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Physics student teachers' misconceptions about basic electronics: A case of BSc. Ed and BEDMAS students at UNZA

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Abstract
This paper is an extract of one of the research questions from a PhD study on conceptions and performance of student teachers of physics in basic electronics. The study sought to investigate the misconceptions student teachers of physics hold about basic electronics in the Zambian context. A mixed-methods approach was employed to investigate the issues involved. The study revealed several misconceptions held by student teachers of physics in basic electronics, the common ones being that: Cathode rays are waves which travel at the speed of light (32%), Half wave rectification produces an output, part of which is direct current and the other part an alternating current (38%), and that a capacitor discharges when it is not part of a circuit (33%). In view of these findings, the study recommended that: Lecturers at the University of Zambia (UNZA) who handle physics student teachers in introductory electronics should address this issue, for a possible solution. Furthermore, the University of Zambia should introduce a course in basic electronics, aimed at changing, overcoming or dislodging such misconceptions so that student teachers enter the teaching profession with viable/valid conceptions.

Keywords: Conceptions, misconceptions, performance, basic electronics

1. Introduction

It is clear from research in physics education that like all other learners, student teachers of physics do not enter the classroom as "empty vessels" but are filled with a lot of conceptions about fundamental physics concepts which they are going to learn (Tytler, 2002; Knight, 2002) [21, 14]. Some of their conceptions are in conformity with scientific explanation while others differ from accepted scientific view points and so are commonly known as alternative conceptions or misconceptions (Yip *et al*., 1998; Groves and Pugh,1999; Knight, 2002) [23, 10, 14]. Examples of such misconceptions are that: 'Gravity gets stronger closer to the ground, which is why objects speed up as they fall; Motion of an object implies a force acting on the object; If half of a lens is covered by a piece of opaque paper, half of the image on a screen will disappear and An electric current gets used up as it flows through a circuit' (Knight, 2002: p. 27) [14].

Many people would like to know the causes of these misconceptions. Yip *et al*. (1998) [23] highlight some causes of student teachers' misconceptions as: Inadequate pre-requisite knowledge, negligence on the conditions and assumptions behind a rule, over generalisation of principles from inadequate evidences, interference of learnt materials, uncritical acceptance of incorrect information, past teaching and a wrong deduction due to fallacious reasoning. Other causes of misconceptions include: the variety of contacts students make with the physical and social world, subjective experience before learning the scientific views, physics textbooks, interaction with people and through the media (Ivowi, 1984; Yip *et al*. (1998) [13, 23].

According to Fisher (1985) [8], once developed, misconceptions tend to be highly stable, resistant to change and very problematic to the students. Due to their strength and flawed content, misconceptions interfere with student teachers' learning of correct scientific principles or concepts (Fisher, 1985; Knight, 2002) [8, 14]. For example they are the source of students' difficulty in learning "formal" notions of probabilistic events, such as the "Law of small numbers" (Shaughnessy, 1985) [19]. Indeed there is enough evidence to suggest that many of the difficulties student teachers encounter in physics content are due to the misconceptions they hold about the subject (Knight, 2002) [14]. Hunt and Minstrell (1977) [12] support this assertion by stating that learners' difficulties in science occur because students' conceptions before teaching are not taken into account and therefore communication barriers between instructors and learner's cannot be overcome. The ideas are logical, sensible, and valuable from the students' point of view, strongly held by the students, but may be significantly different from accepted scientific viewpoints (Osborne, 1983) [18]. This is why many physics educators have at one time or the other experienced the frustration of explaining a concept, in what they thought was the clearest possible way, only to be faced with expressions of mute incomprehension from the class or worse (Tytler, 2002) [21]. Others have had the experience of having successful conversations in class, in which they felt sure they had achieved some clear understandings, only to find on testing that nothing much seemed to have been gained at all (Tytler, 2002) [21].

As if this is not enough, misconceptions also have a negative effect on the teaching of physics (Knight, 2002) [14]. This is why Groves and Pugh (1999) [10] express concern about the ability of all categories of teachers with misconceptions to instruct their learners correctly since they, themselves, do not have proper understanding of how the world works. Both theory and common sense support the argument that teachers' inadequacy in subject content knowledge will affect teaching performance as well as pupils' learning (Ball and Mc Diarmid, 1989; Haambokoma *et al*, 2002) [1, 11]. The complexity and multiplicity of a lesson event, such as selecting suitable content, planning and conducting productive learning activities, asking meaningful questions, answering unprepared questions, diagnosing learning difficulties, and assessing students' progress demand teachers to have a good command of subject knowledge (Yip *et al*., 1998) [23].

Therefore, it is well established from the afore mentioned that student teachers of physics do not come to the classroom with empty minds, but with a wide range of some already strongly held ideas, which in many cases differ from the theories the physics educators must develop (Driver, 1983) [6]. Such ideas are resistant to change and if not taken into account, they make it difficult for such students to learn and later to teach physics effectively (Yip *et al*., 1998) [23]

While this is so, research does not show what misconceptions student teachers of physics in Zambia have about basic electronics as they finish their training. This is not healthy, because as already alluded to, teachers' inadequacy in subject content knowledge affects teaching performance as well as pupils' learning (Ball and Mc Diarmid, 1989; Haambokoma *et al*, 2002) [1, 11].

Hence, this study which sought to determine the misconceptions held by physics student teachers about basic electronics in the Zambian context. The study was important because it aimed at not only making the physics training institutions in Zambia aware of the unrecognized inconsistencies and erroneous set of concepts held by trainee teachers of physics in basic electronics, but also how such misconceptions could be minimised or overcome.

1.1 Statement of the problem

Research in physics education indicates that student teachers of physics enter the classroom with misconceptions about what they learn, which in many cases differ from the theories the physics educators must develop (Driver, 1983) [6]. Such ideas are resistant to change and if not taken into account, they make it difficult for the students to learn and later to teach physics effectively (Yip *et al*., 1998) [23]. However, research does not show the misconceptions which student teachers of physics in Zambia who pursue the BSc.Ed and BEDMAS programmes at UNZA hold about basic electronics.

1.2 Purpose of the study

The study sought to determine the misconceptions which student teachers of physics in Zambia hold about basic electronics as they finish their training.

1.3 Objective of the study

The objective of the study was to determine the misconceptions student teachers of physics have about basic electronics, as they finish their training.

1.4 Research question

The research question to be answered was: What misconceptions do student teachers of physics have about basic electronics, as they finish their training?

1.5 Significance of the study

It was hoped that the findings of the study would inform: the lecturers at UNZA who handle student teachers of physics in electronics for a possible solution to the problem of misconceptions, the Department of MSE at UNZA which should reflect on pedagogical strategies used in teaching basic electronics, Policy makers in the Ministry of Education, Science, Vocational Training and Early Education, who should encourage continuing professional development for qualified teachers of physics. Furthermore, the findings would fill the knowledge gap in this area.

2. Literature review

Electronics is a very important field of engineering and applied physics which has made several triumphs in the whole world, particularly in the area of communication. This is why in Zambia, basic electronics has been and shall continue to be part of the senior secondary school physics curriculum (CDC, 2000; CDC, 2014) [2, 3].

Unfortunately, despite its importance, basic electronics is rated the most difficult section of the Zambian senior secondary school physics syllabus to teach, not only by student teachers of physics but also those who are qualified to teach the subject (Haambokoma *et al*., 2002) [11]. Many teachers in Zambia (65%) rate themselves not confident in teaching electronics (p. 128) and so are least comfortable to teach that section of physics (p.127). The major reason they give is that despite the intensive physics teacher training they undergo at tertiary level, they do not have adequate knowledge in basic electronics (p. 129). Some Departmental Heads of science in Zambia also agree with their colleagues and suggest that teachers of physics need help in understanding basic electronics theoretically and practically (Haambokoma *et al*, 2002: 128) [11]. These expressions confirm the fact that in Zambia, like any other country in the world, both the trainee as well as the qualified teachers of physics have misconceptions about basic electronics. This is supported by Yip *et al*.(1998) [23] and Tytler (2002) [21], who postulated that some of the challenges teachers face in teaching physics are due to their misconceptions about what they teach.

Scanty literature from studies conducted outside Zambia highlights some misconceptions about electronics. Millar (2012) [16] did a study to find out what students thought the nature of cathode rays was. The findings showed that students had mixed feelings about cathode rays. Some thought that cathode rays were particles, others thought they were waves while still others believed that they were both particles and waves. In a study done by Driver (1994) [7] on the behaviour of a resistor in a circuit, the results revealed a preconceived notion held by students that, if there is a resistor before a lamp, the resistor will dim the lamp in a circuit, but if the resistor is after the lamp then it will have no effect on the intensity of the light. This showed that the students did not have the understanding that current in a circuit is a flow of charge that is conserved. Few other misconceptions reported on the diode are: "No current in parallel resistances when a diode is conducting", "The current passing through a zener diode is equal to the current passing through a load resistance", and "No current passes through a load resistance when the breakdown voltage is applied to a zener diode (Chen *et al*., 2013).

The literature is however limited, for a number of reasons.

- First, it is completely based on studies conducted outside Zambia. Therefore, it is difficult to replicate the findings in this country.
- Second, it does not show any misconceptions held by student teachers of physics about basic electronics in the Zambian context.
- Third, it focuses on the diode which is just a fraction of basic electronics. This study focused on the whole section of basic electronics.

3. Methodology of the study

3.1 Research Design:

The study used a mixed – methods approach. A concurrent nested strategy was used to mix qualitative and quantitative methods (Creswell, 2003) [5].

3.2 Sample size

The sample comprised 60 student teachers of physics, who were randomly selected from a population of 191 (3rd and 4th year) BSc.Ed and BEDMAS student teachers of the University of Zambia, from all parts of the country. This number of participants (60) was big enough for a study of this nature to yield valid results (Gay, 1996) [9].

3.3 Research Instrument

The study used a participant questionnaire to capture the data**.** In order to ensure that the instrument was valid, all questions in the questionnaire came from the Zambian Senior Secondary School Physics Syllabus (5054), on basic electronics. The questionnaire was prepared by turning all the twenty objectives on basic electronics in the syllabus into questions for participants to answer. The early version of the questionnaire was examined by two physics educators, two qualified teachers of physics and ten graduate teachers of physics, and their suggestions were incorporated into the final version. After that, the instrument was administered to five undergraduate physics student teachers who were not part of the study and it was determined that they all agreed on the correct answer to each question. The reliability of the instrument was determined through Spearman-Brown's two equivalent half dividing method and Cronbach's alpha and the coefficient was found to be 0.9.

3.4 Procedure for data collection

A questionnaire was administered to the respondents by the researcher. The purpose of the questionnaire was to find out what misconceptions student teachers of physics had about basic electronics in senior secondary physics.

3.5 Data Analysis

Qualitative data were analysed using the Constant Comparative Method. This involved making three main passes through the data. The first pass, **open coding,** required reading through the data carefully and noting the themes or categories which were there. The second pass, **axial coding**, involved trying to see how the categories already identified were related, so that major categories and subcategories could be identified. While the final one, **selective coding**, was intended to bring together the themes identified in the data to determine how they were connected to each other (Strauss and Corbin, 1990) [20]. Quantitative data were analysed graphically.

4. Findings of the study

The question to be answered was:

What misconceptions do student teachers of physics have about basic electronics, as they finish their training?

The study revealed several misconceptions held by student teachers of physics about basic electronics, the common ones being that: Cathode rays are waves which travel at the speed of light (32%), Half wave rectification produces an output, half of which is direct current and the other half an alternating current (38%), and that a capacitor discharges when it is not part of a circuit (33%). Table 1 shows all the misconceptions which were revealed by the study about basic electronics.

Table 1: Physics student teachers' misconceptions as revealed by the study

S/NO.	Sub-topic	Misconception/s	Frequency	%
1	Thermionic emission	Thermionic emission is loss of heat by materials	15	25
2	Cathode rays	Cathode rays are waves; They travel at speed of light	19	32
3	Conventional current	Conventional current (is the same as convection current and so) has no specific direction	8	13
4	Applications of electron beams	Application of cathode rays are same as those of electromagnetic waves	14	23
5(a)	Basic structure and action of cathode rays	The Cathode ray oscilloscope has one X and one Y- plate that form a pair.	6	10
(b)	Basic structure and action of cathode rays	In a CRO the heater produces light which is deflected by X and Y plates	3	5
6	Basic circuit components	Intergrated circuits, Amplifiers, Logic gates, transformers are some of the basic components in electronics.	6	10
7	Determining resistor values using standard colour codes	All band values must be added to find resistance of band resistors	6	10
8	Variable potential divider	A potentiometer acts as an ammeter, detects resistance and measures resistivity of wire	4	7
9	Action of a diode	Half Wave Rectification produces an output, part of which is direct current and the other part an alternating current.	23	38
10	Action of a thermistor	A Thermistor detects temperature	6	10
11	Action of a light dependent resistor (LDR)	LDR depends on light to measure resistance	8	13

12	Action of a capacitor	Capacitor discharges whenever it is not part of a complete circuit	20	33
13	Action of a reed switch	A reed switch operates on the principle of induced current and it regulates voltage	4	6
14	Action of a reed relay	A reed relay uses temperature changes to control current	2	3
15	Action of a bipolar transistor	Bipolar transistor is made up of two transistors; When one is on, the other is off; so it acts as a switch.	8	13
16	Action of a bipolar transistor	Bipolar transistor is made up of two transistors; This enables it to amplify.	8	13
17	Logic gates	In all cases NAND outputs are opposite to NOR outputs.	7	12
18	Logic gates	0+0 = 1 and 1+0 = 0 for AND gate	1	2
19	Action of astable and bistable circuits	Astable circuit has one stable state	10	17
20	Computer hardware and software	Computer hardware as wares that are external while computer software are wares that are stored wares the a computer	7	12
Total Number of participants			**N= 60**	**100%**

After the summary in table 1, the frequency of a misconception per topic were presented graphically in figure 1, in order to show clearly the areas in which participants had more misconceptions and vice versa.

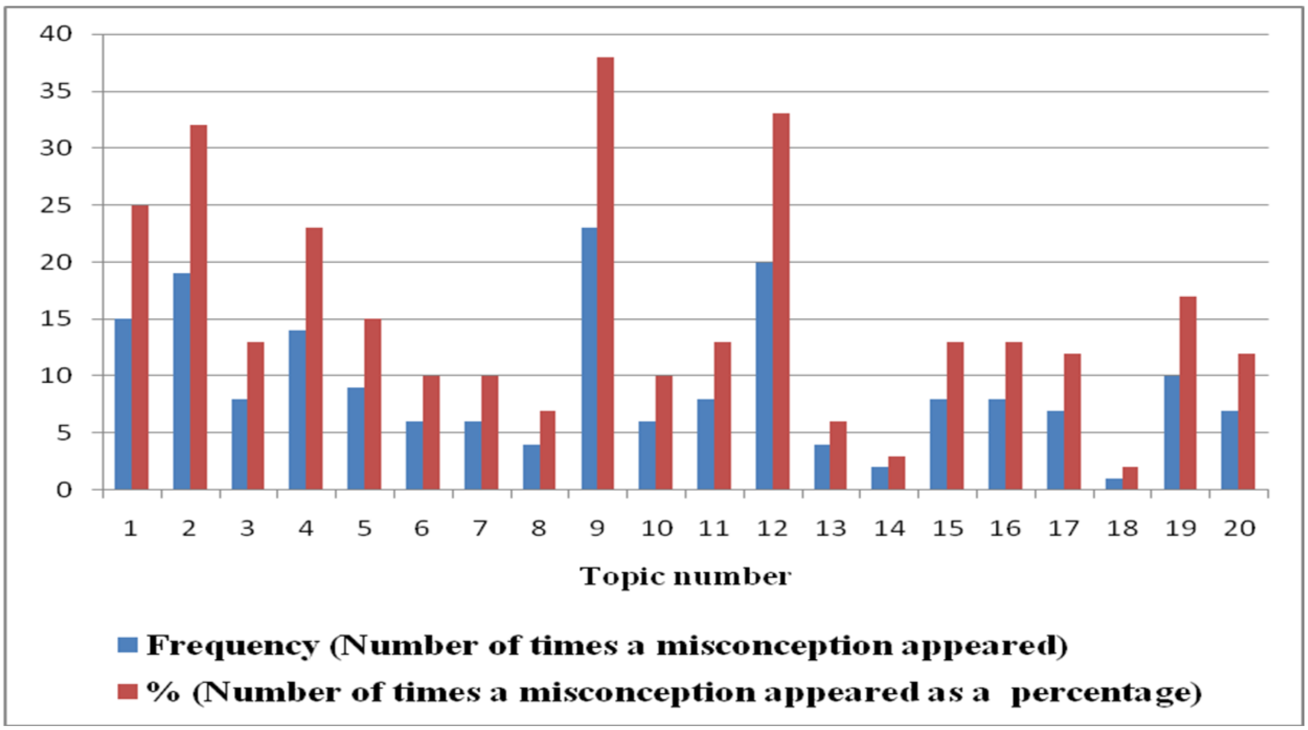

Fig 1: Frequency of a misconception Verses Sub-topic Number

5. Discussion of findings

It can be seen in table 1 that in many cases, student teachers of physics stated, described or explained concepts about basic electronics in ways which were not in conformity with the views of science. For example, several students (25%) indicated that thermionic emission is loss of heat by materials. They justified this answer by explaining that the term ‘thermal’ refers to heat, while ‘emission’ refers to loss. Therefore, thermionic emission should refer to loss of heat by any material. But the literature reviewed gives a different explanation of this concept (Kurup 2013; Nelkon, 1981) [15, 17]. Kurup (2013: 1) [15] explains that “ Thermionic emission is the emission of electrons from a heated filament or substance. When a filament like Tungsten is heated to a high temperature, some electrons acquire sufficient energy and are able to break away from the surface of the material and go into space. This action is accelerated when the filament is heated in a vacuum by connecting it across a 6-V supply.”

This view is supported by Nelkon (1981) [17], who says “In 1902 Richardson found that electrons could escape from some metals such as tungsten when a fine wire of the metal was heated to a high temperature. This is called thermionic emission and the metal is called a hot cathode” (p. 533). What these physics experts say is considered worldwide as the acceptable scientific explanation of thermionic emission. Therefore, students’ conception that thermionic emission is the loss of heat by a given material, was a misconception. The current study used a simple demonstration with local materials, to clarify the concept of thermionic emission.

Many participants (32%) claimed that cathode rays are waves that travel at the speed of light. They substantiated their claim by explaining that a ‘ray’ always had to do with some form of energy i.e. light ray, heat ray, X-ray etc. Therefore, they thought that cathode rays were waves, because according to them (participants), cathode rays were in form of energy. Furthermore, since light and heat rays are electromagnetic in nature, the participants thought that cathode rays were also electromagnetic in nature and they travelled at the speed of light. But the literature reviewed did not explain cathode rays in that manner. According to Wilkinson (1993) [22] "Cathode rays are a stream of electrons" (p. 519) and electrons are particles. They travel in a straight path but can be deflected by an electric and magnetic field due to their negative charge (p. 519). Therefore, the conception students held that cathode rays are waves which travel at the speed of light, was a misconception. However, it was noted that one thing that caused this misconception was the use of the term 'ray.' Students thought that whatever is said to be a ray, is in form of a wave like light. Literature indicates that the confusion on cathode rays was also discovered by Millar (2012) [16], who did a study to find out what students thought the nature of cathode rays was. The findings showed that students had mixed feelings about cathode rays. Some thought that cathode rays were particles, others thought they were waves while still others believed that they were both particles and waves.

In order to clarify and consolidate the fact that cathode rays are not waves but particles, the current study used a simple demonstration with local materials and it helped learners to accept that there was a difference between waves and particles such as cathode rays or electrons (which are in form of particles).

Many subjects, (38%) stated that Half Wave Rectification produces an output, part of which is direct current and the other part alternating current. But Wilkinson (1993) [22], explains that in Half-Wave Rectification a diode removes the negative half-cycles of the a.c input to produce a varying but one-way dc output across an external resistor. Therefore, the participants' conception that during Half Wave Rectification half of the output remains "a.c" was a misconception.

Few years ago, there was a study conducted by Chen *et al*. (2013) [4], on "Correcting Misconceptions on Electronics: Effects of a simulation-based learning environment backed by a conceptual change model. The study focused on concepts of the zener diode, including: some conceptual contents such as "semiconductor concept of a diode", "feature of diode bias", "simplified model of a diode", and "basic circuit of a diode." Results, indicated that there were 7 misconceptions about "semiconductor concept of a diode," 4 misconceptions about "feature of diode bias," 7 misconceptions about "simplified model of a diode," and 10 misconceptions about "basic circuit of a diode." However, the study did not arrive at the finding in the current study, which is that 'In Half Wave Rectification', part of the current output is direct current while the other part is an alternating current." In order to help change this alternative conception, the current study utilised a simple paper model to show how a diode changes ac to dc and the model was helpful.

It was worrying to note that a good number of participants, (33%) said that a capacitor discharges completely whenever it is disconnected from a power supply/circuit. According to Nelkon (1981: 523) [17], "If the plates of a charged capacitor are joined, a current will flow for a short time. Electrons from the negatively charged plate flow round the circuit to the positively charged plate and the charges neutralize each other. The capacitor is then 'discharged". Nelkon (1981) [17] further states, "If a wire is used to connect [the] charged capacitor plates, a spark may be seen as the plates are joined. When the current has stopped flowing, the capacitor is discharged" (p. 523). This implies that what a charged capacitor requires to discharge is just a conductor across the plates. Since a human body is a conductor, using bare hands or any body parts to join the two plates of a capacitor, makes the capacitor to discharge through the body and if the current is huge, this may lead to loss of life. This is why the alternative conception about the action of a capacitor is so worrying. In the current study, participants charged capacitors using low voltage, 3V – 6V and carefully discharged the capacitors using wires. Ammeters and voltmeters were used to show current direction and voltage across capacitors respectively. This helped participants to understand the charging and discharging of a capacitor very well.

Lastly but not the least, it is important to note that although the frequencies and percentages in table 1 and figure 1 of the findings look small, they mean that all student teachers of physics are leaving the training institution with misconceptions about what they are going to teach, especially on the concept of cathode rays (32%), and the action of diodes (38%) and capacitors (33%). Therefore, unless physics educators find a way to address this problem, such teachers will not be effective enough in the teaching of basic electronics.

6. Conclusions and recommendations

6.1 Conclusions

From the results it was concluded that student teachers of physics in Zambia have several misconceptions about basic electronics which affect their ability to demonstrate high level understanding of this section of physics and to teach basic electronics at senior secondary school effectively. The common ones are that: Cathode rays are waves which travel at the speed of light (32%), Half wave rectification produces an output, part of which is direct current and the other part an alternating current (38%), and that a Capacitor discharges when it is not part of a complete circuit (33%)

6.2 Recommendations

- Lecturers at the University of Zambia who handle physics student teachers in introductory electronics should address this issue, for a possible solution
- The University of Zambia should introduce a course in basic electronics, aimed at minimizing or overcoming misconceptions that affect physics student teachers' performance in basic electronics content and teaching.

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