has a discrimination index in the very good category. All of the 29 test items have a discrimination higher than 0.20, which means it qualifies as a good test. Discrimination is defined as the ability of a items to distinguish between high-ability students and low-ability students (Arikunto: 2009). That is, if the test is given to students who are clever will be more likely to be answered correctly, whereas if given to learners who have the low ability will be the more wrong answer.

Table 3  
Items discrimination index of TTSEDT

Item number	Discrimination Index (D)	Criteria	Item number	Discrimination index (D)	Criteria
1	0,39	Medium	16	0,44	Good
2	0,42	Good	17	0,28	Medium
3	0,34	Medium	18	0,45	Good
4	0,43	Good	19	0,34	Medium
5	0,38	Medium	20	0,32	Medium
6	0,24	Medium	21	0,21	Medium
7	0,34	Medium	22	0,35	Medium
8	0,36	Medium	23	0,36	Medium
9	0,25	Good	24	0,47	Good
10	0,47	Good	25	0,28	Medium
11	0,34	Medium	26	0,29	Medium
12	0,30	Medium	27	0,30	Medium
13	0,21	Medium	28	0,24	Medium
14	0,33	Medium	29	1,00	Very Good
15	0,31	Medium			

There are 21 items (72,4%) which have discrimination index in the medium category, 7 items (24,1%) have discrimination index in the good category, and 1 item ( 3.4%) has a discrimination index in the very good category. All of the 29 test items has a discrimination higher than 0.20, which means it qualifies as a good test. Discrimination is defined as the ability of items to distinguish between high-ability students and low-ability students (Arikunto: 2009). That is, if the test is given to students who are clever will be more likely to be answered correctly, whereas if given to learners who have the low ability will be the more wrong answer.

### 3.4 Items Difficulty Index

The results of the difficulty index analysis of TTSED T items are presented in Table 4.

Table 4  
Results of the third level diagnostic test assessment

Item number	Difficulty Index	Criteria	Item number	Difficulty index	Criteria
1	0,51	Medium	16	0,48	Medium
2	0,44	Medium	17	0,39	Medium
3	0,50	Medium	18	0,40	Medium
4	0,53	Medium	19	0,44	Medium
5	0,46	Medium	20	0,47	Medium
6	0,40	Medium	21	0,41	Medium
7	0,41	Medium	22	0,42	Medium
8	0,52	Medium	23	0,42	Medium
9	0,47	Medium	24	0,45	Medium
10	0,43	Medium	25	0,39	Medium
11	0,41	Medium	26	0,40	Medium
12	0,47	Medium	27	0,43	Medium
13	0,35	Medium	28	0,36	Medium
14	0,38	Medium	29	0,42	Medium
15	0,31	Medium			

The results presented in Table 4 reveal that the TTSED T items difficulty index is in the medium category. It can be noted in the question bank and can then be used to identify student's conception of static electricity. The difficulty index of all the TTSED T items is within the range of 0.25 - 0.75, so the test can be said well (Kanli: 2015). The level of difficulty serves to determine whether the research instrument used is too difficult or easy for students to measure conceptual knowledge, so the test results can actually show the misconceptions shown by the student. The difficulty level of the item will show how many students as a test participant are able to answer the problem correctly from the given problem.

### 3.5 Reliability Index

By using KR-20 it was found that the TTSED T reliability index was 0.73. This similar results were obtained by Pesman & Eryilmaz (2010) on the development of the three-tier test for simple electric circuit that is 0.69; Cetin, Dindar, & Geban (2011) that found  $r = 0.72$  for three-tier diagnostic test to assess high school students' understanding of acids and bases; and Oberoi (2017) that found  $r = 0.79$  on three-tier concept achievement test in science. This indicates that TTSED T is a reliable test for measuring student conceptions. Reliability test is one of the criteria of assessment instruments required other than validity. The test is said to have high reliability if it provides consistent results for repeated measurements. Thus, TTSED T will give the same results for repeated measurements of students' conception of static electricity.

### 3.6 Students' conceptions of static electricity

TTSED T is effectively used to identify the type of students' conception of static electricity Based on the students' response to each tier, it can be determined the percentage of students whose knowledge is classified into scientific concepts, lucky guess, misconception, and lack of knowledge as presented in table 6.

Table 6  
Recapitulation of student knowledge variety

Type of students' conception	Percentage of Students
<i>Scientific Concept</i>	44,22 %
<i>Lucky Guess</i>	5,14 %
Misconception	36.92 %
<i>Lack of Knowledge</i>	11,08 %

From table 5 it appears that out of 102 students 44.22% of students whose conception of static electricity is a scientific concept, 5.14% are the lucky guess (no have conception), 36.92% of students are misconceptions, and 11,08% have lack of knowledge. These results indicate that TTSEDТ is effective for identifying students' conceptions of static electricity. Some research on physics material that is also effective for identifying student conceptions is [Caleon & Subramaniam \(2010\)](#) on dynamic electricity; [Taslidere \(2016\)](#) on dynamic electricity; at hydrostatic pressures; [Turker \(2005\)](#) in nature of waves and wave propagation; and [Turgut, Gurbuz, & Turgut \(2011\)](#) in Electric Current.

#### 4. Conclusion

The developed three-tier static electricity diagnostic test is a valid and reliable instrument to identify 12-grade high school students' conceptions about static electricity. Test items are consistent with the entire item, can distinguish high and low ability students, and have a moderate level of difficulty. By using this three tier static electricity diagnostic test, students' conceptions can be categorized into scientific concepts, lucky guesses, misconception, and lack of knowledge. Three-tier static electricity diagnostic test is easy and quick to assess students' conceptions of electricity. It is suggested to physics teachers to use this test to diagnose students' conceptions of static electricity. The results can provide direction for improvements to be made.

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#### *Statement of authorship*

The authors have responsible for the conception and design of the study. The authors have approved the final article.

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