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Using Four-Tier Test to Identify Prospective Elementary Teacher Students' Misconception on Electricity Topic

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Abstract: The topic of electricity is one of the topics in the Advanced Physics course which has abstract dominant characteristics. The abstract nature of electrical material has the potential to be difficult to understand and has the potential for misunderstanding by students. The four-tier test is a type of test that can be used to identify student misconceptions. The research method used in this study is a quantitative descriptive research with a survey research type. The populations of this study were all first-year prospective elementary teacher students who took the advanced physics courses as many as 30 students. The sampling technique of this study used a saturated sample whose number is the same as that of the study population. The research instrument was in the form of a four-tier test related to electricity topics, totaling 20 questions and divided into the sub-topics of electric current, electromotive force and potential difference, resistance, energy and conductivity of electric current, dc electric circuits, and Kirchhoff's Laws. The characteristics of this four-tier test consist of four levels. The first level is a choice of answers by providing five choices. The second level is the level of the respondent's confidence in the answer choices. The third level is the choice of reasons for the answer chosen by the respondent. The fourth level is the level of confidence in the choice of reasons for the selected answer. Respondents' answer patterns were grouped into three categories, namely understanding the concept, not understanding, and misconceptions. The results showed that the percentage of students in the categories of not understanding concepts, understanding concepts, and misconceptions were respectively 49.65%, 29.38% and 20.97%. Overall, it can be concluded that the dominant first grade students do not understand the concept and some experience misconceptions. The findings of this study may have implications for efforts to improve debriefing in Advanced Physics lectures in the future so as to be able to reduce misconceptions and understand student concepts.

Keywords: Advanced physics course; Electricity topic; Four-tier test; Misconception

Introduction

Physics is one of the scientific disciplines that is closely related to natural phenomena and has been provided to students from elementary to tertiary education levels. Even so, it remains that every student when they enter the classroom has brought their respective conceptions or initial knowledge as they hear and see for themselves so that it is not uncommon to find student understandings or concepts that are different from the scientific concepts possessed by experts and experts, generally accepted in learning Physics. This condition was then termed by a number of research results in science education as a concept error or misconception (Hammer, 1994; Hammer, 1996; Mellu & Baok, 2020; Nurjani et al., 2020; Romine et al., 2013). A number of science education research results reveal that misconceptions are one of the inhibiting variables for the success of students and students in achieving learning outcomes (Arslan et al., 2012; Kaltakci-Gurel et al., 2017; Romine et al., 2013; Taslidere, 2016; Wiyantara et al., 2021; Yang & Lin, 2015). In fact, the existence of this misconception is often not realized by students or the students themselves, students often feel right about the

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concepts they understand and seem to defend the concepts they have. This condition can hinder the process of receiving and assimilating knowledge which has an impact on the subsequent learning process (Saputra et al., 2013; Sulistiawarni, 2018; Vellayati et al., 2020; Wulandari et al., 2021).

Research studies on misconceptions about physics learning materials have been carried out in recent decades (Baser, 2006; Bayraktar, 2009; Gurcay & Gulbas, 2015; Hammer, 1994, 1996; Helm, 1980; Kaltakci-Gurel et al., 2017; Novak, 2002; R. Osborne, 1983; Taslidere, 2016). A number of research results state that one of the factors causing misconceptions among students and students is the dominant characteristics of physics material which is abstract and complex so it is difficult to understand, including electricity material (Rahmawati et al., 2021; Suseno, 2014). The results of the study also confirm that students and university students also experience misconceptions about electricity (Bascones et al., 1985; Bilal & Erol, 2009; Didik et al., 2020; Ismail et al., 2015; Maloney et al., 2001; Mellu & Baok, 2020; Novak, 2002). The electricity topic is part of the study of electricity related to a number of concepts related to electric current, series parallel circuits, resistance, electromotive force, Kirchhoff's Laws, direct current electric circuits, and electric power. The characteristics of the electric material resemble other electrical materials which are dominantly abstract in nature so that they have the potential to cause misconceptions for students or university students. Based on this, dynamic electricity material is defined as material that needs to be studied in this study in terms of opportunities for misconceptions among prospective elementary teacher students.

One way that can be taken in diagnosing misconceptions is through the assessment method. The proper assessment method in diagnosing misconceptions can be done using a misconception diagnosis test. A diagnostic test is a test used to find out student weaknesses, so that based on this, appropriate treatment can be carried out (Helm, 1980; Mardapi, 2012; Yang & Lin, 2015). Various types and forms of diagnostic tests have been developed in diagnosing students' misconceptions about physics concepts. One of them is a multiple choice test (Mutlu & Sesen, 2015; Queloz et al., 2017). The forms of multiple choice diagnostic tests are ordinary multiple choice (one-tier test), two-tier test, three-tier test, and four-tier test).

The diagnostic test in the form of a one-tier test presents several answer choices that students must choose. This form of the test is the simplest multiple choice test. A one-level multiple-choice diagnostic test cannot distinguish students who answered correctly with the right reasons and students who answered correctly with the wrong reasons (Gero et al., 2019). The weakness of the one-tier test was then developed into a two-tier test. A two-level multiple-choice diagnostic test provides a choice of answers and reasons for students to choose. Through this method the teacher can find out students who answered correctly with the right reasons and students who answered correctly with the wrong reasons. However, the teacher cannot know how strong students could be understand the concepts given (Odom et al., 1995; Gero et al., 2019; Métioui, 2019; Mutlu & Sesen, 2015; Pujiyati, 2018; Septiana et al., 2015; Tan et al., 2005; Tsai & Chou, 2002; Wang, 2004; Widiyatmoko & Shimizu, 2018).

The reasons for the weakness of the two-level test form became the basis for the development of a three-tier multiple-choice diagnostic test. This three-tier test consists of three levels, namely multiple choice, student reasons and the level of student confidence. The form of this test is that students are given several alternative answer choices, reasons, and the level of confidence in answering questions. The three-level multiple-choice diagnostic test only gives students the opportunity to choose a single level of confidence in choosing answers and reasons for each item. This single level of confidence cannot be detected if students have different levels of confidence in choosing answers and reasons (Arslan et al., 2012; Caleon & Subramaniam, 2010; Lin, 2016; Mellu & Baok, 2020; Nicoll et al., 2001; Osborne et al., 2016; Peşman & Eryilmaz, 2010; Tsai & Chou, 2002; Widarti et al., 2019). In contrast to the four-tier test, the four-tier test instrument consists of answer choices, the level of confidence in the answer choices, the choice of answer reasons, and the level of confidence in the choice of answer reasons.

The four-tier test form provides more in-depth information regarding the level of confidence in the answer choices and answer choices as well as the suitability between the answer choices and the reasons so that the chances of guessing are very small (Ismail et al., 2015; Janah & Mindyarto, 2020; Maison et al., 2019, 2020; Nurjani et al., 2020; Nurulwati & Rahmadani, 2020; Rahmawati et al., 2021; Ibnu et al., 2019; Suteno et al., 2021; Yang & Lin, 2015). Ismail et al. (2015) in their research using a four-tier test diagnostic test to identify high school students' misconceptions about electricity, emphasized that the four-tier test instrument form is a development of the three-tier test form combined with a confidence rating on the reasons for answers so that the level of confidence is more accurate, for the answers and reasons for the answers. Based on a number of existing descriptions, this study decided to identify the misconceptions of prospective physics teacher students on the topic of dynamic electricity by using a diagnostic instrument of four-tier test.

Method

This research is a type of survey research with a quantitative descriptive research method. The subjects of this study were first-year physics teacher candidates who took the Advanced Basic Physics course before receiving material debriefing on Electricity topic with a total of 30 people. The research instrument is a test in the form of a four-tier test which contains material and concepts related to Electricity topic with a total of 20 questions. All possible patterns of respondents' answers were previously interpreted and grouped based on similar answer patterns. The categorization of answer interpretation patterns was adapted from Gurcay & Gulbas (2015) as shown in Table 1.

After categorizing the patterns of interpretation of students' answer, the next step was to develop a scoring rubric for the patterns of interpretation of students' answer. The complete scoring technique for the respondents' answers is given in Table 2.

Table 1. Categorization of Student Conceptions based on Interpretation Patterns of Students' Response

Answer	Level of Confidence	Reason	Level of Confidence	Category
True	High	True	High	Understand
True	High	True	Low	
True	Low	True	High	
True	Low	True	Low	
True	High	False	Low	
True	Low	False	Low	Not Understand
False	Low	True	High	
False	Low	True	Low	
False	Low	False	Low	
True	High	False	High	
True	Low	False	High	
False	High	True	High	
False	High	True	Low	Misconception
False	High	False	Low	
False	High	False	High	
False	Low	False	High	

Table 2. Student Conception Scoring Rubric on Electricity Topic

Category of Answer	Score
Answers and reasons are correct with a high level of confidence in the choice of answers and reasons	3
Answers and reasons are correct with a low level of confidence in the choice of answers and reasons	2
True answers, false reason or vice versa	1
False answers and reasons	0

The next step is to categorize the total score obtained from the respondents' answers by using Table 2 as a scoring guide for the pattern of respondents' answers. The categorization of students' conceptual knowledge is based on the categorization according to Wulandari et al. (2021) which is shown in Table 3.

Table 3. Categorization of Student Conception Knowledge Levels on Electricity Topic

Score Range (%)	Category
0-30	Low
31-60	Middle
61-100	High

Result and Discussion

This test for diagnosing students' misconceptions on the topic of electricity consists of 20 items spread over several sub-topics. The material and electrical concepts developed in this test are electric current, resistance, resistivity, Ohm's law, electric motion voltage, energy and conductivity of electric current, resistors in series, parallel and mixed circuits, Kirchhoff's law, charging and discharging rc circuits capacitor. The distribution of material and items is shown in Table 4. All items on the electrical diagnostic test are arranged and distributed in the dimensions of factual, conceptual, and procedural knowledge with levels of cognitive processes starting at the level of understanding (C2) to evaluating (C5).

As a representative to see the full picture of the diagnostic test form used in this study, the following is an example of one of the items contained in the diagnostic test as shown in Figure 1 to measure the misconceptions of prospective elementary teacher students on electricity topic. The results of the study related to misconceptions were obtained by administering the four-tier electricity diagnostic test to 30 students as shown in Table 5.

Table 4. Blue Print Misconception Diagnostic Test on Electricity Topic

Sub Topic	Material
Current and Resistance	Current
	Resistance
	Resistivity
	Ohm' Law
	Electromotive voltage
	Energy and electrical power
Circuits of Direct Current	Resistors in series, parallel and mixed circuits
	Kirchhoff' law
	Capacitor Charging and Discharging RC Circuit

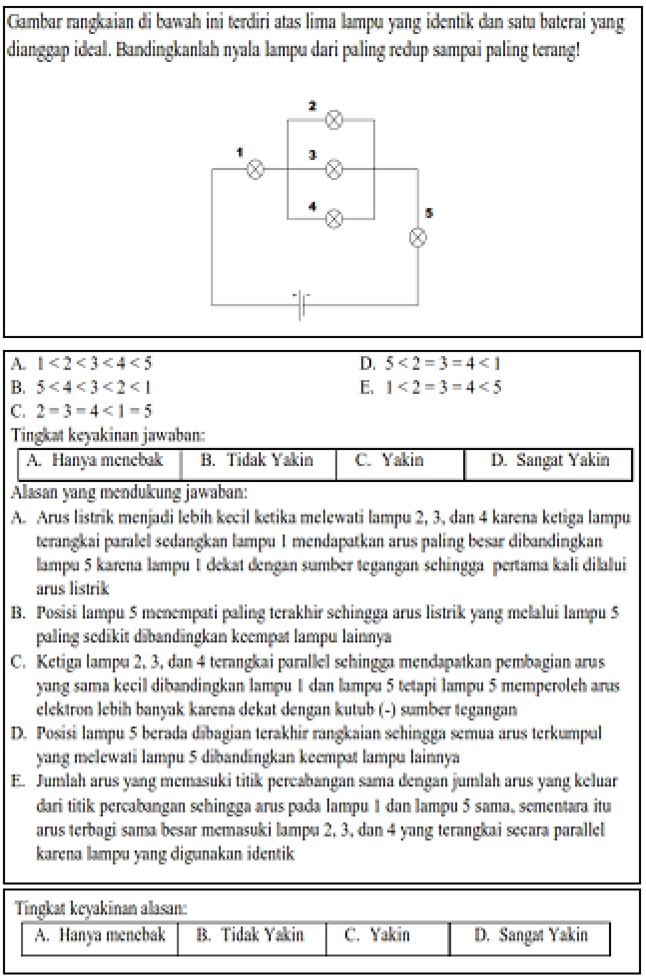
Table 5 shows that the highest percentage of students experiencing misconceptions is in the material of energy & electric current conduction (68%). Many students experienced misconceptions about the material caused by student errors in answering. Students who were not careful in determining electrical components or resistance in a circuit connected in series or parallel cause mathematical calculations to be wrong. This data was reinforced by the second largest percentage of students experiencing misconceptions on the topic of obstacles by 61%. Not only was it wrong to choose the answer with high confidence, many students experienced misconceptions that occurred when students chose the right answer but were wrong in choosing the right reason. This finding was in line with the results of study by Ismail et al. (2015) which also tried to diagnose high school students' misconceptions about electricity-related material that one form of misconception that occurs among students in solving questions was that they were not careful in determining the appropriate reasons for the right answer choices. In addition, the findings of this study are similar to the results of study by Mellu & Baok (2020) that the pattern of students' misconceptions about direct current electrical circuits was that they provide a high level of confidence in the wrong answer choices and choices of reasons.

Table 5. Recapitulation of the Percentage Level of Conception of Prospective Elementary School Teacher Students on the Topic of Electricity

Material	Number of sample (*n*)	Categorization of student conception		
		Misconception (%)	Understand (%)	Not Understand (%)
Electric current	30	23	46	31
Electromotive voltage & potential difference	30	57	21	22
Resistance	30	61	20	19
Energy & electrical power	30	68	14	18
Circuit of Direct Current	30	54	23	23
Kirchhoff' law	30	35	52	13
Mean (%)	30	49.65	29.37	20.98

The next finding was that the highest percentage of students experience misconceptions about the material of electromotive force and potential difference of 57%. Dominant students fail to distinguish between the concept of potential difference and the concept of electromotive force in solving problems of electric circuits consisting of several resistance components connected in series and parallel in one circuit. Thus, impact on the mathematical analysis and the results of the final calculation. The same problem occurred in direct current electrical circuit materials. Not a few students mistakenly understand the concept of electric current, thinking that the concept of electric current was a moving positive charge. Of course the concept held by the student was wrong. Because, electric current basically arisen due to the movement of electron charges. This finding was in line with the results of several studies examining the misconceptions of high school students on simple direct current electric circuits using different types of test instruments. For example, research conducted by Peşman et al. (2010) used a three-tier test to analyze the misconceptions of Turkish high school students. The findings showed that in general high school students give a high level of confidence in the wrong answers related to the concept that positive charges move which cause an electric current in a circuit. Similar research results were also obtained by a number of studies using a two-tier test to diagnose students' conceptions of direct current simple electric circuit material that students had difficulty distinguishing the concepts of positive charge and electron charge in the electric current which was the source the voltage in turning on the bulb (Bilal & Erol, 2009; Métioui, 2019; Métioui & Trudel, 2020).

There were as many as 54% of students experience misconceptions about direct current electric circuits. The biggest problem students experience is misconceptions about direct current circuit material caused by various reasons. Some of them, namely students had high confidence in the choice of answers and the choice of reasons for choosing the wrong answer. As an example, given an example of the case of four identical bulbs (Bulbs A, B, C, and D) with bulbs A and B connected in series, arranged in parallel with bulbs C and D in an electrical circuit equipped with a switch component and several batteries as a voltage source. The switch was connected in series with the bulb C. In this case, students were asked to compare the light of the bulb from the brightest to the dimmest when the switch component was open. Dominant students assumed that the brightness of the lights on bulbs A and B was the same as the lights on bulb D. Students understand that the lights on the lights are the same because the magnitude of the voltage (V) in a parallel circuit was the same as the voltage source. Students assumed that the electric current (I) had a constant value flowing in each lamp component so that it was considered not to affect the intensity of the flame on the lamp. In fact, the scientific concept was that the light bulb was determined by the power value where the amount of electric power was influenced by the variable voltage (V) and the variable electric current (I) with the assumption that the bulb is used as the control variable (identical).


Gambar rangkaian di bawah ini terdiri atas lima lampu yang identik dan satu baterai yang dianggap ideal. Bandingkanlah nyala lampu dari paling redup sampai paling terang!

A. 1 < 2 < 3 < 4 < 5
B. 5 < 4 < 3 < 2 < 1
C. 2 = 3 = 4 < 1 = 5
D. 5 < 2 = 3 = 4 < 1
E. 1 < 2 = 3 = 4 < 5

Tingkat keyakinan jawaban:

A. Hanya menebak	B. Tidak Yakin	C. Yakin	D. Sangat Yakin

Alasan yang mendukung jawaban:

A. Arus listrik menjadi lebih kecil ketika melewati lampu 2, 3, dan 4 karena ketiga lampu terangkai paralel sedangkan lampu 1 mendapatkan arus paling besar dibandingkan lampu 5 karena lampu 1 dekat dengan sumber tegangan sehingga pertama kali dilalui arus listrik
B. Posisi lampu 5 menempati paling terakhir sehingga arus listrik yang melalui lampu 5 paling sedikit dibandingkan keempat lampu lainnya
C. Ketiga lampu 2, 3, dan 4 terangkai parallel sehingga mendapatkan pembagian arus yang sama kecil dibandingkan lampu 1 dan lampu 5 tetapi lampu 5 memperoleh arus elektron lebih banyak karena dekat dengan kutub (-) sumber tegangan
D. Posisi lampu 5 berada dibagian terakhir rangkaian sehingga semua arus terkumpul yang melewati lampu 5 dibandingkan keempat lampu lainnya
E. Jumlah arus yang memasuki titik percabangan sama dengan jumlah arus yang keluar dari titik percabangan sehingga arus pada lampu 1 dan lampu 5 sama, sementara itu arus terbagi sama besar memasuki lampu 2, 3, dan 4 yang terangkai secara parallel karena lampu yang digunakan identik

Tingkat keyakinan alasan:

A. Hanya menebak	B. Tidak Yakin	C. Yakin	D. Sangat Yakin

Figure 1. Examples of items on the four-tier electrical diagnostic test

Misconception problems were also found in materials related to Kirchhoff's Law by 35%. In Kirchhoff's Law material, students' misconceptions occurred because they misunderstood and viewed the motion of positive charges and electron charges in an electric circuit. Another problem was that students have had difficulty determining the direction of current when faced with complex electrical circuits, which consist of series and parallel resistance components in one circuit. In addition, it was often wrong to distinguish the direction of the loop and the direction of the current in solving mathematical equations to determine the variable current strength, potential difference, or resistance in a circuit. The findings of this study were in line with a number of relevant studies in diagnosing misconceptions regarding simple electrical circuits, for example the study conducted by Burde et al. (2020). In his research, Burde et al. (2020) found that the concept of voltage is often seen as a property of electric current by most high school students. Similar research results were found by Ivanjek et al. (2021). Ivanjek et al. (2021) in his research found that students had difficulty distinguishing the magnitude of the voltage in series and parallel circuits.

Subsequent analysis was carried out by looking at the percentages and categorization of the level of conceptual knowledge of students of physics teacher candidates on each material on Electricity topic as shown in Table 6.

Table 6. Categorization of Student Electrical Conception Knowledge Levels

Assessment	Material					
	1	2	3	4	5	6
Mean Score	58%	38%	42%	32%	39%	68%
Category	middle	middle	middle	middle	middle	middle

Note: 1 = Electric current; 2 = Electromotive force and potential difference; 3 = Resistance; 4 = Energy & Conductivity of Electric; 5 = Direct Current Circuits; 6 = Kirchhoff's Laws

Table 6 showed that the students' overall conception of the five sub-materials (electric current, electromotive force & potential difference, resistance, energy & electric current conductivity, and direct current electrical circuits) was in the middle category and there was only one sub-material (Kirchhoff's Laws) where the average student had a conception in the high category. It appeared that students were more successful in solving problems related to Kirchhoff's Laws compared to other problems related to electricity topic. The findings of this study looked unique because students were able to solve problems better on more complex electrical content than simple material content. To obtain additional information related to the findings of this study, the test results were followed up by giving interviews to all students who were the research sample. The results of the interview showed that in general students sometimes forget similar concepts for different cases. However, when students tried to focus on recalling memories on the same concept, students could succeed perfectly in solving different problems. The accumulation of similar concepts in simple and repeated cases in complex cases was an opportunity for students to be successful in solving problems. This condition made some students succeed in more complex cases with similar and repetitive concepts.

The test results obtained were then categorized based on the student's response. Categorization of students' conceptual knowledge was divided into three categories according to Wulandari et al. (2021), namely high, middle, and low. The results of the analysis of the level of conceptual knowledge on student responses based on their categorization were shown in Figure 2.

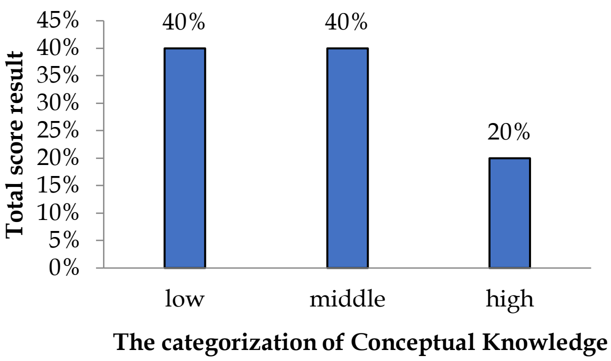


Figure 2. Students' conceptual knowledge on electricity topic

Figure 2 showed that the highest percentage of students' conceptual knowledge was in the low and medium categories with a percentage of 40%. Based on the analysis of students' conceptual knowledge, it was found that the characteristics of electricity and magnetism material were abstract. The abstractness of this electrical material was one of the reasons why it was difficult for students to understand (Finkelstein, 2005), even though there were other factors that can cause failure to understand the material.

There were three factors that cause electrical material to be understood. *First*, the characteristic of the electricity topic. *Second*, the techniques used by educators in presenting the lecture material. *Third*, the level of thinking skills that student must have to be able to learn it. The results of similar previous studies indicated that the difficulties experienced by students in understanding electrical material were caused by the level of thinking skills possessed by students who have not been able to accommodate rather than comprehensively understand abstract electrical material (Hekkenberg et al., 2015). These inadequate thinking skills cause difficulties for students in analyzing, accessing, and constructing parts of the knowledge gained while attending lectures. However, apart from all these problems, one of the keys to student success in the learning process lies in selecting the right learning strategy by the lecturer.

Conclusion

The level of prospective elementary teacher students' conceptual knowledge was divided into three categories, namely understand of concept, not understand, and misconceptions. The four-tier test is a type of various test specifically designed on the topic of electricity to identify students' level of concepts. The four-tier test was also a development of misconception diagnosis instruments such as two-tier and three-tier which are considered to be very simple and unable to provide comprehensive information. Administering a four-tier test to prospective elementary teacher students provided information that the highest percentage of student conceptions on electricity topic was in the category of misconceptions. The highest percentage of misconceptions was found in the material of electromotive force and potential difference, resistance, as well as energy and electric current conductivity respectively by 57%, 61% and 68%. The implication of the results of this study is that the results of this research become the basis for developing strategies and learning models that are able to reduce student misconceptions, especially in Advanced Physics courses.

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