A study of student teachers' misconceptions on uniform circular motion

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Abstract. Uniform circular motion is one of the key mechanics topics in Physics that students fail to comprehend and master. In South Africa, uniform circular motion is currently not taught to Physical Sciences Matriculate learners and thus students are only introduced to it at university level. It is appreciated that poor comprehension of fundamental concepts and tenets of uniform circular motion leads to difficulties in understanding related topics such as *Rotational Kinematics* and *Rotational Dynamics*. This study investigated student teachers' misconceptions about uniform circular motion and its pertinent underlying concepts such as tangential acceleration and centripetal acceleration. The study also attempted to figure out the source(s) of the ensuing misconceptions. The sample of the study consisted of 41 second-year Physical Sciences student teachers at a South African university. A multiple-choice test consisting of 20 questions on uniform circular motion was administered. Simple and explanatory statistical techniques were employed to analyse the data and appropriate intervention methods were proposed to curtail the identified misconceptions. The study revealed that factual misconceptions and conceptual misunderstandings were prevalent amongst the student teachers who took part in the research exercise.

1. Introduction

It is generally known that physics is regarded by many people as a difficult subject and it is unfortunate that most of the crusaders of this negative gospel may never have studied the subject during their entire schooling life. This tag on the subject has undoubtedly caused a lot of anxiety amongst potential physics students and if the myth is not unmasked, the world may lose brilliant minds that may advance this important and beautiful subject. At the centre of the perceived difficult nature of the subject is the issue of misconceptions, also referred to as alternative conceptions.

2. Background of the study

Due to various reasons, South African students who obtain very good grades in their high school matriculation examinations opt to pursue other qualifications instead of the Bachelor of Education (BEd) degree programme. It can thus be argued that the BEd qualification appears not to be a programme of choice for the gifted learners. Of particular concern is the fact that almost all of our BEd students have relatively low scores in their matriculation Physical Sciences (generally less than 50 %). This is in sharp contrast to their peers at our institution who enroll for programmes such as the

Bachelor of Science (BSc) in Physics who have an average score of 57 % in their matriculation Physical Sciences.

After teaching a second year Physics module for five consecutive years, the researcher observed a trend of students consistently struggling to cope with the topic on uniform circular motion. The current Curriculum and Assessment Policy Statement (CAPS) on high school Physical Sciences does not have a topic on uniform circular motion. Having noted the challenges and scenario stated above, the researcher found it appropriate to interrogate the issue so as to come up with potential solutions to the problems. The main purpose of this study was therefore, to investigate the student teachers' misconceptions about uniform circular motion and to reveal the sources of the observed misconceptions.

3. Literature

In one of his highly regarded writings, Lee Shulman intimates that "after 30 years of doing such work, I have concluded that classroom teaching … is perhaps the most complex, most challenging, and most demanding, subtle, nuanced, and frightening activity that our species has ever invented. In fact, when I compared the complexity of teaching with that of much more highly rewarded profession, 'doing medicine,' I concluded that the only time medicine even approaches the complexity of an average day of classroom teaching is in an emergency room during a natural disaster" [1]. From this argument, it is clear that teaching is a demanding and important profession that requires to be manned by the best available personnel. In an ideal world, this would translate to the best high school students enrolling into the teaching profession qualifications such as the BEd. This is unfortunately not the case in most countries since the teaching profession is lowly regarded in society and thus the *crème de la crème* of the high school populace chooses to pursue more rewarding and highly regarded professions such as engineering and medicine. In the end, the teaching profession is largely left in the hands of the "second best" personnel.

Most of physics students are generally good at memorizing equations and relevant algorithms but are largely found wanting when it comes to tackling conceptual questions [2]. Teachers should be equipped with the skills of showing their students the reasoning processes involved in getting solutions, instead of just offering examples.

Types of misconceptions

According to Piaget, children look for meaning as they interact with their surroundings and utilize such encounters to test and modify existing schemas [3]. However, some of the meanings extracted from these experiences lead to the development of misconceptions. Misconceptions may be viewed as ideas that provide an incorrect comprehension of ideas, objects or events and usually emanate from an individual's experiences [4].

Authors in [5] categorise misconceptions into five types, and these are: *preconceived notions, non-scientific beliefs, conceptual misunderstanding, vernacular misconceptions* and *factual misconceptions.*

Preconceived notions are widespread conceptions that are anchored in our daily experiences. Some of the prevalent preconceived notions in science are [6]:

i. When substances dissolve, they "disappear."
ii. Melting and dissolving are the same.
iii. Particles of solids do not move.

Non-scientific beliefs comprise ideas learnt by learners from other teachings that are not scientific in nature. In almost all African countries, the majority of the populace believe in taboos, witchcraft, spirits and rituals that mirror the highest level of amassed experience in a given society [7]. In countries such as Ghana, Zimbabwe and Burkina Faso, certain mountains and forests are believed to

possess some supernatural spiritual powers and are thus sacred and not everyone is allowed to visit such places [8], [9]. It is therefore important to note and appreciate the negative role that culture, religion and superstitions may play in the learning of science [10], [11].

Conceptual misunderstandings are conceptions that emerge when learners are exposed to scientific information in a manner that does not aid them in "rectifying" their own preconceptions and non-scientific beliefs. As a result, learners end up constructing inaccurate models that are themselves incomprehensible and confusing to them.

Vernacular misconceptions stem from the usage of words that have one meaning in everyday life and a distinct meaning in the scientific realm. Some examples of such words include, "power", "work", "weight" and "energy". The conceptions are further exacerbated by literal translations from one language to another by teaching and learning material translators who are not conversant with scientific jargon.

Factual misconceptions usually arise from conceptions that are normally acquired at a tender age and remain engrained and even perpetuated into adulthood. Some of the common examples of these misconceptions are:

i. Lightning never strikes the same place twice [5].

ii. Water goes down a plughole clockwise in the southern hemisphere and anticlockwise in the northern hemisphere.

There are plenty of ways that educators can employ to help in clearing learners' misconceptions, but before this can be successfully done, teachers need to come up with strategies that can aid them in identifying the prevalent misconceptions that their learners may have.

4. Methodology

The population in this study comprised of all BEd second year students who majored in Physical Sciences in 2018 at a state university in the North West province of the Republic of South Africa. The total number of the population was 41, of which 21 were females and 20 were males. Due to the size of the class, the sample was the same as the population.

A multiple-choice test consisting of twenty (20) questions on uniform circular motion was administered at the end of topic. A sample of some the multiple-choice questions is shown in figure 1. An online Sakai platform that is owned by the university, called *efundi*, was used to both compile and administer the test for a duration of forty minutes. The multiple-choice test was made up of both conceptual and calculation questions. The test was validated by three experienced colleagues in the Physics department of the Faculty of Natural and Agricultural Sciences within the same institution.

5. Results

Of the 41 students who wrote the test, 30 scored a mark of 50 % and above. Figure 2 shows the distribution of the overall marks. Only 29 % of the students attained a mark that was above 70 % and this indicates that the quality of the marks that was obtained was not impressive. Figure 3 shows the relationship between gender and the percentage of the students who scored 50 % and above in the test. It is clear from the graph that the female students outshone their male counterparts. Future studies linked to this research should interrogate this outcome to try and grasp the reasons behind this glaring disparity in performance of the female and male students.

Given that a car moves in a circular path at a constant speed. Which of the following is true?

A. The car's acceleration is zero because it has a constant speed

B. The car's acceleration is not zero and causes the car to slow down

C. The car's acceleration is not zero and causes the car to speed up

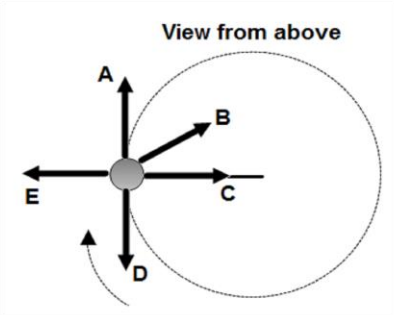
D. The car's acceleration is not zero and causes the change in the direction of the car's velocity

E. None from the above

An object undergoes uniform circular motion in a horizontal plane as shown in the diagram. The direction of the net force is:

A.) A B.) B C.) C

D.) D E.) E



An object moves around a circular path at a constant speed and makes five complete revolutions in 20 s. What is the period of rotation?

A.) 5 s B.) 10 s C.) 4 s D.) 20 s E.) 15 s

A girl stands at the edge of a huge rotating turntable. Which of the following forces prevents her from sliding off the turntable?

A. The force of gravity

B. The normal force

C. The static friction

D. The kinetic friction

E. None from the above

Figure 1: A sample of some of the test questions

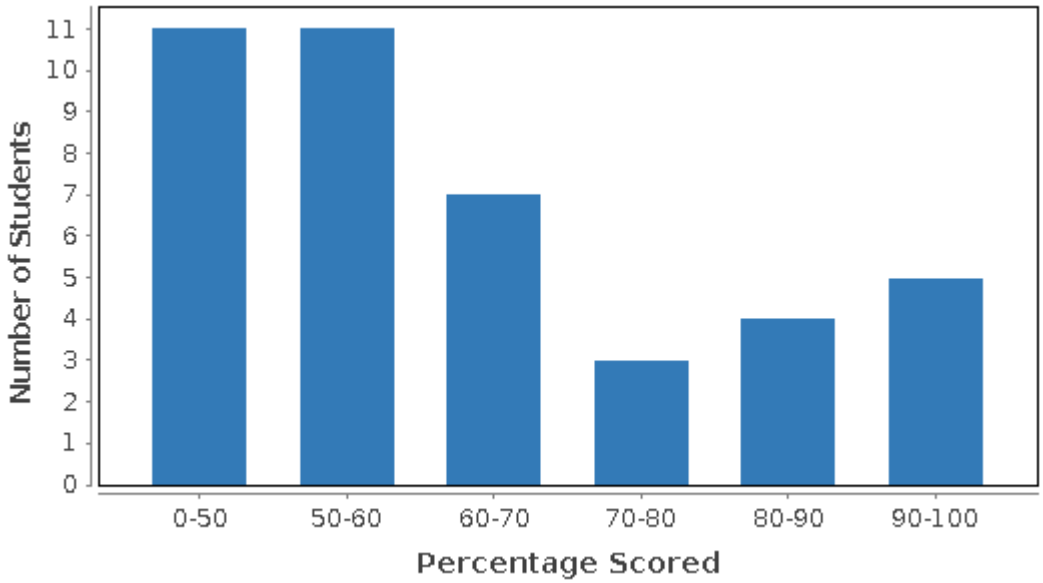


Figure 2: Overall marks distribution for the test

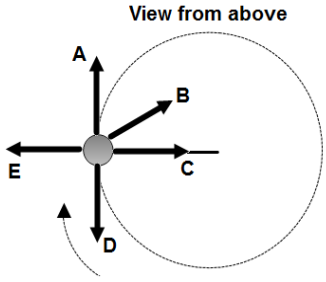
A staggering 85 % of the students got the following question wrong:

Given that a car moves in a circular path at a constant speed. Which of the following is true?
A. The car's acceleration is zero because it has a constant speed
B. The car's acceleration is not zero and causes the car to slow down
C. The car's acceleration is not zero and causes the car to speed up
D. The car's acceleration is not zero and causes the change in the direction of the car's velocity
E. None from the above

Most of the students (90 %) gave option A as their answer. This may be an indication to the disturbing fact that most of the students believe that speed and velocity refer to one and the same quantity and thus can be used interchangeably. Only one student got the following question correctly:

An object undergoes uniform circular motion in a horizontal plane as shown in the diagram. The direction of the net force is:

A.) A *B.) B* *C.) C*
D.) D *E.) E*



Many of the students (75 %) gave option E as their solution. This may be attributed to the misconceptions that students amass due to the experiences they encounter when moving in vehicles negotiating curved motorways. This therefore gives rise to the belief that there should be a force (centrifugal force) that should counter the centripetal force (labelled C) when objects move on circular paths.

Overall, students generally did well with calculation problems since 65 % of them got all calculation problems correctly.

6. Discussions and Conclusion

This study revealed that students have deep-seated misconceptions in as far as uniform circular motion is concerned. It is apparent that there is a tendency to "extend" (mis)conceptions from linear motion to uniform circular motion since most students failed to distinguish the terms "uniform speed" and "uniform velocity". This may be explained as the manifestation of the existence of both factual misconceptions and conceptual misunderstandings amongst the student teachers. The study also exposed the notion that students tend to mix-up concepts on tangential and angular variables encountered in uniform circular motion such as angular velocity and tangential velocity. Again, this points out that conceptual misunderstandings are rife amongst the students on this particular topic. Another crucial observation was that students tend to just use the formulae to get answers without proper comprehension of the fundamental concepts involved. This argument is supported by the fact that most students (65 %) got all the calculation problems in the test correctly. It implies that students are not firmly grounded in as far as the basic concepts in mechanics are concerned. There should be no room for just plugging-in figures in formulae for the effective teaching and learning of physics, rather, learners should be guided in grasping the crucial basic concepts that enables them to make meaningful connections of physics phenomena.

From this study, it can be inferred that most of the students have challenges with two main misconception types, and these are: conceptual misunderstandings and factual misconceptions. Bearing in mind the above observations, it can be recommended that the Department of Basic Education in South Africa should assist high school teachers via workshops and short-learning programmes to better handle the "tricky" basic mechanics and related physics concepts (legacy issue). A critical review of the current CAPS curriculum on Physical Sciences may be necessary so that important topics such as uniform circular motion may be included to avert the current challenges that students face when they enrol for their bachelor's degrees in the physical sciences and related fields. It is further proposed that there should be an increase in the number of tutorial and support sessions available to the BEd (Physical Sciences) students. Furthermore, it is recommended that the university takes into consideration the introduction of an extended programme for BEd students with low Physical Sciences high school marks.

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