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LEARNER'S ALTERNATIVE AND MISCONCEPTIONS IN PHYSICS: A PHENOMENOGRAPHIC STUDY

Abraham Motlhabane

Abstract. *This phenomenographic case study attempted to determine the alternative and misconceptions of learners in selected concepts in Physics. The research adds another dimension to understanding alternative conception in kinematics by qualitatively determining how learners describe/define a distance of 0m, a displacement of 0m, a speed of 0m/s, a velocity of 0m/s as well as an acceleration of 0m/ss. Data were gathered by means of a free response test. Senior high school grade 12 learners were purposefully selected to complete the test. Data were analyzed by qualitatively interrogating the descriptions and related graphs and pictures to look for the ways in which learners described these concepts. The research revealed that some learners were not able to comprehend the meaning of a displacement of 0m, thus they experienced challenges in the understanding of the concepts such as a speed of 0m/s, a velocity 0m/s and an acceleration 0m/ss. The data seems to suggest that learners fail to formalise and contextualise "0" as a concept in kinematics.*

Key words: *alternative and misconceptions, contextualising "0" concept, kinematics concepts, phenomenographic study.*

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Introduction

Various studies (Halloun & Hestenes, 1985; Molefe, Lemmer, & Smit, 2005; Rosenquist & McDermott, 1987; Shaffer & McDermott, 2005) show that learners confuse the concepts of time, position, velocity and acceleration and relate them unscientifically. In particular learner's descriptions are often qualitative and relative, and consequently differ from the operational definitions of physics. For instance scientific meaning is often lost in a description, for example, the words "rate of" are omitted in the description of acceleration. In an example involving displacement, displacement is described as a short distance. Surely, by a Newtonian account, forces do not cause motion (velocity); they cause change in motion (acceleration). If there is no net force on an object, it moves at a constant speed in a constant direction; if there is a net force, the object's speed, direction of motion, or both changes. Students often have difficulty understanding this account (Molefe et al., 2005), due, from the misconceptions perspective, to their misconceptions about forces and motion.

McCloskey (1983) described students as having an intuitive impetus theory similar to the impetus theories articulated by medieval physicists. Students see the motion of an object as caused by an internally stored impetus, which they typically call force or energy. As the impetus runs out, the object stops moving. McCloskey identified two variations of the impetus theory, one in which the impetus runs out on its own and another in which the impetus is drained by gravity, friction, or both. Other researchers have identified similar misconceptions without attributing to them the coherence of a theoretical framework. Clement (1983) described students' use of a misconception that "motion implies a force" in a range of situations. This is a misconception that the motion of an object indicates the presence of a continuing force causing that motion.

Confusion of kinematics concepts is revealed when learners apply features of one concept to another. Examples given by DiSessa (1993) are as follows:

- Being ahead implies having gone faster (independent of relative starting point).
- Less distance covered means less time.
- Going faster means going for more time.

The first two examples in the above list can be ascribed to everyday observations, for example, all objects moving on or near the earth come to rest and the effects of irregularities are more obvious for slow-moving objects (Lemmer, 2013). The last example in DiSessa's list given above, called changes take time can be attributed to the medieval impetus theory that perceives impetus as the causal agent 'injected' into a moving object and then fading or draining away (McCloskey, 1983). Many learners who believe that objects acquire some kind of impetus when kicked, hit or thrown that either starts wearing out after it has left the source or is maintained for some time before wearing off (Halloun & Hestenes, 1985).

Learners may indiscriminately use different terms for this impetus idea, namely power, force, acceleration, velocity, momentum, inertia or energy (Halloun & Hestenes, 1985). In terms of force, the so-called force-as mover misconception is found to occur all over the world and is particularly resistant to change with tuition (Thijs & Van den Berg, 1995; Trowbridge & McDermott, 1981). A consequence of this conception is that learners always ascribe a force in the direction of motion, whether the moving object has a positive, negative or zero acceleration (Lemmer, 2013).

Research (Lemmer, 2013) indicated that a moving object that undergoes a constant acceleration is generally perceived as if the velocity were constant. Similarly, at slow speeds where the ratio of acceleration to velocity becomes high, changes in velocity are detectable, but not at higher speeds. According to Calderone and Kaiser (1989), the physics definition of acceleration as change in velocity per time unit is inappropriate in psychophysical measurements. The reason is that (Lemmer, 2013) observers' sensitivity to velocity changes probably depends on the duration of the acceleration and the initial velocity of the object. Therefore, researchers in the field find it more useful to characterize acceleration either as a ratio of final to initial velocity or as a ratio of change in velocity to the average velocity. Limitations in visual perception of changes in velocity may contribute to the reported confusion of velocity and acceleration (Rosenquist & McDermott, 1987).

In accordance with research observations, learners may differentiate only between moving and stopping objects. The term 'stopping' may refer to the part of the motion where an object moves with a speed that is small enough to observe the slowing down of the object. Due to learners' inability to detect a change in speed of a faster moving object, they may not understand the differentiation made in physics between constant velocity and accelerated motion (Lemmer, 2013). Therefore, velocity–acceleration confusion may lead to a misunderstanding of the scientific association of the concept of force with acceleration as well as the distinction in Newton's laws between constant velocity and constant accelerated motion (Lemmer, 2013).

Even if concepts like acceleration are ostensibly well defined, the procedural knowledge needed to interpret such definitions is rarely taught. For example, most physics textbooks define acceleration as the "rate of change of velocity" and state this definition as $a=\Delta v/\Delta t$, but almost none spells out explicitly the complex procedure needed to interpret this definition (Basson, 2002).

In studies of learner understanding of the concepts of velocity and acceleration in one dimension, learners were asked specific questions about simple motions they observed (Trowbridge & McDermott, 1981). In the case of velocity, virtually every failure to compare velocities for two simultaneous motions could be attributed to use of a *position* criterion to determine relative velocity. Although learners could generally give an acceptable definition for velocity, they did not understand the concept well enough to be able to determine a procedure they could use in a real physical situation for deciding if and when two objects have the same speed. Instead they fell back on the perceptually obvious phenomenon of passing. Some identified being ahead or being behind as being faster or slower. The research also provided evidence that for some learners certain preconceptions may be remarkably persistent, even after intervention by course facilitators (Basson, 2002).

The main thrust for the study on acceleration was for the qualitative understanding of the ratio $\Delta v=\Delta t$. Unlike in the case of velocity where one difficulty, the confusion with position, occurred in most cases, the situation with acceleration has been reported as complex. Some of the difficulties learners displayed are: using a non-kinematical approach, confusion between position and acceleration, confusion between velocity and acceleration, discrimination between velocity and change in velocity but neglect of corresponding time interval (Basson, 2002).

Research suggests that a distinction can be made between distance and displacement, before speed and velocity are introduced. At the same time a learner should have a clear grasp of the concept of rate, to be finally able to move

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on to acceleration. The focus here should be to learn how to describe motion and not to learn about vectors. Hence during the study of motion the terms vector and scalar can be introduced with a classification objective in mind, namely to distinguish between those quantities with or without a direction associated with them (Basson, 2002).

Lemmer (1999) found that the effect of language and culture were more significant than gender or environment in alternative conceptions concerning space and time as well as related concepts such as the kinematic concepts. The alternative perceptions of the kinematic concepts held by the learners involved in the study consequently explained the lower gains. The proper understanding of the kinematics concepts (e.g. distance, displacement, speed and acceleration) is a prerequisite for the understanding of kinematic graphs (Molefe et al., 2005).

The ability to comfortably work with graphs is a basic skill of the scientist. Line graph construction and interpretation are very important because they are an integral part of experimentation, the heart of science (McKenzie & Padilla, 1986). A graph depicting a physical event allows a glimpse of trends which cannot easily be recognized in a table of the same data. Mokros and Tinker (1987) noted that graphs allow scientists to use their powerful visual pattern recognition facilities to see trends and spot subtle differences in shape. The ability to use graphs may be an important step toward expertise in problem solving since "the central difference between expert and novice solvers in a scientific domain is that novice solvers have much less ability to construct or use scientific representations." (Larkin, 1981). Perhaps the most compelling reason for studying students' ability to interpret kinematics graphs is their widespread use as a teaching tool. Since graphs are such efficient packages of data, they are used almost as a language by physics teachers (Beichner, 1994).

However, research has uncovered a consistent set of student difficulties with graphs of position, velocity, and acceleration versus time. These include graph as picture errors, slope/height confusion, problems finding the slopes of lines not passing through the origin, and the inability to interpret the meaning of the area under various graph curves (Beichner, 1994; Basson, 2002; Christensen & Thompson, 2012; Planinic, Ivanjek, & Susac, 2013). The types of problems physics students have in this area have been carefully examined and categorized by McDermott, Rosenquist, and van Zee (1987) as well as Planinic, Ivanjek, and Susac, (2013). Several of these studies have demonstrated that students entering introductory physics classes understand the basic construction of graphs, but have difficulty applying those skills to the tasks they encounter in the physics laboratory.

Kinematics graphs have position, velocity, or acceleration as the ordinate and time as the abscissa. The most common errors students make when working with these kinds of graphs are: (1) thinking that the graph is a literal picture of the situation and (2) confusing the meaning of the slope of a line and the height of a point on the line (Basson, 2002).

In general, students tend to find slopes more difficult than individual data points. They also have a hard time separating the meanings of position, velocity, and acceleration versus time graphs (Halloun & Hestenes, 1985). Regardless of the type of errors students make, it is generally agreed that an important component of understanding the connection between reality and the relevant graphs is the ability to translate back and forth in both directions (McDermott, et. al., 1987; Basson, 2002).

Although a number of studies have been conducted on learners' understanding of the concepts acceleration, velocity, speed, distance as well as displacement, the literature reviewed does not seem to have reported on studies related to learners' definition of an acceleration of 0m/ss, a velocity of 0m/s, a speed of 0m/s, a distance of 0m and a displacement of 0m. Hence it is envisaged that the investigation of learners' conception of these concepts can reveal important insights into the learners' ways of thinking and understanding in science (Duit, Treagust & Mansfield, 1996), therefore assisting researchers and teachers to revise and develop their own scientific knowledge.

Consequently the research question for this research is as follows: What are the alternative conceptions and misconceptions that learners have on the description/definitions of the following, a distance of 0m, a displacement of 0m, a speed of 0m/s, a velocity of 0m/s and an acceleration of 0m/ss.

Methodology of Research

Phenomenography

Ontologically this phenomenographic case study assumed a theoretical point of view aimed at describing the different ways a group of learners understand a phenomenon (Larsson & Holmstrom, 2007). Thus, this research focused on the experiential, that is, the different qualitative ways in which content-oriented and interpretative descriptions of their reality is understood and perceived. The research was directed at the variation in learner's ways of understanding the phenomenon. This is referred to as a second-order perspective. A second order perspective was used because it was assumed that learners may have different experiences about phenomena accumulated throughout their high school career and their daily experiences. In addition, their meaning attached to the phenomena may emanate from their experiential association with language, values, beliefs and the environment they live. For this reason, the focus on the apprehended (experienced and conceptualised) content as point of departure for carrying out research and as a basis for integrating the findings is seen as the most distinctive feature. Therefore, the conceptions and ways of understanding were not seen as individual qualities but conceptions of reality were considered rather as categories of descriptions to be used (Marton, 1981).

Sample Selection

Phenomenographical research requires selection of participants who have significant experience of the phenomenon, and criterion sampling of participants who fulfil certain criteria is the most suitable methodology (Cilesiz, 2011; Creswell, 2007) for participant selection. The sample sizes of participants for a phenomenographic study are small, around seven participants, with a view to allowing the researcher to become deeply involved in the data and, therefore, the phenomenon (Connelly, 2010). In addition, Mouton and Babbie (2001) emphasise that in a qualitative research of this nature 5 to 20 respondents are seen as a sufficient number of participants. This is because qualitative research is aimed at investigating small and distinct groups normally regarded as a single-site study. Qualitative research was used to describe and analyse phenomena from the learners' perspectives (Glesne, 1999).

Research was conducted in one of the high schools in the North West Province of South Africa. From the sample of 26 grade 12 learners fourteen (14) learners were purposefully selected to participate in this research. Learners' performance in Physical Science was used to select the participants. The academic year consists of four terms and learners write class tests to evaluate their progress. The research took place in the last term of their academic year. Only learners with an average of 70% in Physical Science and above from all the tests written in the four terms were chosen to participate. Their ages ranged between 15 and 18 years. In terms of gender, eight were females and six were males. The language of teaching and learning is English, however their mother tongue is Setswana. Grade 12 is the highest grade in high school in South Africa. Therefore, the grade 12 learners were identified as information rich and likely to be knowledgeable (McMillan & Schumacher, 1997) about the concepts of displacement, distance, velocity, speed and acceleration.

Instrument and Procedures

A free response test originally consisting of eight items was developed to investigate learners' conceptions qualitatively. The test was piloted in a different high school on a group of ten grade 12 learners and their teachers. This was done in an attempt to establish content validity. Based on the results of the pilot study, and the comments from teachers, the test was modified resulting in the removal of three items. The final paper-and pencil test consisted of five items. The test was administered to a sample of fourteen grade 12 Physics high school learners. The test was administered in a regular class period and lasted 45 minutes. The free response test was preferred because truthfulness of responses to questions was assured due to the fact that the learners were asked to be anonymous. The test allowed for in-depth descriptions and drawing of graphs/pictures. In addition learners were given sufficient time to think properly through their responses. Ethical clearance was obtained from the University Research Ethics Committee. Prior to administering of the test, participants read and signed informed consent forms. Participants were given pseudonyms to protect their privacy. In addition, the learners were made aware that they have the right to withdraw from the research at any time without being penalised. Smaller number of items was chosen to enable learners to answer all the questions in detail. The concepts indicated in the free response test were questions requiring learners to give a description/definition of a distance of 0m, a displacement of 0m, a speed of 0m/s, a velocity of 0m/s as well as an acceleration of 0m/ss. Learners were also required to support their answers with a diagram, graph, or picture.

Data Analysis

The expected sets of data were 70 definitions/descriptions and 70 graphs/pictures (14 learners multiplied by 5 test questions). The data analysed were 67 definitions and 69 graphs/pictures. A small number of learners did

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not attempt some definitions and one definition/description was not supported by a graph/picture. A phenomenographic case study was used to qualitatively study the different ways in which grade 12 learners think of the concepts in the test. In other words, the aim was to discover qualitatively different ways in which learners experience, conceptualize, realize as well as understand various aspects of the phenomena (Kinnunen & Simon, 2012). In particular the research identified the multiple conceptions that learners have for a particular phenomenon. Hence, the aim was not to find the single view, but the variation and the architecture of this variation by different aspects that define the phenomena (Thompson, 2010). The research was concerned with the ways in which physics learners experience or understand selected concepts and principles of physics (Kinnunen & Simon, 2012). The main issue of credibility in a phenomenographic research is the relationship between the data obtained from the categories for describing the ways in which learners experience a certain phenomenon. To combat this, the learners were asked to define/describe the concept in words and represent their descriptions with a graph or picture. Therefore in the analysis of their descriptions, the data were triangulated between the concepts themselves, the graphs and pictures drawn by learners. The process of analysis, referred to here as 'reduction' Smith, Flowers, & Larkin et al., (2009) was used to reduce the data into themes. Analysing the data yielded themes that described the learner's definitions and conceptions. Two themes were derived, alternative conceptions and misconceptions. Furthermore, two more themes were identified, namely stationery and no movement. Learners' definitions that belonged to these themes were highlighted in the results. During the first iteration of analysis both similarities and the differences among definitions were searched. Significant statements were selected and compared in order to find cases of variation or agreement and thus grouping them accordingly. Getting a sense of the data could be described as moving into the content of the definitions with a sense of self-trust in one's analytical process (Storey in Lyons & Coyle 2007). Following this, each text was broken down into more manageable units of meaning. This was achieved by removing any other tracts of the text that were deemed general statements. What remained was the text that described the participants' responses to the key points of each question in the test.

Coding as a process of organizing and sorting data was used. The codes served as a way to label, compile and organize the data. In coding the data, phrases were assigned to the descriptions by the learners. Initial coding and marginal remarks were done on hard copies of learners' responses. The marginal codes were helpful when thinking about how codes fit together. To ensure reliability of data, the coding practice/training was used to enhance the consistent interpretation of data and reduce individual interpretive bias (Creswell, 2007). Hence before coding the descriptions, three researchers were requested to practice coding independently until 90% or greater reliability of coding was achieved. Differences in coding were constantly compared, discussed, and resolved to meet this level of consistency. At that point, a coding book was developed for use during the remaining data analysis. Additional coding rules were defined to establish consistency in segmenting the descriptions for coding.

The codes derived were as follows: The codes from the learner's descriptions of a distance of 0m were *no distance covered*, *stationery* and *the absence of movement* while the codes from learner's descriptions of a displacement of 0m *were no distance covered, the shortest distance, distance covered between A and B, same distance* as well as *stationery.* On the other hand, the codes derived from learner's descriptions of a speed of 0m/s were *no movement* and *stationery* while the codes *stationery, no movement* and *constant displacement* were from learner's descriptions of a velocity of 0m/s. This means that the codes *stationery* and *no movement* appeared in both the speed of 0m/s and a velocity of 0m/s. For an acceleration of 0m/ss, the codes derived were *constant velocity, moving constantly, no acceleration, stationery* as well as *no force.* The code that was common to all descriptions was *stationery*.

Once the data had been coded, regularities, variations and peculiarities were examined and patterns identified. The process of identifying substantive connections by associating codes or linking data was done (Dey, 2003). Correlations or relations between different codes were studied and a picture of the data was built.

Results of the Research

The results are indicated in Tables 1, 2, 3, 4 and 5. For ethical reasons, respondents' names are not mentioned; they are labelled as A,B,C,D,E,F,G,H,I,J,K,L,M and N in the first column of the tables. In the next column a description/ definition of a concept is given. The description included a highlighted keyword in each respondent's description. Selective coding (Babbie, 2009) was used to identify the central code of this research. The responses of learners, given in Tables 1, 2, 3, 4, and 5, were coded for a description of a distance of 0m, a displacement of 0m, a speed of 0m/s, a velocity of 0m/s and an acceleration of 0m/ss, respectively.

In the last two columns, the learner's descriptions are further coded into two themes (alternative conception and misconception). For the purpose of this research, the meanings that are generally accepted by the scientific community of practice are regarded as alternative conceptions and those that are not accepted by the scientific community of practice are seen as misconceptions. An (X) is used to mark the appropriate column to indicate where the meaning belongs. The responses of learners are recorded verbatim. Since the quality of the graphs/ pictures were very poor, examples of learners' graphs/pictures were redrawn.

Table 1. Learners' descriptions of a distance of 0m.

	Descriptions of a distance of 0m	Alternative conception	Misconception
A	The zero distance means there is no distance covered	X	
B	When an object is stationary or does not move over a period of time. (the total distance from point A to B)	X	
C	When an object was stationary this means no distance has been travelled from point A to B	X	
D	The is no movement taken	X	
E	Being stationary or not moving at all	X	
F	This object is not moving, its distance is 0, therefore it is stationary	X	
G	There is no distance covered	X	
H	There is no distance or if the distance is 0 that means is initial velocity	X	
I	Is when the body or object has not undergone motion Basically when the body is at rest	X	
J	There was no motion or movement done for a thing to move to either side of any direction.	X	
K	It is a distance that is not taken	X	
L	Nothing has been travelled, there is no movement of something, it is just stationary	X	
M	No forward or backward movement has been taken	X	
N	The is no distance being taken the object is constant	X	

Distance is defined as the magnitude of the path length. This means that if the trolley travelled X m from point A to point B, then the distance will be X m. Distance is a scalar quantity; therefore we do not consider the direction.

If the trolley travelled 0 m, the distance travelled will be 0 m. It is thus scientifically acceptable to say that the trolley remained stationary. This is indicated by the majority of learners (Table 1). The respondents in this research associated a distance of 0m with the object being stationary. The respondents used a variety of words to explain the scenario of a stationary object. The words included the phrases 'no distance', 'no movement', 'no motion' and 'stationary'. Though none of them included a phrase 'zero path length' their responses have been interpreted to mean that the object did not cover any distance, hence stationary. An example of the graphical representations of a distance of 0m drawn by learners is indicated below.

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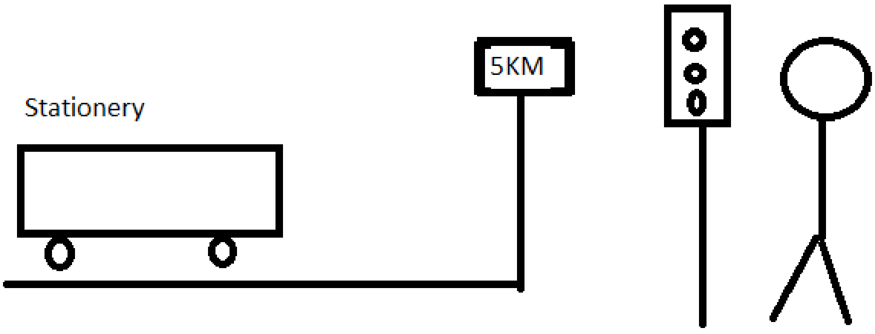

Figure 1: An example of a learner picture representing a distance of 0m.

The picture representation (Figure1) depicts a stationery car and a person standing still at the robot, waiting for the robot to open.

Table 2. Learners' description of a displacement of 0m.

	Descriptions of a displacement of 0m	Alternative conception	Misconception
A	No distance covered		X
B	The shortest distance between two points. When an object remains stationary or moves between two points and returns to the original point		X
C	When a specific distance is being covered from point A to B, then back from point B to A		X
D	Is the same distance from and to .It is a direction where a person goes to a particular point and comes back where they were		X
E	Moving a distance from the starting point and cancelling it out by coming back to the starting point. Moving from one point and come back to the same point	X	
F	-	-	-
G	Moving from the same area back and front, covering no displacement		X
H	When someone move but with 0m		X
I	Is when you walk a certain/particular distance and return to your original position	X	
J	Displacement is the shortest time taken to go to another point, but zero displacement explains that there was no displacement taken		X
K	Without shortcuts		X
L	It is just stationary there is no movement	X	
M	No distance has been covered in a certain direction	X	
N	When something is not moving is zero	X	

To describe the motion of an object, we must be able to specify the location of the object at all times. Figure 2 shows one way of accomplishing this for one-dimensional motion, such as a trolley travelling along a straight road. Suppose that the initial position of the trolley is indicated by the vector labelled $X_{0.}$

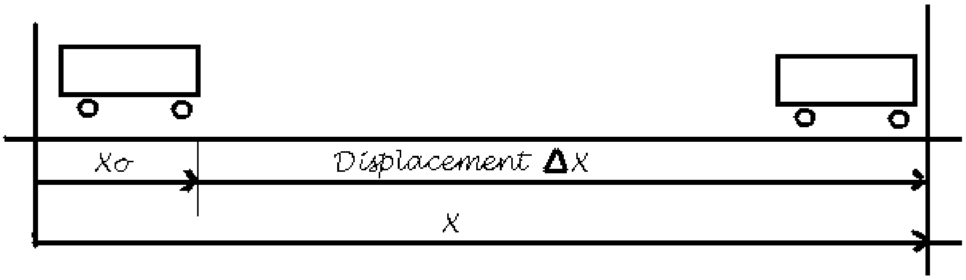

Figure 2: Trolley travelling along a straight line.

As the drawing shows, the length of X_0 is the distance of the car from an arbitrarily chosen origin. At the later time the car has moved from its initial position X_0 to a new position that is indicated by the vector *X*. The displacement is a vector quantity conveying both a magnitude and direction. This can be illustrated by:

$\Delta X + X_0 = X$ or $\Delta X = X - X_0$

Thus, the displacement is the difference between *X* and X_0, and the symbol (Δ) for the Greek capital letter delta is used to denote this difference. The displacement of the object is a vector, whose magnitude is the shortest distance between the initial and final positions of the motion and whose direction points from the initial to the final position (Cutnell & Johnson, 1995).

From Figure 2, if X_0 is equal to *X*, meaning that if the initial position is equal to the final position, the difference between the initial and final position is then zero (0m). This can be illustrated in Figure 3.

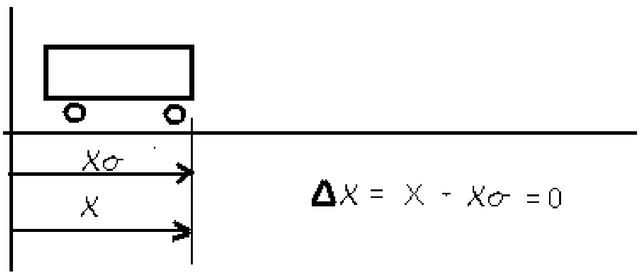

Figure 3: Stationary trolley.

This is a situation where the trolley is stationary. Alternatively, the trolley can move from point A towards point B, and then reverse to its original position, point A, as illustrated in Figure 3.

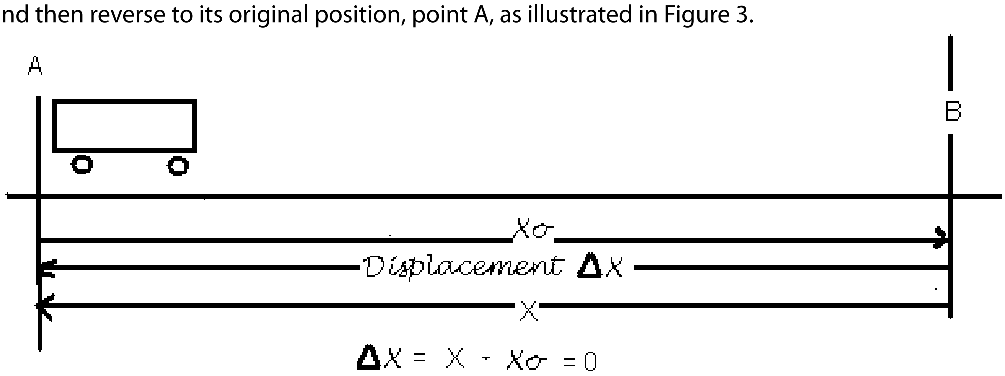

Figure 4: A trolley travelling from Point A to B and back to Point A.

In both Figure 3 and Figure 4, the difference between the initial position and the final position is zero (0m). Whilst the a displacement of 0m was obtained in Figure 3, it does not necessarily mean that a displacement of

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0m can only be obtained when the object is stationary. As indicated by Figure 4, when the object returns to the original position a displacement of 0m can be obtained. Some learners perceive a displacement of 0m to be zero motion (no movement).

The graphical representation of a displacement of 0m is represented in Figure 5.

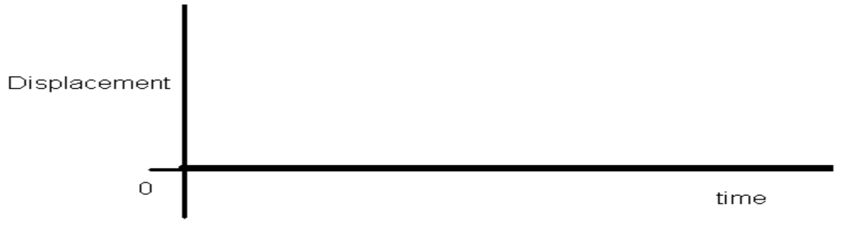

Figure 5: Graphical representation of zero displacement (0m).

A displacement of 0m is represented by the line drawn over the time axis (Figure 5).

However, according to one of the learners, the figure below (figure 6) represents a graph of a displacement of 0m, which is a misconception. In addition, the vertical and the horizontal axis are not been labelled.

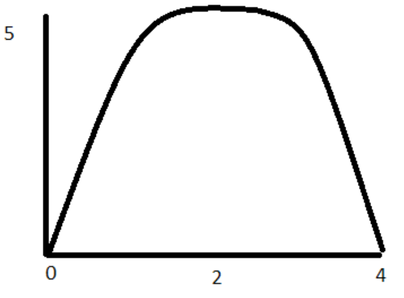

Figure 6 An example of a learner graph representing a displacement of 0m.

Table 3. Learners' descriptions of a speed of 0m/s.

	Descriptions of a speed of 0m/s	Alternative conception	Misconception
A	The is no movement the object is just stationary	X	
B	When an object does not increase or decrease its speed. It remains stationary	X	
C	An object is stationary but tend to travel with zero speed	X	
D	It is the same as a stationary object there is no movement	X	
E	Covering no distance per time or in a certain time, not doing anything at all	X	
F	When an object has 0 speed that means this object does not move it is stationary	X	
G	The is no speed taken not moving anywhere	X	
H	When something from the starting point but moving zero speed or not going anywhere	X	
I	Is when the object has not undergone motion/distance over a particular time. When the object is at rest	X	

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	Descriptions of a speed of 0m/s	Alternative conception	Misconception
J	Zero speed explains the distance and the time taken for one to complete or travel on a certain journey. This means that at zero speed it is not moving	X	
K	A speed that is not increasing		X
L	There is no distance, there is no movement	X	
M	The rate at which a body moves with is 0		X
N	A speed without moving		X

One of the features of an object in motion is how fast it is moving. If a car travels 300 m in 20 s, its average speed is 30 m/s. The average speed is the distance travelled divided by the time required to cover the distance:

$$\text{average speed} = \frac{\text{Distance}}{\text{Elapsed time}}$$

Zero speed

If a car travels a distance of 0 m in 20 s, its average speed will be 0 m/s. Basically the car is stationary. Therefore we have zero speed.

The graphs representing zero speed are indicated below:

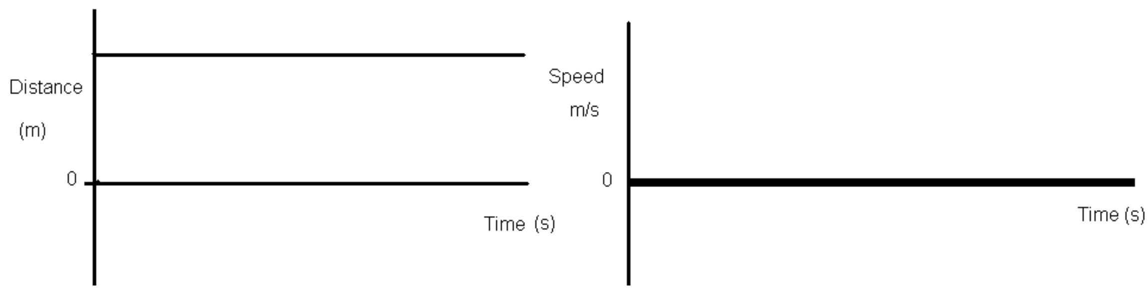

Figure 7: Graphs representing a speed of 0m/s.

Since there is a relationship between distance and speed, the majority of learners indicated (Table1) that a distance of 0m and a speed of 0m/s (Table 2) mean that an object is stationery. Few responses were misconceptions, for example, respondent K, defined a speed of 0m/s as "a speed not increasing" while respondent M said that a speed of 0m/s is when "the rate at which a body moves with is 0". Respondents N defined a speed of 0m/s as "a speed without moving". These responses indicate lack of understanding of the concept of speed equal to 0m/s. It is not clear what the learners meant by the statements made.

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Figure 8: An example of a learner graph representing a speed of 0m/s.

Figure 8 above shows an example of a graph representing a speed of (0m/s). It shows clearly that the learner was unable to represent a speed of 0m/s graphically.

Table 4. Learners' descriptions of velocity of 0m/s.

	Descriptions of a velocity of 0m/s	Alternative conception	Misconception
A	No work is done		X
B	when an object remains stationary over a period of time	X	
C	An object travels a certain distance with no velocity at a particular time. Meaning it is stationary	X	
D	There is no movement the object has stopped	X	
E	Not covering any displacement in a certain time, which simply means not moving	X	
F	A stationary object usually have zero velocity because it doesn't move	X	
G	Being unable to move at the required velocity just standing	X	
H	When something moving with initial velocity		X
I	When an object undergoes constant displacement, or gradual increase in displacement		X
J	Zero velocity is the time and the distance travelled for the object to reach certain point up or down left or right and then to return again		X
K	Without a car accelerating		X
L	No movement, no work, it's just stationary	X	
M	The amount at which a body is travelling with is zero, that means it is standing still	X	
N	-	-	-

The average speed of the object does not reveal anything about the direction. If the object's initial position is X_0 when the time is $t(0)$. A little later the object arrives at its final position X at time t. Dividing the displacement of the object by the elapsed time gives the average velocity.

$$\text{average velocity} = \frac{\text{Displacement}}{\text{Elapsed time}}$$

If displacement of an object is (0m), then the average velocity becomes 0m/s. As indicated earlier a displacement of 0m does not necessarily mean that the object is stationary. If the displacement is constant this means that the initial position is equal to the final position, and then the change in displacement will be 0m. The result is an average velocity of 0m/s.

The graph representing a velocity of 0m/s is indicated below:

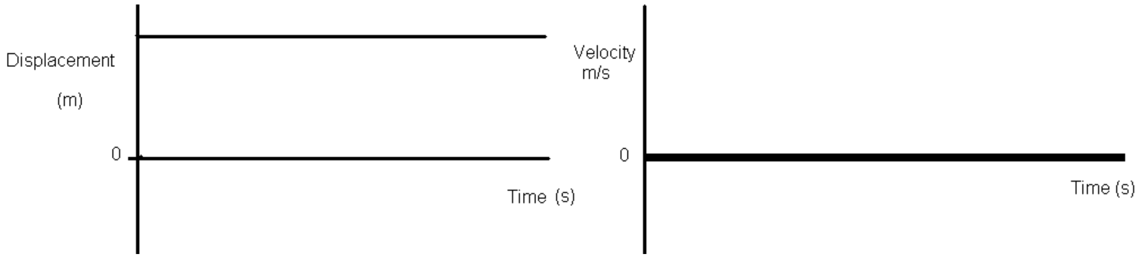

Figure 9: Graphs representing a velocity of 0m/s.

The learners in this research related a velocity of 0m/s to a stationary object and they used the phrase no movement to describe a velocity 0m/s. Though it is an acceptable description, none of the respondents mentioned that the object should travel with a constant displacement for the velocity to be 0m/s. Five responses were misconceptions and one did not attempt to describe a velocity of 0m/s.

One of the misconceptions is indicated graphically in Figure 10 below.

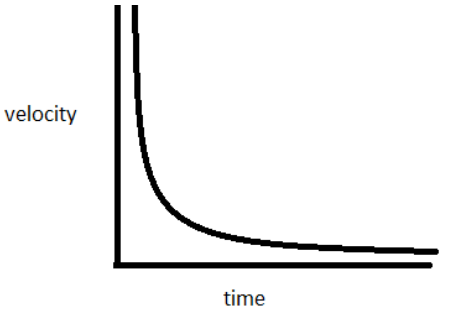

Figure 10: An example of a learner graph representing a velocity of 0m/s.

In the learner's mind the graph above represent a velocity of (0m/s).

Table 5. Learners' understanding of an acceleration 0m/ss.

	Description of an acceleration of 0m/ss	Alternative conception	Misconception
A	When an object move at a constant velocity	X	
B	No increase in speed just moves constantly		X

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	Description of an acceleration of 0m/ss	Alternative conception	Misconception
C*	An object travels a certain distance with no acceleration, it does not increase its speed but at that point there is no speed		X
D	There is no increase in the velocity of the car it means it is constant velocity	X	
E	No motion, or simply something that is not doing anything or moving	X	
F	-	-	-
G	increasing		X
H	Something move from top to bottom, sliding to the ground		X
I	Is when the velocity of an object is constant, or the object experiences no velocity at a given time	X	
J	Zero acceleration explains that object did not up or move up		X
K	If an object is not moving	X	
L	No force exerted	X	
M	There is no increase the speed at which a body is travelling		X
N	No force being made	X	

Whenever the velocity of an object is changing, then the object is accelerating (Cutnell & Johnson, 1995). For example, a car temporarily stops at a traffic signal, and accelerates when the light turns green. Examples involve an increase or a decrease in velocity.

$$a = \frac{V - V_0}{t - t_0}$$

The graphs representing an acceleration of 0m/ss are indicated below:

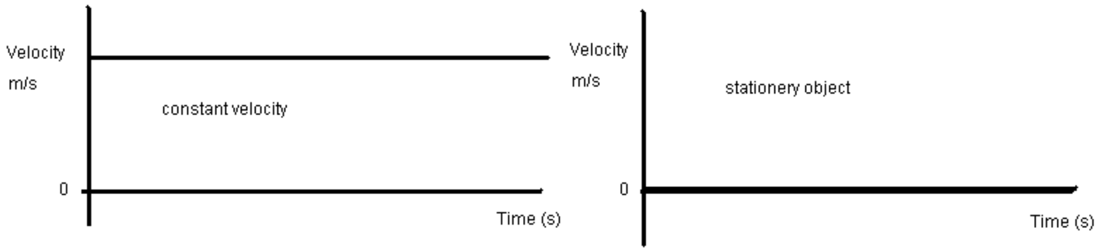

Figure 11: Graph representing an acceleration of 0m/ss.

For an acceleration to be 0m/ss, the object should travel at a constant velocity. Therefore, the final velocity (*V*) will be equal to the initial velocity V_0. This means that the difference between the final and initial velocity will be 0m/s and the acceleration will be zero (0m/ss). In addition, if the object is stationary then its acceleration is also zero (0m/ss). Out of the 14 respondents in this research, 6 respondents (43%) could not describe zero acceleration (0m/ss). Only respondents D and E defined both zero velocity (0m/s) and zero acceleration (0m/s) correctly. The rest of the respondents defined zero velocity (0m/s) but could not define zero acceleration (0m/ss) and vice versa. Respondents related a velocity of 0m/s to stationary objects and they did not mention that the object has a velocity of 0m/s when it travels at constant displacement. Learners use the concept zero speed (0m/s) and zero velocity (0m/s) interchangeably hence they could not explain zero acceleration (0m/ss).

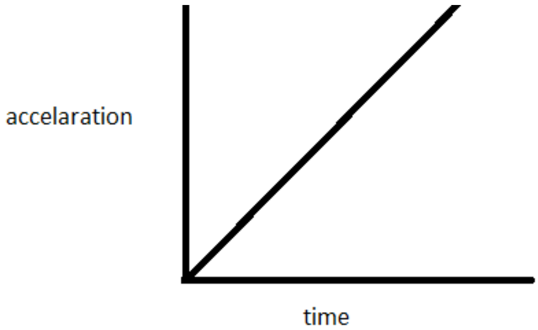

Figure 12: Example of learner graph representing an accelation of 0m/ss.

An example of learner's view of zero acceleration (0m/ss) is represented graphically above (Figure 12).

The research revealed that many of learner's descriptions included the phrase 'nothing' "no" associating the 'zero (0)' to 'nothing'. This resulted in defining some of the concepts non-scientifically, hence the misconceptions were displayed. One important reason contributing to the misconceptions in definitions/descriptions of concepts was their association of zero (0) to everyday mother tongue talk. Since the concept "zero (0)" shares common properties with the concept "nothing" in their mother tongue, for these learners these properties were necessary and sufficient to define the concepts given in the test. The research also confirms that students hold misconceptions in kinematics. Furthermore, the research reveals that students fail to formalise and contextualise 0 as a concept in kinematics.

Discussion

Kinematics seems to pose a number of challenges to learners. Consistent with (Roschelle, 1998) there is ample evidence that the students' understanding of the concepts such as velocity and acceleration is not complete. Learners experienced challenges in correctly defining the kinematics concepts. Generally, the majority of the respondents used the description of a distance equal to 0m to define a displacement of 0m. This finding is consistent with Lemmer (2013) that learners confuse distance and displacement. Similarly some learners think that displacement is the same as distance, the only difference is that displacement has a small value, that is, shorter distance (Lemmer, 2013). Hence, now that they were required to define a displacement of 0m and a distance of 0m, in their minds a displacement of 0m should be defined in the same way as the distance of 0m.

The results show that 64 % of the respondents could not give an acceptable definition of a displacement of (0m). Learners confused distance and displacements resulting in a further confusion between the meaning of a distance of 0m and a displacement of 0m. For example, respondent (A) used the same explanation to describe both a distance of 0m (Table 1) and a displacement of 0m (Table 2). Generally many of the respondents attempted to give meaning of the concept of displacement but could not contextualise a displacement of 0m.

Responding to the meaning of a velocity of 0m/s (Table 4), respondent (A) for example indicates that a velocity of 0m/s means "no work done". This can be explained by the fact that learners see motion of an object as caused by the internally stored impetus (McCloskey, 1983), for example force or energy. Since work done is actually the energy transferred when a force moves an object over a distance. Learners used the same impetus theory that because there is no work done (no energy transferred) then the object cannot move, meaning a velocity of 0m/s.

The results shows that some of the respondents could not explain a speed of 0m/s (Table 3), a velocity of 0m/s (Table 4) and an acceleration of 0m/ss (Table 5). The implication of these is that, when a learner cannot conceptualise the meaning of a displacement of 0m, he or she is likely to have difficulties in the understanding of the concepts such as a speed of 0m/s, a velocity 0m/s and an acceleration 0m/ss. In addition to errors in the definitions/descriptions of concepts, there were many errors in the graphs/pictures drawn by learners to support their descriptions/definitions. Some of the learners could not correctly represent their descriptions/definitions in the form of a graph or picture. Consistent with Beichner (1994) the graph is considered to be like a photograph of the situation. It is not seen to be an abstract mathematical construct, but rather a concrete duplication of the motion event. This finding is consistent with research by McDermott et al., (1987) that, students find it difficult to represent continuous motion with a line or curve, differentiating between the shape of a graph and the path of the motion. In addition researchers (Hale, 2000; Beichner, 1994; Basson, 2002; Christensen & Thompson, 2012; Planinic, Ivanjek, & Susac, 2013) argue that misinterpretations of kinematics graphs are common among students. Consequently, adding to the inconsistencies between the textual definitions/descriptions and graphs/pictures. In agreement with Roschelle (1998), the key finding is that students rapidly construct heuristic associations, but those associations may not include enough knowledge to support an integrated understanding. In simple terms, learners may know that a relationship exists between certain kinematics concepts, but they are unable to accurately define concepts in terms of these relationships.

One of the reasons that can be attributed to the incorrect descriptions of these concepts is the fact that learners interpreted these concepts in the context of their mother tongue "Setswana". Setswana is one of the South African languages. In Setswana, "0" means nothing, added to that the terms acceleration, velocity and speed are all represented by the same terminology in Setswana thereby meaning the same thing "moving faster" or "moving slower". If the object is not moving faster or slower then it stopped or stationery. In other words, if the value of the acceleration, velocity, speed, distance or displacement is given a value of 0, then the term is described using terminology such as "not moving" or "stationery". That is why most of the learners used the term stationery or not moving. Similarly, the issue of language is consistent with findings by Lemmer (1999) who also found that language and culture contribute towards alternative conceptions of learners in kinematic concepts.

Similarly in the research by Shaffer and McDermott (2005) about half of the students stated that the acceleration is zero at the turnaround point for the one dimension pre-test involving the ball on the ramp. Similar errors were made at the end points on the pendulum problem. Often students reasoned that because the velocity is zero, the acceleration is zero. This widely-recognized conceptual error is closely related to the tendency to confuse velocity and acceleration. In addition some students seemed to believe that an object about to move must have nonzero velocity. Many drew nonzero vectors at the starting point for the oval and pendulum. On the two dimension pre-test, about 20% of the students stated that the acceleration is zero for an object moving with constant speed along the oval track. They treated the motion as if it were one-dimensional, not realizing that a change in direction of the velocity means a change in the velocity vector and so corresponds to a nonzero acceleration. This was the most common error made by the graduate students on the pendulum problem. Furthermore Shaffer and McDermott (2005) argue that the confusion between velocity and acceleration were also evident on the colliding carts pre-test. Many students claimed that the acceleration of cart A is to the right. Some seemed to be thinking of an average or "overall" velocity and reasoned that because the car's initial velocity to the right is larger than the final velocity to the left, the acceleration is to the right. Even some students who answered correctly seemed to relate the acceleration to the direction of the final velocity, not to the change in velocity.

In another related research a pulling metaphor in the form 'acceleration pulls the tip of velocity was used. This use of a pulling metaphor is important because it provides grounds for mapping the students' knowledge to scientific knowledge and indeed, a common-sense definition of 'force' often invokes pushing or pulling. Scientists think about the relationship between velocity and acceleration with one unifying concept, the derivative. The use of a pulling metaphor provides an explanation of these knowledge elements in terms of a single unifying abstraction (Roschelle, 1998).

Likewise textbooks present only a narrow subset of the scientific meanings available to practising scientists. Discussions of qualitative interpretations and explanations, for example, hardly ever appear. Likewise, while students can construct misconceptions, they also can construct knowledge that demonstrates clear progress towards scientific understanding. The focus on opposing textbook concepts and student misconceptions or on opposing textbook equations to students' knowledge systems, therefore potentially misses much of the developmental action (Roschelle, 1998).

Therefore, the results confirm findings by researchers (Basson, 2002, Halloun & Hestenes, 1985, Molefe et al., 2005, Shaffer & McDermott, 2005) that learners confuse the concepts of position, velocity, and acceleration and they relate them unscientifically. Similar findings (Trowbridge & McDermott, 1981) identified alternative conceptions encountered by students in kinematics. Similarly (Beichner, 1994) students see little difference between distance, velocity, and acceleration. They often believe that graphs of these variables should look identical. This might be related to the graph as picture error. If a graph is like a photograph, it shouldn't matter what is graphed, it will look like a replication of the object's physical motion. Nonetheless, Lichtenberger, Vaterlaus and Wagner (2014) argue that there are two basic mathematical concepts that are crucial for the understanding of kinematics: the concept of rate and the concept of vector (including direction and addition). If a student understands the concept of rate, he is able to answer correctly to questions about velocity and acceleration in different contexts.

However, in terms of understanding the concept of zero (0) as used in the definition of kinematics concepts acceleration, velocity, speed, displacement and distance, the context and the content should play a major role.

Conclusion

The results of this research show that learners who participated in this research have difficulty in describing/defining the concept of a displacement of 0m, a distance of 0m, a speed of 0m/s, a velocity of 0m/s as well as an acceleration of 0m/ss. To date the literature has shown that there are misconceptions in kinematics, but this research offers misconceptions associated with the concept of "0" zero numerically attached to concepts distance, displacement, speed, velocity and acceleration. While this research does not offer a conclusive answer to the question of the alternative conceptions and misconceptions that learners have on the description/definitions of a distance of 0m, a displacement of 0m, a speed of 0m/s, a velocity of 0m/s and an acceleration of 0m/ss, it does offer new knowledge in the sphere of misconceptions in kinematics.

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