

Five-Tier Diagnostic Test to Reveal Conceptual Understanding of Electrical Engineering Students

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Abstract

The purpose of this research was to produce a valid five-tiered misconception diagnostic assessment product and reveal the understanding of electrical engineering students' concepts on the subject of simple electrical circuits. Assessment development consisted of defining, designing, developing, and disseminating stages. Data collection techniques were online questionnaire methods, online tests, and online interviews. Construct validity was obtained that the assessment was valid and reliable. A total of 19 questions were categorized as medium and one easy question. The analysis of the conceptual understanding test obtained results 29.98% of students who understood the concept, 31.4% did not understand the concept, 2.82% of false positive, 3.38% of false negative, and 31.12% with misconception. There were 26 kinds of student misconceptions identified. The dominant misconception identified in the concept of circuit resistance arrangement was 40.2%. Students assumed that electrons flow from high to low potential in a closed circuit with a DC voltage source. The research results in a five-tier diagnostic assessment can be used in vocational colleges in general. The results of data analysis show that the five-tier format of the assessment can reveal students' misconceptions in detail and, more specifically, distinguish students who have misconceptions from students who are false positive and false negative to reveal students who have misconceptions better. The researcher's development procedure can be used as an example for other researchers to develop a five-tier format diagnostic assessment on other basic concepts.

Keywords: Conceptual Understanding; Electrical Engineering; Five-Tier Diagnostic Test

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INTRODUCTION

Learning Physics according to the 2013 Curriculum has goals including so that students have the ability to mastery of concepts, knowledge, and skills of physical processes, and strengthen mastery of science and technology as well as confidence in continuing education. Based on empirical experience, Physics is a subject that is

considered scary. Students own correct understanding of concepts in the basic concepts of physics to be able to attend lectures. Students' lack of understanding of some fundamental physics concepts must be overcome (Muna, 2016).

Conceptions that are different or contrary to the conceptions of experts are called misconceptions (Berg, 1991). A

misconception is a concept that does not follow scientific understanding or understanding accepted by experts in mathematics and science.

Misconceptions can be in the form of an inaccurate understanding of concepts, misclassification of concepts mastery, incorrect examples of concepts application, different meanings of concepts, confusion of different concepts, and incorrect hierarchical relationships of concepts (Suparno, 2013). It will be more difficult to straighten out if teachers do not realize that they have misconceptions. For this purpose, a misconception diagnostic test for teachers is needed. Misconception diagnostic tests can be in the form of multiple-choice and are considered more efficient. Various forms of multiple-choice diagnostic tests have been developed, one of which is the Four-tier diagnostic test (Eryilmaz & McDermott, 2017).

The four-tier diagnostic test consists of four levels: multiple-choice questions with four choices of answers, an index of student confidence in choosing answers, reasons for answers with four choices, and an index of student confidence in choosing reasons for answers. In its development, in the initial study in the field, the researcher found that some students in choosing the reason for the answer sometimes believed that the reason for the answer was correct. However, the students were not sure that there was a correlation between the answer and the reason. Students often hesitate to determine whether these reasons have a cause-and-effect relationship (correlation) to the chosen answer. The four-tier format diagnostic test needs to be equipped with confidence questions on the correlation of the answers and their reasons. Hence, it is

necessary to develop a four-tier format test into a five-tier format by adding a correlation between the answers and the reasons for the answers at the fifth level. The development of the five-tier format of assessment aims to produce valid diagnostic instruments, be more specific in classifying students' conceptual understanding, and reveal a more detailed profile of students' conceptual understanding.

METHOD

This research was conducted on D3 Electrical Engineering students at two polytechnics in the city of Tegal with a total sample of 60 students consisting of 30 students of the Electrical Engineering study program in the second and fourth semesters of the Politeknik Muhammadiyah Tegal and 30 students of the Electrical Engineering study program in the second and fourth semesters of Politeknik Harapan Bersama Tegal.

The variables studied included expert validity, readability level, construct validity, assessment reliability, and profiles of students' conceptual understanding of simple electrical circuits. The development model used a 4D model consisting of four steps: define, design, develop, and disseminate (Thiagarajan, 1974) (Figure1).

The assessment development consists of "define", "design", "develop", and "disseminate" stages. However, this research only reached the "develop" stage due to time and energy limitations. The "define" stage consists of needs analysis, literature study, curriculum analysis, and peer input. The "design" stage consists of preparing the assessment and its grid, preparing an expert validation questionnaire, and a legibility test questionnaire.

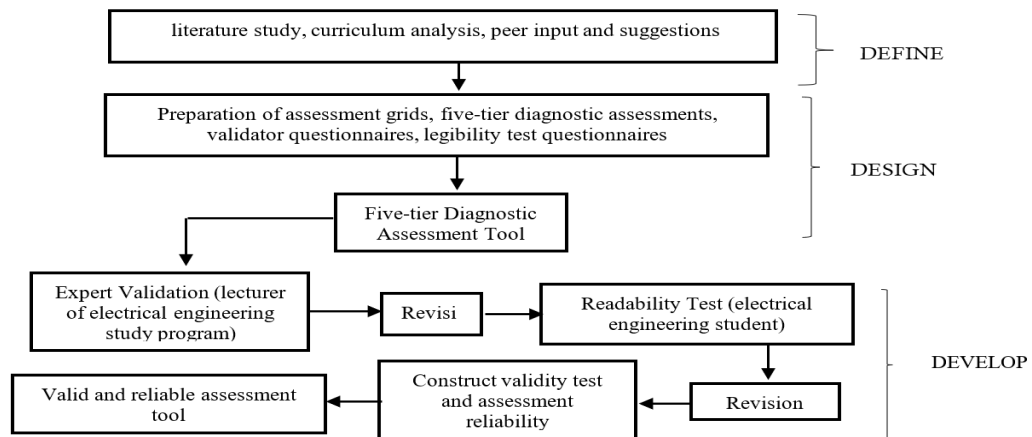


Figure 1 The Assessment Development Flow

The "develop" stage consists of expert validation by two electrical engineering study program lecturers. The expert validation questionnaire consists of the material suitability, the assessment readability, and the assessment suitability with the learning objectives. The results of expert validation obtained the validity of the assessment and revision according to the validator's suggestions. The test questionnaire legibility includes the readability of sentences, the ease of the assessment language to be understood, and the clarity of the images. Questionnaires were given to ten students. The large-scale test aimed to determine the construct validity, reliability, level of difficulty, and discriminating power of questions in the assessment. A large-scale test was carried out on 25 second-semester electrical engineering students at the Muhammadiyah Tegal Polytechnic. Construct validity analysis with Pearson

product-moment correlation analysis with the help of SPSS software. Analysis of the instrument's reliability with Cronbach's Alpha formula, the minimum value of reliability (0.600) (Sujarweni, 2014). If the value of $r_{\text{count}} > 0.600$, then the assessment is reliable.

The student's concept understanding test results were analyzed by matching the true-false answers and the confidence index to the answer interpretation guidelines. The results of the interpretation of the answers are then mapped and classified into understanding the concept, not understanding the concept, false positive, false negative, and misconception. Students indicated misconceptions were then conducted in-depth interviews to strengthen the findings and explore the factors causing misconceptions (Eryilmaz & McDermott, 2017). Conceptual analysis and the causes of student misconceptions are shown in Figure 2.

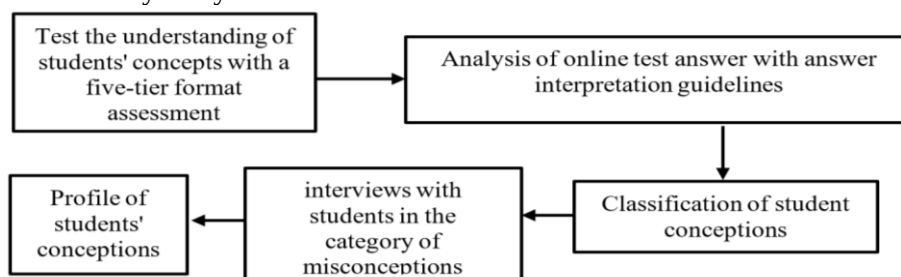


Figure 2 Conceptual Analysis and Cause of Student Misconceptions

Confidence index analysis used the certainty of response index (CRI) method (Syuhendri, 2014). CRI is a good instrument to distinguish a person's conception, whether he has the correct conception, lacks knowledge, or experiences misconceptions. The confidence level is high if it has a CRI >

2.5, while the confidence level is low if it has a CRI < 2.5. The answer interpretation guidelines use the interpretation guidelines developed by Setiawan & Faoziyah (2020), adopted from Gurel et al. (2015). Interpretation Guidelines Five-tier diagnostic test answers are presented in Table 1.

Table 1 Guidelines for Interpreting Five-Tier Diagnostic Test Answers

Answer	Answer confidence level	Reason	Reason confidence level	Confidence correlation answer with reason	Criteria
right	high	right	high	Sure	Understand Concept
right	high	right	high	not sure	Do not Understand the concept
right	low	right	low	Sure	
right	low	right	low	not sure	
right	high	right	low	sure	
right	high	right	low	not sure	
right	low	right	high	sure	
right	low	right	high	not sure	
right	low	false	low	not sure	
false	low	right	low	not sure	
false	low	false	low	not sure	
right	high	false	low	not sure	
false	low	right	high	not sure	
right	low	false	high	not sure	
right	high	false	low	sure	
right	low	false	low	sure	
right	low	false	low	sure	
false	high	right	low	sure	
false	high	right	low	not sure	
false	high	right	high	not sure	
false	low	right	high	sure	
false	low	right	low	sure	
false	high	false	low	sure	
false	high	false	low	not sure	
false	low	false	high	sure	
false	low	false	high	not sure	
false	low	false	low	sure	
right	high	false	high	sure	False Positive
false	high	right	high	sure	False Negative
false	high	false	high	sure	Misconception

The interpretation results of the answers were then grouped, and the percentage of each category of understanding was calculated using the formula (1) (Sudijono, 2009).

$$J = \frac{n}{N} \times 100\% \quad (1)$$

Where :

J = Percentage of each category of student understanding

n = Percentage of each category of student understanding

N = Total number of respondent

RESULTS AND DISCUSSIONS

The resulting assessment product was a misconception diagnostic assessment tool consisting of: an assessment grid, online diagnostic test instruments in a five-tier format, scoring guidelines, and interview sheets to explore in-depth students' misconceptions and the factors that cause misconceptions. Expert validation was carried out by three lecturers of the electrical engineering study program at the Politeknik Muhammadiyah Tegal. Assessment in expert validation includes the suitability of the material with the grid, clarity of images, grammar used. The results of expert validation showed that of the 22 questions, 15 questions could be used with slight revisions.

The readability test was conducted on ten electrical engineering students in the second semester of the Politeknik Muhammadiyah Tegal. The readability test includes the ease of language in the assessment, the clarity of the picture, and the material suitability with the learning objectives. The readability test results

showed that the assessment had a good level of readability, was easy to understand, the pictures were quite clear, and the material corresponded to the learning objectives. It is in line with Setiawan & Faoziyah (2020) which stated that a readability test needs to be carried out on a five-tier diagnostic assessment to obtain the assessment readability level, the ease of the language to be understood, the clarity of the images in the assessment, and the suitability of the material.

Validity and reliability tests were conducted on 20 electrical engineering students. The validity test uses the moment product correlation formula proposed by Pearson (Arikunto, 2012). The test results on 22 questions with SPSS software obtained 15 valid questions. The analysis results with SPSS software obtained the value of $r_{count} = 0.825$ so that the assessment was reliable. It is in line with Setiawan & Faoziyah (2020), which stated that the reliability test results on the developed five-tier diagnostic assessment are reliable.

The conceptual understanding test involved 50 electrical engineering students of the Politeknik Muhammadiyah Tegal and the Politeknik Harapan Bersama. The conceptual understanding tests were conducted online using google form media. The results of the conceptual understanding test were then obtained by students who understood the concept, did not understand the concept, false positives, false negatives, and misconceptions. The profile of the understanding of the concept of electrical engineering students in detail is presented in Table 2.

Table 2 . Profile of Concept Understanding of Electrical Engineering Students

Subconcept	Concept understanding (%)				
	Understand	Do not understand	false positive	False-negative	misconception
Electric current	29.1	38.1	3.4	3.2	40.2
Electrical voltage	40.1	20.1	3.5	3.9	32.4
Kirchoff's Law	24.6	40.2	2.6	3.9	22.2

Subconcept	Concept understanding (%)				misconception
	Understand	Do not understand	false positive	False-negative	
Energy and Electrical Power	22.5	35.8	2.8	4.3	34.6
Circuit resistance	33.6	22.8	1.8	1.6	26.2
Average (%)	29.98	31.4	2.82	3.38	31.12

The biggest misconception is that 40.2% is found in the circuit resistance sub-concept, while the lowest misconception is 22.2% is in the electric current sub-concept. It is in line with Setiawan (2019) in his research on the analysis of understanding the concept of dynamic electricity with a four-tier format assessment in maritime schools where the most dominant misconceptions about electric power are 44.8%. The other largest misconception is 34.5% in the concept of simple electrical circuit resistance, electric current in a closed circuit, and the composition of a mixed resistance circuit. Another similar study was also conducted by Mavhunga et al. (2016), which stated that the results of the analysis of the understanding of physics teachers' concepts on electrical circuit material found teachers' misconceptions about electrical circuit material in transferring concepts to other materials. It confirms many misconceptions about electrical material for students and teachers, especially on the concepts of circuit resistance and electric current, where the percentage of students' misconceptions on these two concepts is relatively high.

The interview results showed that the factors that caused students' misconceptions were: reading textbooks, learning activities, the intuition of daily

life, and conceptual appreciation. According to Suparno (2013), the factors that cause the emergence of conception include intuition in daily life, learning, reading textbooks, knowledge as fragments, knowledge as a theoretical structure, and conceptual appreciation. Students sometimes get their conceptions from reading textbooks, both printed and electronic books. So, the cause of the misconceptions they experience is derived from the factor of reading textbooks.

Students sometimes explain that their conceptions are obtained during the face-to-face learning process, so the cause of their misconceptions is the learning activities. Some other students said that the concepts they had were obtained when they related the problems in the test to everyday events that they had experienced. The reason for their misconceptions was intuition in daily life (Bayuni et al., 2018).

Some students explained that their conceptions were obtained from thinking according to logic associated with the theories they had studied so that the reason for their misconceptions was conceptual appreciation (Linuwih, 2013). In general, the various student misconceptions and the factors causing the misconceptions are presented in Table 3.

Tabel 3. Various student misconceptions and the factors causing the misconceptions

Subconcept	Misconceptions	Causative factor
Electric current	The lamp lights up because the free electrons in the conductor move towards the lamp.	Textbook reading
	In a closed circuit with a DC voltage source, electrons flow from high potential to low potential	Learning activities and reading textbooks

Subconcept	Misconceptions	Causative factor
Electrical Voltage	The electric current flowing at the junction is the same because the voltage source is the same	Intuition in daily life
	The electric current at the point closest to the voltage source has the most significant value.	Intuition in daily life
	An electric current flows from low potential to high potential.	Textbook reading
	Large diameter wire onerously conducts electric current because of the large resistance load	Intuition in daily life
	The potential difference at each point of a series-parallel mixed circuit is equal to the source voltage.	Conceptual appreciation
	The voltage at each point is proportional to the number of conductor resistance arrangements; reducing the conductor resistance makes the voltage at each point reduced.	Conceptual appreciation
Kirchoff's Law	The electric current flowing through two parallel branches is always divided equally.	Textbook reading and intuition in daily life
	The greater the branching resistance, the greater the value of the electric current.	Intuition in daily life
	The electric current flowing in a parallel circuit is always the same because the voltage value is the same.	Textbook reading and learning activities
Energy and Electrical Power	The addition of resistance/resistor causes the electric power to increase.	Intuition in daily life
	The addition of a resistor does not affect the value of the electric power of the circuit	Intuition in daily life
	The more the number of resistors, the greater the electric power.	Learning Activities
	The power dissipation of a parallel voltage source array is less than that of a series array	Intuition in daily life
	The arrangement of lights that are located closer to the battery will absorb more electrical energy.	Intuition in daily life
	The point closest to the voltage source has the most significant potential difference.	Intuition in daily life
	The electric power of the circuit is only affected by the number of voltage sources.	Intuition in daily life
	The arrangement of series and parallel voltage sources produces the same amount of electrical energy.	Conceptual appreciation
	Electrical energy in a conductor without a resistor has a magnitude equal to zero	Conceptual appreciation
Circuit resistance	The series arrangement causes the electric current to flow the same even though one conducting resistance is replaced or removed.	Textbook reading

Subconcept	Misconceptions	Causative factor
	The addition of a resistor causes the voltage and electric current to be hampered	Intuition in daily life
	The total resistance remains when the switch is opened.	Conceptual appreciation
	Reducing the resistance in a parallel circuit causes the electric current to increase so that the voltage increases.	Conceptual appreciation
	Larger conductors/cables always carry more current.	Intuition in daily life
	A wire without a resistor cannot carry an electric current	Intuition in daily life

The most dominant misconception is that students assume that electrons flow from high to low potential in a closed circuit with a DC voltage source. This conception is caused by factors of learning activities and reading textbooks. The results of interviews that students get the concept during the learning process and when studying material from textbooks. During the learning process, students misunderstood the explanation of the concept from the lecturer, so that they experienced misconceptions. When reading textbooks, students also often misunderstand the conceptual material in the book, thus causing students to have misconceptions.

Another dominant misconception is that students think large diameter wires onerously carry electric current because of the large resistance load. Students argued that large diameter cables could only be used for high-voltage power transmission, so the wire has a large resistance. The intuition factor of everyday life causes this student's conception. It is because students associate their conceptions with everyday processes according to events they have experienced.

CONCLUSION

The misconception diagnostic assessment tool developed is valid and feasible to use. Expert validation results were obtained that among 22 questions, 15 questions could be used with slight

revisions. The readability test results showed that the assessment had a good level of legibility and was easy to understand. The results of the validity test on 22 questions with SPSS software obtained 15 valid questions. The results of the reliability test obtained $r_{\text{count}} = 0.825$ so that the assessment is reliable.

The students' concept understanding profile was that 29.98% of students understood the concept, 31.4% did not understand the concept, 2.82% false positive, 3.38% false negative, and 31.12% with misconception. There were 26 types of student misconceptions identified. The biggest misconception of 40.2% was in the sub-concept of circuit resistance, while the lowest misconception was 22.2% of the electric current sub-concept. The most dominant misconception is that students assume that electrons flow from high to low potential in a closed circuit with a DC voltage source. This conception is caused by factors of learning activities and reading textbooks. The overall interview results obtained that the factors causing student misconceptions are reading textbooks, learning activities, the intuition of daily life, and conceptual appreciation.

REFERENCE

- Arikunto, S. (2012). *Dasar-dasar evaluasi pendidikan*. Jakarta: Bumi Aksara.
- Bayuni, T. C., Sopandi, W., & Sujana, A.

- (2018). Identification misconception of primary school teacher education students in changes of matters using a five-tier diagnostic test. *Journal of Physics: Conference Series*, 1013. <https://doi.org/https://doi.org/10.1088/1742-6596/1013/1/012086>
- Berg, E. V. D. (1991). *Miskonsepsi fisika dan remediasi*. Universitas Kristen Satya Wacana.
- Eryilmaz, A., & McDermott, L. C. (2017). A review and comparison of diagnostic instruments to identify students' misconceptions in science. *Eurasia Journal of Mathematics, Science ,& Technology Education*, 11(5), 989–1008. <https://doi.org/10.12973/eurasia.2015.1369a>
- Gurel, D. K., Eryilmaz, A., & McDermott, L. C. (2015). A review and comparison of diagnostic instruments to identify students' misconceptions in science. *Eurasia Journal of Mathematics, Science and Technology Education*, 11(5). <https://doi.org/https://doi.org/10.12973/eurasia.2015.1369a>
- Linuwih, S. (2013). Konsepsi alternatif mahasiswa fisika pada materi termodinamika. *UPEJ (Unnes Physics Education Journal)*, 2(3), <https://doi.org/10.15294/upej.v2i3.2929>.
- Mavhunga, E., Ibrahim, B., Qhobela, M., & Rollnick, M. (2016). Student teachers' competence to transfer strategies for developing PCK for electric circuits to another physical sciences topic. *African Journal of Research in Mathematics, Science and Technology Education*, 20(3), 299–313. <https://doi.org/https://doi.org/10.1080/18117295.2016.1237000>
- Muna, I. A. (2016). Identifikasi miskonsepsi mahasiswa pgmi pada konsep hukum newton menggunakan certainty of response index (CRI). *Cendekia: Journal of Education and Society*, 13(2), 309. <https://doi.org/https://doi.org/10.21154/cendekia.v13i2.25>
- Setiawan, D. (2019). Mengungkap pemahaman konsep listrik dinamis di sekolah berbasis kemaritiman. *JIPFRI (Jurnal Inovasi Pendidikan Fisika Dan Riset Ilmiah)*, 3(2), 113–120. <https://doi.org/https://doi.org/10.30599/jipfri.v3i2.361>
- Setiawan, D., & Faoziyah, N. (2020). Development of a five-tier diagnostic test to reveal the student concept in fluids. *Physics Communication*, 4(27), 6–13.
- Sudijono, A. (2009). *Pengantar evaluasi pendidikan*. Jakarta: Raja Grafindo.
- Sujarweni, V. (2014). *Metodologi penelitian*. Yogyakarta: Pustaka Baru Press.
- Suparno, P. (2013). *Miskonsepsi &Perubahan Konsep Pendidikan Fisika*. Jakarta: Gramedia Widiasrana Indonesia.
- Syuhendri, S. (2014). Konsepsi alternatif mahasiswa pada ranah mekanika: analisis untuk konsep impetus dan kecepatan benda jatuh. *Jurnal Inovasi dan Pembelajaran Fisika*, 1(1), 56–67.
- Thiagarajan, S. (1974). *Instructional development for training teachers of exceptional children: A sourcebook*.