Pre-service students' misconceptions about simple

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Abstract. Despite all the efforts made by Physics Education Researchers in terms of strategies to enhance students' conceptual understanding of electric circuit phenomena, students still have conceptual difficulties related to solving problems related to electric circuits. The difficulty is worsened by the presence of misconceptions about electric circuit phenomena. In terms of constructivism, the preparation for teaching should start with identifying what students know prior to instruction. In line with this pedagogy, the research reports how a three-tier concept test was used to the identify misconceptions the pre-service students have. Although the current study found significant correlation between students' level of confidence and conceptual understanding, it did find that most misconceptions are identifiable through explanations where students feel confident about their incorrect choices in the first tier.

1 Introduction and background

Teaching is a multifaceted endeavour that aims to facilitate students' comprehension of concepts applicable to real-life problem-solving. The same principle applies to the teaching of electricity, upon which we all rely to enhance our lives. Literature revealed that the teaching of electricity comes with a challenge because students interpret the relationship of potential difference, current and resistance using the mathematical equation of ohm's law. Previously it was found that Introducing Ohm's law mathematically before qualitatively grasping its underlying physical quantities poses a challenge, resulting in students applying the formulae without comprehending its significance [1]. [2] also highlighted that most students graduating from secondary school have a very basic understanding of basic circuits concepts like voltage, resistance, and current. Research conducted all over the world has revealed that students frequently hold different beliefs about the nature of electricity and how it behaves in basic circuits, and that these beliefs are resistant to modification even after several years of secondary school and post-school training [3]. These different beliefs students have that are not consistent with the conceptions of scientists are also termed misconceptions. The use of a three-tier test to assess or diagnose misconceptions is common. For example, [4] developed a three-tier test to assess students' misconceptions about basic electric circuits and [5] did the same in assessing misconceptions in algebra to mention just a few.

The present study, the three-tier test was structured as follows: the first part of the tier was a multiple choice, the second part was the reasons to be given by students for selecting the option in the first tier, and the third tier was their confidence level. When students explain the reasons behind their choice there will be the possibility of identifying new unreported conceptions and misconceptions. The confidence students have is an indication of how certain they are in terms of understanding the concept [6]. According to [6] , students who are correctly confident can build more understanding of core concepts which is advantageous for applying and handling of sophisticated ideas. On the other hand, those who are incorrectly confident are likely to have misconceptions.The present study presented how the three-tier concept test assisted in revealing misconceptions. The study was guided by the following research questions:

i. How do students understand the impact of an electric field on the movement of charges in a circuit?
ii. How do students understand the difference between the conductor and a resistor in the context of basic electric circuit?
iii. How do students understand the global impact in a circuit of changing circuit element or the value of the circuit element?
iv. How do students compare the speed of charges in a conductor and a resistor?

2 Research Designs and Procedures

The participants were forty-three first year Bachelor of Education (B.Ed) preservice students (52.4 % males and 47.6 % females) who were purposely chosen considering that they had learnt the subject in high school. The main intention was to diagnose misconceptions they have about basic electric circuit before instruction.

The three-tier concept test was designed to target some of the misconceptions reported in literature. preservice students' understanding of the impact of an electric field on the movement of charges in a circuit, the difference Data was collected using the google form for easy retrieval and analysis. The responses from the multiple choices and level of confidence were numerically counted and sorted according to similarities of the responses, and the explanation were phenomenographically [7] categorized. Figure 1 shows items on the designed three-tier test.

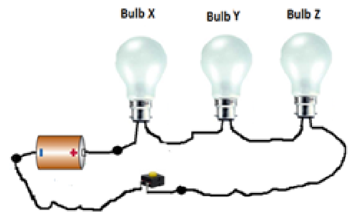
Instructions: Use figure 2 for answering all questions. In each question, first select your correct answer, then explain the reason(s) for your choice and lastly, rate your level of confidence in your choice of answer and the explanation you gave on the scale from level 1 to level 5. Level 1 represents not confident at all, while level 5 represents the fact that you are very confident.

Question 1: *When switch S is put on, which bulb will shine/glow first?*
A: All B: Bulb X C: Bulb Z
Explanation_________________ Confidence level___

Question 2: *When switch S is put on, what will happen to the brightness of bulbs X and Z if the resistance of bulb Y is increased,*
A: bulbs X and Z will be brighter B: bulbs X and Z will be dimmer C: Bulb X same, bulb Z dimmer D: Bulb X brighter, Bulb Z same
Explanation_________________ Confidence level___

Question 3: *When switch S is on, it was found that bulbs X and Z are glowing , but bulb Z did not glow at all. The reason for bulb Z not glowing is because:*

A: Bulb Z has a very high resistance B: Bulb Z has a very low resistance C: Current will be too weak by the time it reaches z
Explanation_________________ Confidence level___



Question 4: *When switch S is on, do you think the speed of charges through the whole circuit will be the same?*

A: Yes B : No C: Not sure
Explanation_____________ Confidence level___

Figure 1: Three-tier concept test

3 Results and Discussions

In this section, the question will be presented , then its intention and later the results per question will be presented as subsections of the options selected by participants. The correct options are colored red together with their level of confidence

3.1 Question 1 results: Which bulb will glow first?

The question probed students' understanding of the global establishment of electric field that causes all charges in the whole circuit to move the switch is put ON, hence all bulbs shine at the same time. Table 1 (left) represents percentage options and level of confidence selected by students. According to table 1, 40 % of students opted the correct choice which is " ALL", and another 40 % chose bulb X while the remaining chose bulb Z. It should be noted that all percentages were converted to the nearest whole number.

Confidence Level	ALL	Bulb X	Bulb Z
Level 1	7	5	0
Level 2	5	9	2
Level 3	9	9	0
Level 4	5	7	7
Level 5	14	9	9
Total	40	40	19

Confidence Level	Bulbs X &Z will be brighter	Bulbs X &Z will be dimmer	Bulb X same, and Z dimmer	Bulb X dimmer & Z brighter
Level 1	7	2	0	9
Level 2	2	9	5	0
Level 3	14	7	2	2
Level 4	0	7	5	0
Level 5	5	23	0	0
Total	28	49	12	12

Table 1: (left) Preservice students' responses to questions 1, (right) Question 2 responses

3.1.1 The ALL option

Only one student (2 %) with a level 5 confidence rating gave the correct explanation. It was expected that all students with a level of confidence above 3, which is 20% of the correct choices will give the correct explanation, but their explanations were opposite. For example, one of the notable explanations given by a student with level 4 confidence rating was: "*In a series circuit, all the bulbs (X, Y, and Z) will light up at the same time when the switch is turned on. This is because in a series circuit, the current flows through each bulb one after the other, so the same amount of current reaches all bulbs at the same time. Therefore, none of the bulbs will light first they all light up together as soon as the switch is on*." The statement revealed two misconceptions: " current flow in a sequence" and "same time related to same current in the series circuit." The explanation shows that the students opted the correct answer with the incorrect reasoning even if the level of confidence was high.

Another notable explanation given by student with level 1 rating was "*Before the lights go on the current and voltage given by a battery will start by moving from positive to negative terminal without lighting the bulbs, by that it will be observing whether the bulbs are connected is series or parallel then the second move after checking it will turn on the light at the same time."* The explanation shows student's lack of understanding what a voltage is and misconception at the same time. The idea that voltage first observes if the circuit is in series or parallel before turning the light is misconception.

3.1.2 The Bulb X

Forty percent chose bulb X. One of the notable explanations given by student with level 1 " Current flows from positive to negative terminal of the battery and bulb X is connected to the positive terminal of the battery, which means it will receive the current first to light." This is what was called " the conventional direction of current challenge" . It shows that conventional direction of current is not explained qualitatively [8].

3.1.3 The Bulb Z option

One of the notable explanations given by a student was about the position of the switch in a circuit. *"As current flow from positive to negative, current will not pass switch S to reach Bulb Z"*

3.2 Question 2 results: The impact of changing the resistance of bulb Z

The question probed students' understanding of the global impact of changing and circuit element. The correct choice is: The brightness of bulbs X and Z will decrease because increasing the resistance of bulb Y will automatically increase the total resistance of the circuit, reducing the current at the same time. In series circuits the brightness of the bulb depends on current.
Table 2 shows that 49 % of students opted for the correct choice. and about 30 % of the 49 % have the level of confidence of above level 3, which means that they are confident about their choices and explanations they gave.

3.2.1 Bulbs X and Z will be brighter

Table 1 (right) shows that this option was chosen by 28 % of the participants, and most of the were not that confident. However, one of the explanation by a student with confidence level 5 was:" *Since resistance is inversely proportional to the current bulb X and Z will receive a great current which will make them to increase in bright since their resistance is lowered"* and another one with confidence level 1 was:
One of the notable explanations was: "*The current flow to the bulb Y will be decreased allowing more current flow to the other two bulbs thus increasing their brightness*."

3.2.2 Bulbs X and Z will be dimmer option

Table 2 shows that the correct option was chosen by almost 50 % of students and only 14 % gave the correct explanations, the others revealed lack of understanding as revealed by the following statement: "the answer i'm looking for i can't see...i would say the brightness of both X and Z would remain the same ...they are not affected by bulb Y's change...unless if the switch plays a part."

3.3 Question 3 results: Why is bulb Z not glowing?

This question was aimed at checking students' understanding of the difference between the conductor and the resistor.

Confidence level	Very high resistance	Very high low resistance	Current too weak by the time it reaches Z
Level 1	14	2	2
Level 2	14	2	0
Level 3	21	0	7
Level 4	12	2	5
Level 5	14	0	5
Total	74	7	19

Confidence Level	Yes	No	Not sure
Level 1	12	12	0
Level 2	2	2	5
Level 3	14	9	2
Level 4	5	16	2
Level 5	7	12	0
Total	**40**	**51**	**9**

Table 2: Preservice students' responses to question 3 (left), (right) Responses to question 4

In a basic series electric circuit with bulbs, when the switch is put on, energy transformation which causes the bulb to glow will happen in a resistor due to the speed of charges through the resistor. The series circuit was chosen because it has been noted that students already memorized that current is the same in series circuit. The results of this question were consistent with the one reported previously. The following sub-sections discuss the options and explanations preservice students gave.

3.3.1 A very high resistance option. Based in table 3, this option was chosen by 74 % of preservice students and 26 % of their level of confidence was above level 3, which shows that they were confidence about the choice of option and their explanations. However, their explanation revealed the misconception they have. They indicated that bulb Z has a very high resistance, that's why it is not glowing. Their reasoning was based on their lack of knowledge of the difference between a conductor and a resistor.

3.3.2 A very low resistance option. This was the correct option scientifically. Bulb Z is not glowing because it is acting as the conductor with low resistance which doesn't get burnt when charges are moving through it. Only 7 % of the students opted for this one. Based on their explanations, it can be concluded that they guessed the answer. One of the explanations with level 4 confidence level was " *The more resistance a bulb has, the brighter it will be.*" This is only applicable when resistors are connected in series.

3.3.3 Current too weak by the time it reaches Z. This option was a misconception also reported previously. Based in table 3, only 19 % selected this option , however their explanations revealed additional misconceptions as evident on the following notable explanations: **"***Current moves from positive to negative, so current was able to move from battery to X and Y then it is situated after them and it was opened leading to less current delivered to bulb Z because of the open switch."* Another interesting explanation by students with level confidence of 5 was as follows: *"Charges take a longer distance to reach Bulb Z which by then it will receive a shorter current."* This is the distance misconception and again can be solved by introducing the field model to teach basic DC circuit [3]. Again, another student indicated that: "*In a series circuit, the current flows through each component in sequence. As the current flows through each component, some of the energy is lost, reducing the current, by the time the current reaches bulb Z, it may be too weak to light it up*." This misconception was also reported in literature [8].

3.4 Question 4 results: The speed of charges in basic electric circuit

This question was a continuation of question 3. The speed of charges in an electric circuit determines how energy can be converted. Scientifically charges move faster in a resistor than in a conductor even in a series circuit. The most appropriate answer is “yes”. 40 % of students opted for the correct answer and their level of confidence is shown in table 2 (right).

3.4.1 The “yes” option. This is what a sub-sub-section looks like, and this is where it stops. There are no deeper sections than this and notice this one doesn’t change line after the title. You will need to manually remove the italics after the heading.

3.4.2 Notable “no” option
Some of the misconception revealed by those who are confident but opted for incorrect choices are the following: Student 1 (confident level 5): “*The speed of the charges remains the same throughout the circuit*” This is a misconception that arises from the fact that current is the same in series circuit. To address this misconception, it is advisable to define current as “ the number of charges that passes through a cross-section in one second. Student 2 indicated that: “*The flow of charges is referred to as current, and it must be noted that resistors in series divide voltage and share current, hence since the current is the same throughout, the speed of charges will be the same throughout as well*.” Lastly, student 3 (confident level 4) indicated that: “*In a series circuit, the current flows through each component in sequence, resulting in a constant current that is the same throughout the circuit. As a result, the speed of charges is also the same throughout the circuit, as it is determined by the electric field.”* Nothing significant about the last option “not sure option”

4 Conclusion
Generally, misconceptions revealed in the present study can be resolved using the field model advocated by [3], However, teachers are not using the field model while teaching the basic electric circuit. The study recommends that textbooks or guides be written on how to teach basic electric circuits using the field model so that teachers can be professionally capacitated to teach using the model. Below is the summary of key findings.

4.1 The difference between a conductor and a resistor.
Based on the analysis of preservice students’ responses, it can be claimed that the students who participated in the study do not understand the difference between the conductor and resistor and in addition they also don’t understand the fact that charges can move at different speed in a series circuit while maintaining the same current. According to [3], these challenges can be addressed by introducing the field model when teaching basic electric circuit, and by teaching the role of the physical components of basic electric circuit qualitative before dealing with the conceptual quantities, like resistance, current and potential difference.

4.2 Ohm’s law challenge
The study presented two conceptual challenges related to Ohm’s law and the conventional direction of electric current. *Ohm’s law challenge* can be described students’ misinterpretation of Ohm’s law as follows: While the current in the circuit depends on the resistance of the resistors, resistance do not depend on current but at the same time, during calculations related to Ohm’s law equation V=IR, both current and potential difference can be used to estimate the resistance of the resistor. This challenge concept if not handled qualitatively, can lead to misconceptions about the dependance of resistance on current and potential difference. This is what was called Ohm’s law challenge in this study.

4.3 The current convention challenge
In this study, the current convention challenge was described as pre-service students’ inability to understand that the current convention deals with direction of a positive test charge in an electric field region which is taken as the direction of current, not that current flow sequentially from one point to another. This challenge can be resolved also using the field model where the rapid establishment of the field through the whole circuit almost at the speed of light explains the movement of all charges at the same time. If this challenge is not resolved, students can have misconceptions related to sequential reasoning as revealed by some of the students who confidently answered question 1 as follows: *Bulb X will shine first because it is nearer to the positive terminal of the battery.*

4.4 Confidence “level and conceptual understanding
Although the current study found no correlation between students' confidence and conceptual understanding, it did find that most misconceptions are identifiable through explanations where students feel confident about their incorrect choices.

4.5 Limitation of the study

Based on the qualitative nature of the study, it cannot be generalized to other different contexts, however teachers can use the knowledge when doing their preparations.

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