Learners' understanding of ammeter and voltmeter in DC schematic circuits

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Abstract. This study explores learners' knowledge of measuring devises in a direct current resistive circuit. It investigates learners' understanding of how ammeter and voltmeter should be connected and why they have to be connected in a particular way. Ammeter and voltmeter are used to determine the behaviour of a circuit by indicating the readings of current and voltage, respectively. To an educator an ammeter does not change the characteristics of a circuit; it is therefore an invisible component. However, a learner views an ammeter differently. A pen and paper questionnaire was administered to grade 12 learners and group interviews were used as additional evidence. The study seeks to promote the understanding of measuring devises and the role they play in electrical circuits. The results indicated that learners lacked the basic understanding of the role played by measuring devises. It was also evident that because of lack of practical experience with real circuits, some learners did not know how measuring devises should be connected. The findings imply since learners had difficulties with concepts differentiation the role played by their measuring devises was not understood.

1. Introduction

The present study seeks to promote the understanding of measuring devises and the role they play in electrical circuits. A clear understanding of the measuring devises is essential, if one is to introduce a scientific vision of electrical circuits to learners. After secondary education, learners are expected to have developed mental models of what is going on in electrical circuits that enables them to demonstrate an understanding of key concepts like current and potential difference [5]. The measuring devises helps to visualize the abstract concepts that cannot be seen with a naked eye. In connecting devises such as ammeter and voltmeter to a circuit, their roles should be understood and taken into consideration. Their presence to a good degree should not affect the functioning of the circuit [6]. Learners are expected to appreciate the effect of changes made by adding measuring devises in parallel or series in a circuit. It is expected that they be able to connect measuring devises and also to offer explanations in terms of scientific principles [9]. However, numerous studies on current, potential difference and brightness of bulbs have shown that learners still have difficulties and misunderstandings after systematic instruction [7]. This study focused only on learners' knowledge of the use of ammeter and voltmeter in a direct

current resistive circuit. It investigated learners' understanding of how measuring devices should be connected and why they had to be connected in that particular way.

2. Research Methods

2.1 Instruments

In this study, a questionnaire was administered to secondary school learners. The questionnaire consisted of multiple-choice items and a part where learners had to provide reasons for their responses. Structured group interviews were used to support the questionnaire data. Due to limited space, in this paper only quantitative data will be presented. To check for content and language validity, questionnaire was checked by two Physics (foundation) lecturers and one foundation English lecturer.

2.2 Sampling

A total of 137 grade 12 learners comprising of males and females from two public schools (township and a rural school) in Mankweng circuit participated in this study. This study used cluster sampling technique [2] where the researcher selected the two schools and tested all the grade 12 learners. The selected schools did not have laboratories or apparatus to perform experiments. A relatively larger percentage (56%) of the respondents came from the rural school whilst 44% were from the township school. The average age group for the sample was 18 to 20 years old. It is worth indicating that learners had completed their electricity topics at the time of collecting the data.

2.3 Data analysis

The collected data was analyzed by counting the frequencies of selected options from each multiple-choice question. Written responses were analyzed by extracting patterns and or themes emerging from learners' written responses and to categorize them and counting the frequencies for each category. Chi-square was used to check statistical significance of the results.

3. Results and Discussions

3.1 Role of ammeter

An Ammeter is used to measure current. To measure the current, one need to break the circuit and insert the ammeter at the point where current is to be measured. An ideal ammeter has zero internal resistance, so as to drop as little voltage as possible as charged particles flow through it. However, real ammeters have as little resistance as practically possible [5]. To an educator an ammeter does not change the characteristics of the circuit; it is therefore an invisible component used to indicate current readings in a circuit [9]. However, a learner views ammeter differently.

Learners were requested to indicate what they thought to be the role of an ammeter in a circuit and the results are summarised in figure 1 below.

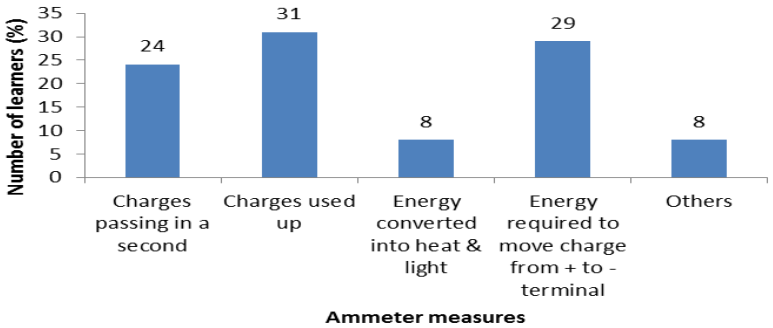


Figure 1. Learners' responses about the role of an ammeter in a circuit

Figure 1 shows that majority of learners 60% hold well documented misconceptions about electricity concepts [1, 9]. Of the given misconceptions, 31% of the learners indicated that the ammeter measured the charges which were used up by circuit components (like bulbs, resistance, etc.). The former misconception has been attributed to confusion from not relating concepts properly (namely, potential difference, current and resistance) [1, 9], whilst the latter could be due to lack of differentiation between the concepts thus voltage and current being the same. In addition, 29% of the learners indicated that ammeter measured the energy required to move a charge from one point to the other. This view was evident from the interview with learners from both schools. Only 24% presented scientifically acceptable responses.

3.2 Role of voltmeter.

Voltmeter is connected between two points therefore not necessary to break the circuit to connect it. A real voltmeter has the highest resistance possible to prevent draw of current from the circuit [6, 5]. Learners were requested to indicate what they believed to be the role of a voltmeter in a circuit and the results are summarised in figure 2 below.

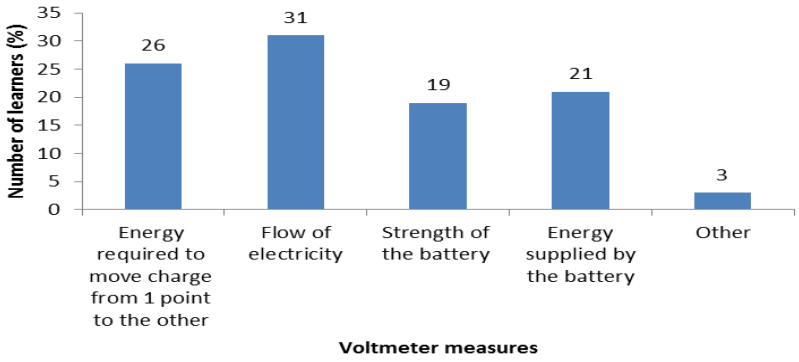


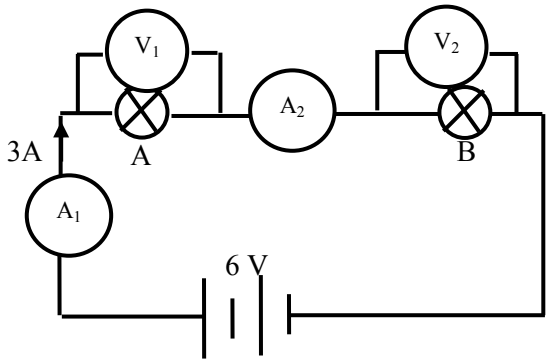
Figure 2. The role of a voltmeter in a circuit

It can be seen in figure 2 that majority (71%) hold misconceptions about electricity. Of these, 31% of them thought that the voltmeter measured the electricity flowing through the conductor. This indicates learners were using electricity to refer to current. Difficulty with concepts differentiation is well documented in literature [1, 3]. The usage of electricity can be traced to African's everyday languages where electricity, power and current are used interchangeably [7]. The substance flowing through a conductor is said to be electricity which is measured with a voltmeter that is connected across components. The findings are consistent with literature. Only 26% of learners indicated a correct option.

About one in five of the learners thought that the voltmeter was measuring the energy supplied by the battery to the circuit and the interview with learners confirmed this view. It was apparent that learners did not understand the role played by voltmeter in a circuit. The later could be attributed to not understanding voltage as alluded by Gilbert [5].

3.3 Voltmeter and ammeter in a series circuit

Learners were presented with a schematic circuit diagram (see circuit 1) below.



Circuit 1

The circuit consisted of two identical dry cells, two identical light bulbs and two ammeters all in series and two voltmeters across each bulb. Ammeters and voltmeters were labelled A_1, A_2, V_1 and V_2, respectively. The light bulbs were labelled A and B as shown in circuit 1. The total current and voltage of the circuit were presented as 3A and 6V respectively.

3.3.1 *Using voltmeters correctly in circuits.* Learners were required to indicate the expected readings on the two voltmeters. The results are presented below in figure 3.

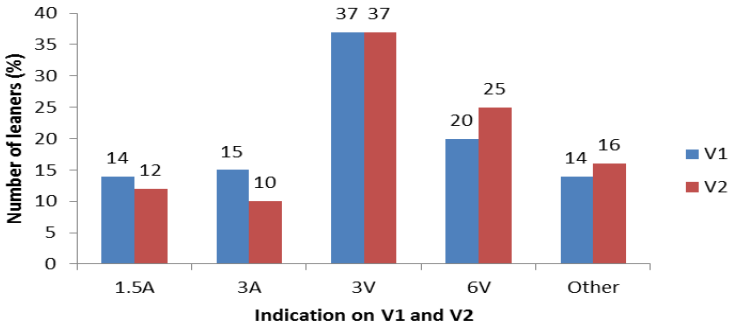


Figure 3. Learners' responses to readings on voltmeters V_1 and V_2

Figure 3 shows that 57% and 62% correctly identified V_1 and V_2 respectively (shown by 3V and 6V). This suggested that learners knew how to correctly connect the voltmeter to electric circuits. On the other hand, 30% and 22% of the learners thought V_1 and V_2 were ammeters (1.5A and & 3A). Thus, these learners did not know how to correctly connect voltmeter in a circuit. Only 37% presented correct indications for both V_1 and V_2. The later shows that learners did not understand that potential differences sums in a series circuit. This finding confirms literature that voltage is not understood by learners [1, 5, 7].

3.3.2 *Using ammeter correctly in circuits.* Learners were also required to identify A_2 (ammeter) and to indicate the current through it. They were expected to apply the conservation of current in a series circuit. The results about A_2 are presented in figure 4 below.

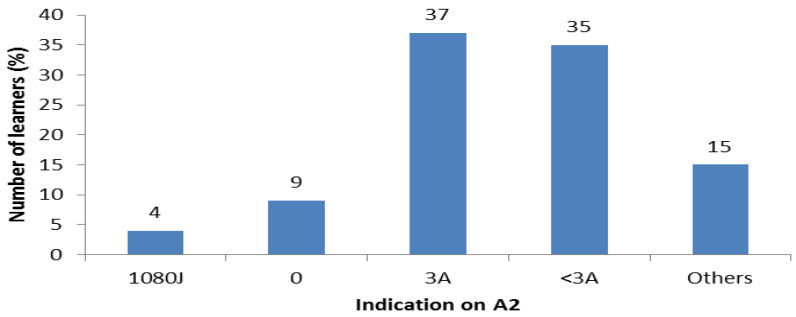
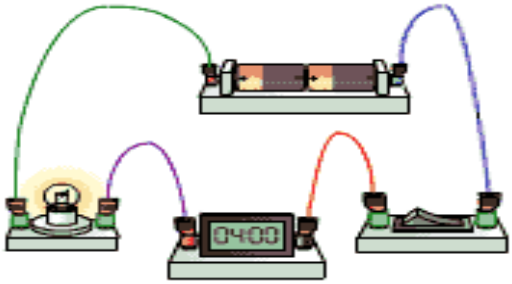


Figure 4. Learners' responses about the indication on A_2

Figure 4 indicates that majority of learners (72%) correctly identified A_2 to be an ammeter (indications 3A and <3A). This suggests learners knew how ammeter should be connected in a circuit. However, only 37% of them indicated the correct reading meter A_2 would have indicated, while the other 35% thought ammeter A_2 would indicate less than the total current of the circuit. The results imply learners did not understand the conservation of current in a series circuit. This result confirms the observations made in figure 1 where 31% of learners preferred the current consumption model. Some studies indicated that learners believed that an ammeter consume current for it to function [8].

The learners were also presented with a pictorial representation of a realistic circuit (as in circuit 2 below), which they had to evaluate to identify the corresponding schematic circuit diagrams.



Circuit 2. Representation of a realistic circuit.

Figure 6 shows learners' responses to matching realistic circuit to a schematic diagram.

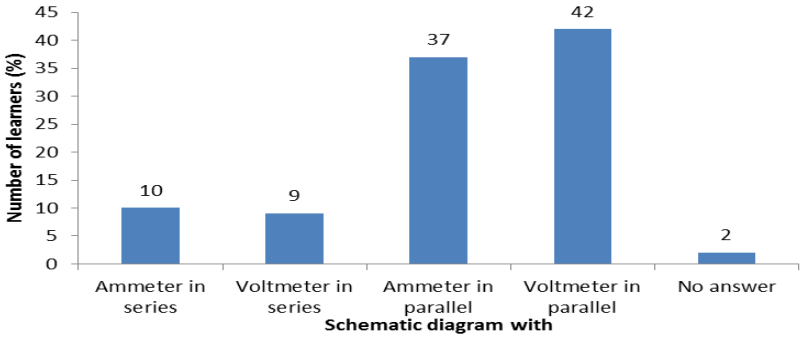


Figure 5. Learners responses to matching realistic circuit to a schematic diagram

It can be seen that 51% of the learners were unable to recognise the measuring devise in question to be an ammeter, as they have chosen circuits with voltmeters. During the interview, learners were requested to identify the components. Majority identified battery, bulb, switch but ammeter. One learner said "*...not sure whether there is voltmeter or not*". Some of the learners (46%) chose options

which indicated ammeter and voltmeter connected incorrectly. Only 10% gave scientifically accepteble responses. Carstensen et al. [1] indicated that learners who cannot differentiate between voltage and current tend to struggle in connecting their measuring instruments.

Dzama [3] in their investigation on London and Malawian students found that learners were unlikely to make mistakes of how measuring devises should be connected if they had practical experience with electrical circuits. Engelhardt et al [4] found that learners had difficulties in translating from schematic circuits to real circuits not vice versa. This study showed that learners had difficulties in translation from realistic circuit to a schematic circuit which could be attributed to not understanding the role played by measuring devises, not understanding the concepts and lack of paractical experience with electrical circuits.

4. Conclusions and Recommendations

This study investigated learners' knowledge about the role played by the ammeter and voltmeter in an electrical circuit. The results indicated that learners knew how measuring devises should be connected in a circuit but lacked the basic understanding of the role played by these devises. It was also evident that because of lack of practical experience with real circuits, some learners did not know how this devises should be connected. There were also findings such as current consuption and difficulty with concept differentiation which are well documented in literature thus not supprising. It also emerged that learners could not translate a realistic circuit into schematic circuit due to lack of practical experience with electrical circuits, and not understanding concepts and the role played by the measuring devices. It is therefore necessary for educators to take into considerations the role played by measuring devises in planning their instructions. Learners need to understand why devises have to be connected in a particular way.

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