Misconceptions about the Concepts of Continuity and Continuity Equation by Physics Undergraduates in Teacher Capacity Development Program

E.Mudzamiri[1]; T.Manyeredzi[2]; N. Zezekwa[3]
[1,2,3] *Bindura University of Science Education, Zimbabwe*

Abstract: **This qualitative study inspired by Constructivist Theory ideas identified misconceptions held by 40 purposively selected Teacher Capacity Development Program part 1.2 physics undergraduate students concerning the concept of Continuity and the Continuity Equation. The study was conducted at a state university in Zimbabwe .The main argument being that, if learning is based on prior knowledge, then instructors must know the misconceptions held by their students so that they can provide learning environments for development of learners from their current understandings. Identification of the misconceptions was done through a Multiple-True- False diagnostic test. Analysis of the ethically collected data revealed twenty six misconceptions held by the students which instructors can target when teaching the two concepts. The researcher challenges future researches to identify the sources of the misconceptions and their categories.**

Keywords: **Preconceptions, Misconceptions, Teacher Capacity Development Program (TCD), Continuity, Continuity Equation**

I. INTRODUCTION

Over the last three decades, many studies have been conducted to identify students' pre-instructional conceptions on various Physics topics. Pre-instructional conceptions constitute prior knowledge (correct or not), which students may have about a concept before it is formally taught in school [1], [2]. It is argued that, every student enter physics classes with their preconceived ideas or a well-established systems of common sense beliefs and opinions about how the physical world works derived from years of personal experiences[2], [3], [4]. These preconceived ideas have been named differently by various authors[5]: alternative conceptions[4], children's science[6], personal knowledge or spontaneous knowledge[7],[8], misconceptions[9]andpreconceptions[10], [8].

Some authorities use the terms preconceptions and misconceptions interchangeably [11]. However, [12] distinguished them by noting that *preconceptions constitute* any prior knowledge (correct or not) while *misconceptions* are solely erroneous knowledge of the concept. Therefore misconceptions can be viewed as a mental representation of a given concept that does not correspond to the currently held scientific theory [13], [14]. The distinction made by [12] is going to be followed in the present article to avoid terminological confusion, that is; the term *misconception* will be used to describe those preconceptions that do not conform to up-to-date scientific theories. In this vein, students' preconception that conform to currently held scientific theorystrongly support learning, while those that are in conflict (misconceptions) can be a barrier to learning[15], [4] .

Misconceptions related to Physics theories have been reported to be widespread among high school and university students [2], [16]. Of interest in this study are the misconceptions about causes of the thinning of water flowing from a tap. This is a phenomenon that is well explained in fluid dynamics, by applying idea of continuity and the continuity equation. When learners try to describe and explain the causes of the phenomena, they unconsciously reveal their misconceptions about the concept of continuity and the Continuity Equation as applied in fluid dynamics. A study was therefore carried out to probe the misconceptions held by TCD students in explaining the thinning out of water flowing from a tap.

This was motivated by observations during one of the laboratory activities on behavior of fluids when students were collecting water from tapes that were in the laboratory. They were puzzled by the behavior of water as it flowed out from the tap. The students had a heated argument on their observations particularly the causes of the decrease in the cross-section area of water column as the water falls from the tap to the ground.

Various arguments emanated from the students' discussions prior to a formal lesson on Continuity and Continuity equation which, in its understanding, requires analytical skills to link theory with phenomena or facts [17]. The arguments exposed various forms of misconceptions which, according to[18], can be categorized as; non-scientific beliefs, conceptual misunderstandings, preconceived notions, factual misconceptions and vernacular misconceptions.

Non-scientific beliefs are beliefs that include conception learned by students from non-scientific sources, such as religious or mythical teachings [14]. Conceptual misunderstandings are preconceptions based on misapplying a general principle such as the belief that blood flows like ocean tides, or tornadoes are attracted to mobile home parks[19]. Conceptual misunderstandings arise when students are taught scientific information in a way that does not provoke them to confront paradoxes and conflicts resulting from their own preconceived notions and nonscientific beliefs [20].

Preconceived notions occurs when student are thinking about a concept in only one way. In most cases once a person knows how something works it is difficult to imagine it working in a different way [18]. Vernacular misconceptions (misconceptions of language) are also part of the list and these are based on misunderstanding about the meaning of the words. Vernacular misconceptions arise from the use of words that mean one thing to laymen but something totally different when you are talking about science [20]. e.g. Sun “rises” and “sets” [21]. Factual misunderstandings are falsities, often learned at an early age, and retained unchallenged into adulthood [14]. e.gSome movies show rocket explosion outside the earth cell and explosion and indicate that a big sound heard. Actually sound needs a medium to be heard; and there are no mediums in a vacuum making this a misconception. The nature and types of misconceptions about a concept are influenced by teachers, parents, teaching materials/literature, context, teaching methods [14].

In all their forms, misconceptions directly affect students' future learning and understanding of concepts [22], [4]. Misconceptions hamper the learning of individuals and may lead to their loss of interest in the subject [23], [8]. Detecting the misconceptions in earlier stage may help in the learner to arose interest and boost the confidence[11]. Misconceptions may also lead to confusion or eventually loss of self-confidence, and even confidence towards the teacher [11].

To address misconceptions, teachers first need to identify them prior to new learning and use them as a starting point to build scientific conceptions [21]. Choosing to ignore students' misconceptions with the optimism that sooner or later they will adapt, correct, and refine them on their own is incorrect[24].Observational and interview studies show that although teachers know that preconceptions exist and influence science learning, they do not consider them in lesson planning or teaching[22]. When teachers explicitly address their students' preconceptions and choose teaching strategies that enable students to connect new conceptual ideas with their existing knowledge, a progression toward more scientific conceptions is possible [8]. However many instructors have limited abilities of noticing students' preconceptions. This study therefore focuses on the identification of the misconceptions of the TCD students with the ultimate intention of helping instructors in fluid dynamics to gain insight into student thinking. The instructors would use the identified misconceptions to plan and design the right strategy to adopt, correct, and reconstruct the misconceptions to become scientific concepts [24].

During teaching and learning processes pre-instructional conceptual structures inclusive of misconception, of the learners have to be fundamentally restructured to allow students to acquire science concepts [26]. Instructors need to re-shape students' misconceptions into coherent concepts [7]. Misconception can influence how students perceive, assimilate, organized, and make connection of new information [15]. The studies on misconceptions of students may improve understanding of the reasons behind the difficulties that they experience in learning physics concepts[5]. Misconceptions may be considered as essential and unavoidable features of learning [27].

When teachers are informed about the misconceptions students are likely to be holding they will be quick to identify them[22] and also at helping them to explain and incorporate them into the process of conceptual change[14]. Conceptual change is a process of using strategies to bring students' thinking in line with that of scientists [28].

II. THEORETICAL FRAMEWORK

This study adopts a constructivist view of learning particularly the view that 'knowledge cannot be transferred ready-made directly from one knower to another, but is actively built up by the learner and this [29]. Constructivism is a major theoretical perspective informing science teaching[30]. The theory emphasizes the importance of preconception in learning as it argues that students learn through the process of reconstructing existing knowledge [16]. The main idea is that Students' learning is centered on building new knowledge upon the foundation of preconceptions acquired from both formal and informal settings. Knowledge is constructed by building new understandings on preconceptions which may be correct or incorrect. When the preconceptions are incorrect (misconceptions), the impact on learning is detrimental. Generally, developing students' understanding in science needs to start from their existing concepts. Preconceptions serve as a platform from which students interpret their world [16].

If learning is based on prior knowledge, then instructors must know the preconceptions inclusive of misconceptions so that they can provide learning environments for development of concepts from learners' current understandings, while accommodating new experiences [22],hence the undertaking of this study.

III. METHODOLOGY

This study included both qualitative and quantitative techniques. It was conducted ethically with 40 TCD part 1.2 physics undergraduate students at Bindura University of Science Education which is one of the state universities in Zimbabwe. A case study approach was employed which facilitated in-depth investigation. The TCD physics class is composed of students who hold Diplomas in the teaching of physics from science teachers training institutions. The students in the sample had studied the concepts on Fluid dynamics at different levels from elementary school to diploma level at university because of the spiral and integrative nature of the science curriculum in Zimbabwe.

Purposive sampling was considered in selecting the university and the students for the study. Among the methods used to identify misconceptions are: multi-tier diagnostic tests, open–ended questions, multiple-choice questions, True or False questions, drawing methods, concept inventory and word relationship tests [31], and Questionnaire of Writing Sentences (QWS) [32].

This study adopted the use of a diagnostic test (DT) of the Multiple-true-false (MTF) nature with valid and reliable questions. A diagnostic test is an assessment instrument consisting of some questions to be tested, where the questions are focused on the difficulties and weaknesses of students in a concept [33]. Diagnostic tests are deemed suitable for exposing scientific concept misconceptions [34. Multiple-true-false (MTF) is often used to assess familiarity of students with course content and to check for popular misconceptions [35], [36], [37]. Multiple-true-false (MTF) required students to provide answers with respect to predetermined response options [36]. It requires students to separately mark each option as true or false, rather than selecting one correct option like in Multiple Choice (MC) questions. MC questions require students to select just one answer, whereas MTF questions enable students to evaluate each option as either true or false thereby engaging higher-level thinking[35], [21]. MTF responses more accurate in identifying misconceptions held by student compared to Multiple- Choice responses [35]. The questions for the test were adopted from fluid dynamics textbooks. Questions probed students' misconceptions about the concept of Continuity and the Continuity Equation through question on the causes of the thinning of the water column as it flows from a tap. Twenty six predetermined response options with erroneous understanding observed in previous pilot study and literature were proposed and students were asked to mark each option as true of false.

The face and content validity of the question and the predetermined responses were established in two different ways. First, early versions of the question and predetermined responses were examined by a number of physics educators and their suggestions were incorporated into the final version. Second, the test was administered to 15 TCD undergraduate physics students who did not take part in the actual study. The students were given 25 minutes to answer the physics test.

The question was based on the diagram in Figure1 which shows water flowing from an open tap

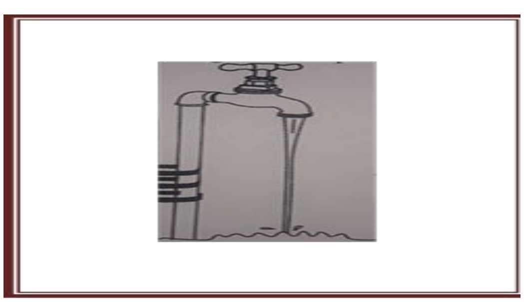

Fig 1: Water flowing out from an open tap

The question actually read: *Figure 1 shows water flowing from an open tap. Using ideas of the Concept of Continuity and Continuity Equation indicate whether the following statements are True or False about the causes of the thinning out of the water column as the water falls to the ground.*

This question basically required the application of ideas of Continuity and Continuity equation and could probe most of the misconceptions of the students. Students were expected to use the idea of uniform mass flow in their explanations, stating that the velocity of the water is increasing from the outlet of the tape to the point where the water strikes the ground because of gravity indicating understanding of the principle of conservation of mass or its implications for incompressible fluids. They were also expected to show the role that this principle plays in the context of fluid flow. Generally students were expected to invoke the idea of Continuity and Continuity Equation in their search for the appropriate response to the causes.

The reference to the equation of continuity would involve applying the relationship between Cross sectional area (A) and Velocity of water (V) or flow rates at different points along the water column; e.g.

$A_1V_1 = A_2V_2$ Where A and V are cross section Area and Velocity at points 1 and 2 along the water column.

Students were not expected to base their answers on other types of reasoning when they were deciding on whether the predetermined responses were True or False. Only wrong responses were considered for analysis since they implied some misconceptions imbedded in them. The revealed misconceptions are discussed in the next section. The level of the misconception that was among the students was determined using the criteria designed by [38] summarized in table 1.

Table 1: The Criteria of Misconceptions

Number	Percentage (%)	Criteria
1	0< misconception ≤ 30	Low
2	30< misconception ≤ 70	Medium
3	70< misconception ≤100	High

(Adopted from Kurniawan and Suhandi (2015)).

IV. FINDINGS AND DISCUSSIONS

Misconceptions of TCD students on the causes of the thinning out of the water as it falls from the tap are indicated in table 2. Table 2 also shows the distribution of Misconceptions among the TCD undergraduates. The extend of the misconception was indicated as a percentage in the table to allow assessment of the degree or level of the misconception according to decisions made by[39] in Table 1.

Table 2: Distribution of misconceptions among the TCD undergraduate students

Students Misconceptions	No. of students with the misconception	Percentage misconception	Criterion level

Evaporation of water from the surface of the column as temperature increases with decrease in height of the column of water above the ground.	35	87.5	High
Force of air molecules around the water column compressing the water. The force increases with decrease in height	30	75	High
Frictional force that wears off the sides of the water column thereby reducing the cross-section	34	85	High
Eating away of the sides of the water column.	27	67.5	Medium
Stretching of the water column just like tensile forces acting on plastic or a ductile material.	32	80	High
Stretching of water molecules thereby deforming their shape and size which affect the cross section.	26	65	Medium
Reaction force at the point where the water column touches the ground pushing up particles some of the water molecules.	27	67.5	Medium
Natural competition of water particles some particles moving faster than others just like in races.	16	40	Medium
Heavy particles falling faster than lighter particles.	36	90	High
Resistance/ drag acting more on particles on the outside layer of the water column thereby reducing their velocity compared to that of the particles in the inner layers.	19	47.5	Medium
Elasticity of water	10	25	Low
Slipping or large displacement of one layer of water over another layer along their boundaries	12	30	Low
Pressure decreases as the distance of water coming out from the tape increases. This is based on incorrect assumption about the pressure variations at the different points towards the ground.	18	45	Medium
As water flows pressure decreases causing water to thin out	25	62.5	Medium
As the water drops pressure increases thus compressing the water molecules and thinning them	38	95	High
Gravitational force compresses the water and in doing so the gases in it are removed thus making it thin	32	80	High
Lack of barrier to control the shape of the water	38	95	High
Water molecules attract each other when they move out from the tape hence the water thins out	15	37.5	Medium
Pressure pumping the water is not constant	29	72.5	High
Increase in velocity of the particles due increase in acceleration due to gravity	33	82.5	High
Gravitational force which is causing acceleration of the water molecule	31	77.5	High
Acceleration due to gravity casing an decrease in water velocity as it falls towards the ground	32	80	High
Opposing nature of the relationship between cross-section area and velocity	27	67.5	Medium
Because as distance increases the pressure of the water decreases	30	75	High
Magic and the work of spirits:	10	25	Low
God	7	17.5	Low

The analysis of data indicates that students held some misconceptions concerning the concept of Continuity and Continuity equation. Some of the misconceptions were more popular and fundamental than others. Considering The Criteria of Misconceptions adopted from [39] high level misconceptions among the students constitute 50%, Medium Level 38% and Low level 12%. All Non- Scientific beliefs were found in the low category indicating that misconceptions due to religious and cultural influences were very low among the students. The other functional types of misconceptions (i.e. conceptual misunderstandings, preconceived notions, Factual misconceptions, Vernacular misconceptions) were found in the Medium and the High categories. Interviews would have enabled the researcher to get the reasons why each responded made his/her choices of responses and this information would have been used to classify the responses according to the types of misconceptions.

V. CONCLUSION

This study identified Misconceptions held by the TCD part 1.2 physics undergraduate about the concept of Continuity and the Continuity Equation particularly. The diagnostic test item focused on the cause of the narrowing of the water columns as the water falls from an open tap. Results indicate that students have misconceptions in the concepts of Continuity and Continuity question as the causes of the narrowing of the water required explanations derived from the two concepts. This study helps teachers to design appropriate learning strategies to enhance students' understanding and mastery of these concepts while avoiding the issue of misconceptions.

Further studies should now look at the categorization of the preconceptions into scientific concept, misconceptions, lack of concepts, and errors. Other studies can also conceptual misunderstandings, preconceived notions, Factual misconceptions, Vernacular misconceptions, and non-scientific beliefs.

AVAILABILITY OF DATA STATEMENT

The data generated and/or analyzed during the current study are not publicly available for Legal/ethical reasons but is available from the corresponding author on reasonable request

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