

An Evaluation of Undergraduate South African Physics Students' Epistemological Beliefs When Solving Physics Problems

Leelakrishna Reddy ^{1*}

¹ University of Johannesburg, SOUTH AFRICA

Received 3 April 2019 ▪ Accepted 27 May 2019

Abstract

Students' epistemological beliefs are beliefs centred on one's own learning and knowledge. Such beliefs play a major role in the way one approaches problem solving in physics. The intention of this study is to evaluate such beliefs amongst undergraduate physics students. An analytical tool developed by Hammer has been used as a criterion for measuring such beliefs whilst engaged in physics problem solving. A case study of seven students with varying academic abilities and genders were chosen for this study. Each of these students' epistemological beliefs were examined through a clinical interview when they were presented with three different problems to be solved. To achieve a more holistic characterisation of the students' epistemological beliefs, a second person independently, evaluated their beliefs as well. The results reveal that students have personal epistemological beliefs that are different from each other and with respect to each of the problems, they solved.

Keywords: epistemological beliefs, learning, knowledge, physics problem solving

INTRODUCTION

Problem solving is a fundamental act in any human experience. Significant effort is sought from literature to understand how people become expert problem solvers (Wampler, 2013), and in particular to the domain specific discipline of physics. An important aspect of student learning and achievement is their epistemological beliefs. Epistemological beliefs are assumptions made about the nature of knowledge and knowledge acquisition. Such knowledge is important as it dictates how knowledge should be channelled in problem solving approaches. On the topic of problem solving, research has shown that epistemological beliefs can be regarded as a good predictor of success (Romana & Thomas, 2013; Schommer-Aiken et al., 2005). According to Romana & Thomas (2013), there is a possible link between epistemological beliefs and problem solving but that it is not directly related. This is because epistemological beliefs are related to cognition, study skills and learning strategies (Ongen, 2003) while problem solving requires students to use multiple ways to analyse a problem (Erdamar & Alpan, 2013). Self-efficacy appears to be the only link between epistemological beliefs and problem solving. In this

instance efficacy would be the belief that a student uses his epistemological belief to successfully solve a problem.

Much research has been done on epistemological beliefs in science, but little has been focussed on students' epistemological beliefs in the area of physics. In particular, Hammer (1994) has conducted ground-breaking work on epistemological beliefs of students on problem solving strategies in physics. His findings reveal that students understanding of the structure of physics is a weak combination of bits and pieces of information instead of physics being connected in a coherent structural framework. Through this process, he was able to classify students' problem solving strategies into one of two categories: those with an expert-like view and those with a novice like view (Wampler, 2013). Thus it can be said that novices focus on the surface features and rely on rote memorization when attempting to solve a problem (Walsh, Howard & Bowe, 2007) while the expert-like problem solvers do a quantitative analysis of the problem they have to solve.

There are various techniques used for the assessment of beliefs, and they are questionnaires, interviews, reflections and observations (Ozturk & Guven, 2016). Of

Contribution to the literature

- Provide an evaluation of students' epistemological beliefs when solving physics problems.
- Epistemological beliefs in solving physics problems were measured through interviews and clinical discussions with students.
- Findings of this study reveal that students have personal epistemological beliefs that are different from each other when solving different kinds of physics problems.

these techniques, the use of the questionnaire may have some disadvantages over other techniques in that it may overlook information such as changes in beliefs, emotions, behaviour and feelings whilst students are engaged in problem solving in physics. In this research, the interview method together with observation and reflections will be chosen because it can reveal insights into the way students think and understand physics (Redish & Steinberg, 1999). This is useful in the sense that it allows students to describe and explain their thinking when attempting to solve problems in physics.

Epistemological Beliefs and Problem Solving

Over the years, there has been an increased interest in studies that focusses on an individual's epistemological beliefs (beliefs on knowing and the nature of knowledge) (Erdamar & Alpan, 2013). Such beliefs (Faber, 2015) about knowledge and knowing were found to influence an individual's problem solving strategies (Bromme, Pieschl & Stahl, 2009; Muis & Franco, 2009a, 2009b). There are two schools of thought about epistemological beliefs; one that focusses on the development of epistemological beliefs (Kuhn & Weinstock, 2002) and the other that focusses on the structure and dimensions of epistemological beliefs (Schommer, 1994; Schommer-Aikens, 2002). In respect to the latter, an individual's epistemological belief was found to differ from one person to another (Ekinci, 2017). According to Erdamar and Alpan (2013), there exists a relationship between epistemological beliefs and problem solving (Schoenfeld, 1983; Schommer-Aiken, Duell & Hutter, 2005). On the other hand, research by Kizilgunes, Tekkaya and Sungur (2009) alludes to the relationship between an individual's epistemological belief and their learning. Thus students' with sophisticated beliefs about the nature of knowledge and learning have a deep understanding of problems and are thus more able to cope with complex tasks (Schommer-Aiken & Hutter, 2002). According to Erdem (2005), problem solving is based on the knowledge derived from authority or from one's own existing knowledge. It is from one's epistemological belief that one is able to draw on appropriate strategies in problem solving.

Perry was the first person in 1970 to study epistemological beliefs. He described four developmental stages to advance epistemological beliefs (as described by Wampler, 2013):

- Dualism – that knowledge remains certain and only comes from authority;
- Multiplism – that knowledge is subjective, and that every view has an equal value;
- Relativism – that knowledge has different degrees of certainty and that each must be judged in context; and
- Commitment with relativism – that some knowledge can be accepted and can be applied in a variety of situations.

In the research done by Perry (1970), it was found that undergraduate students tend to believe in knowledge that is simple, certain and derived from authority. Their beliefs only changed in their senior years of study (Angeli & Valanides, 2012). With respect to the above beliefs, it was mentioned by Perry (1970), that most students beliefs could be taken to be aligned to one of the first three developmental stages of epistemological beliefs. Others, such as Schommer (1990, 1998) have stated that epistemological beliefs of students are multidimensional and that not all beliefs develop at the same rate amongst students. Schommer (1990) proposed that individual students might have different interpretations of the same problem. Some students see the derivation of the formula from fundamental principles as a way of improving their understanding of physics, while others may perceive the formula in its exact nature to be a reflection of the theory and could be used freely in their problem solving strategy (Relish et al., 1998; Sachin, 2009). In this respect, it might be worthwhile mentioning that student' beliefs about learning physics to be different from the way both novices and experts perceive it (Redish et al., 1998). Schommer (1990) proposed a taxonomy of epistemological beliefs, namely (Erdamar & Alpan, 2013):

- Omniscient authority – belief about the source of knowledge;
- Certainty of knowledge – belief that knowledge is certain;
- Simple knowledge – belief about the structure of knowledge;
- Quick learning – belief about the speed of knowledge acquisition, and
- Innate ability – belief in the stability of knowledge.

In the context of the above, individuals can be categorised as being underdeveloped (novices), where knowledge is absolute or naïve and that knowledge is transferred from authority. On the other hand, those with sophisticated beliefs (expert-like) are those that believe that knowledge is either correct or incorrect depending on the situation. It is these individuals that have knowledge whose structure is sophisticated that has been modified from rational or experimental evidence (Erdamar & Alpan, 2013).

Another issue of interest in literature is the level of domain specificity in epistemological beliefs (Schommer-Aikins & Duell, 2013). In this sense epistemological beliefs can be domain general (applies across all domains) while domain specific (applies to a specific discipline) such as mathematics, physics and social science. Over the years, there has been substantial research in the domain general area but few in the domain specific area. Our research will focus in the domain specific area and with respect to the subject physics.

As mentioned earlier, the challenge of associating problem solving with the concept epistemological beliefs is difficult. It is said by Romana and Thomas (2013) that the connection is through self-efficacy. Because of this, if a certain problem solving strategy is chosen and leads to success then that strategy leads to performance (Romana & Thomas, 2013). Thus the problem solving ability of an individual must be take into consideration their cognitive ability as well as their ability to choose appropriate strategies in solving problems. It is the view of Bandura (1997) that self-efficacy is the ability of a person to solve difficult tasks based on the person's competence (Romana & Thomas, 2013). Efficacy is a difficult concept to measure and in this study efficacy is measured through observation of both written and verbal explanations of students whilst they were engaged in problem solving. Two independent members from the department were used to assess the students' beliefs. In the observation, consideration was given to the rubric given in Table 1 as well as the observation of the various strategies the students use to solve problems. In the evaluation of the students, the assessors were in general looking for the following procedures in their approach to problem solving (Mudd, 1997):

- The students' drawing of free body diagrams,
- The students reads the problem a number of times,
- The student isolates the various components of the problem and uses appropriate equations of motion,
- The student completes the algebra by using symbols, and
- The student looks at the answer to see if it makes sense.

Hammer has done research on epistemological beliefs of American students on problem solving in physics. A similar research is done for South African students within a different cultural setting. Within this context, the reformation of the curriculum has led to changes in the pedagogical practices of the teacher. In this respect, the incorporation of problem solving strategies is still in its infancy in many schools in South Africa and it is against this background the aim of this study is to look at the epistemological beliefs of South African students whilst engaged in solving different kinds of problems in physics, with the hope drawing comparisons with their international counterparts.

Research Question

This research is underpinned by following question:

What are the students' epistemological beliefs when engaged in physics problem solving and how can these beliefs be characterised into the beliefs structures as highlighted by Hammer.

Theoretical Framework for the Study

The analytical tool used for this study is taken from Hammer (1994). The original tool of Hammer (1994), which consisted of three dimensions of beliefs, has been modified to include a fourth dimension, namely "Beliefs about Problem-solving approaches in Physics" (Wampler, 2013), because of the associated link between beliefs about problem solving and epistemological beliefs. Furthermore, the third dimension of belief has also been modified to exclude the teaching aspect but more to focus on the learning aspect of physics as part of this study. Such a framework is given in the Table 1. Included in this table, is a column on rating. This column, which was meant for the methodology section, is done to avoid repetition and will be explained for further clarity in that section again.

Students' epistemological beliefs will be judged from the observation and participation of the students in the problem-solving situation and their beliefs will be accordingly characterized and evaluated, using the above table to make such judgements.

METHODOLOGY

In order to choose the participants for this study, a request was made to one of my colleagues, who was the best performer in the previous year, to choose a few best performing students (students with an average of 80% and higher) from his Chemical Engineering class to be part of this study. Because of his expertise at teaching this course, the talented students chosen for this study could be considered as part of my case study for this research in terms of how they solve problems in physics. In the end, only seven students out of a class of 140 students volunteered to be part of this study. The criteria for selection was that the students had to be talented,

Table 1. Modified version of the epistemological beliefs developed by Hammer (1994). Included in this table is a belief structure consisting of various dimensions as well a physical interpretation of each of the dimensions. The last column is a rating of the beliefs scale from -2 to +2.

No.	Dimensions	Structure of Dimensions	Physical interpretation	Rating
1	Belief 1: Beliefs about the Structure of Physics knowledge	(a) Fragmented	Physics is a collection of discrete and unrelated facts. Students will struggle to solve a physics problem if any kind of information is lacking or missing from the text.	-2
		(b) Weak coherence	The structure of physics knowledge is categorised at an intermediate level between coherent and conceptual. In a sense, this implies that different levels of understanding maybe expected from different students.	0
		(c) Coherent	Physics ideas and facts are connected in a coherent and fluent manner. Students could also use an alternate method to solve a problem.	+2
2	Belief 2: Beliefs about the Content of Physics knowledge	(a) Formulae	Physics is made up of facts and formulae that is memorized or learnt by rote. Students make use of the formulae by either substitution or manipulation.	-2
		(b) Apparent concepts	The content of physics knowledge is at an intermediate level between formulae and concepts. In this case the student could be using a wrong formulae to find a solution to the problem.	0
		(c) Concept	Physics is made up of concepts, represented by formulae or symbols. Students have a sound conceptual understanding of the physics problem and finds the appropriate formula to use.	+2
3	Belief 3: Beliefs about the Learning of Physics	(a) Authority	Student receives knowledge from what was taught with no modifications. Learning physics takes place from remembering what was taught in class.	-2
		(b) Weak authority	Students' beliefs about learning physics is at an intermediate level between authority and independence. In this case, the student could be using his method that is conceptually wrong.	0
		(c) Independence	Students consider learning to be a process of reconstruction of ideas to make sense of it. In a sense, the student modifies his understanding to build a stronger belief about his learning in Physics.	+2
4	Belief 4: Beliefs about Problem solving approaches in Physics	(a) No clear approach	Student analyses the problem but proceeds with no clear direction.	-2
		(b) Memory-based approach	Students analyses the problem and then replicates a solution from previous solved problems.	-1
		(c) Unstructured plug and chug	Students analyses the problem and then choses a formula based on the given variables. The procedure followed is then a trial and error method.	0
		(d) Structured plug and chug	Student analyses the problem qualitatively based on the formula and then finds the solution	+1
		(e) Scientific Approach	Student qualitatively analyses the problem and plans to find its solution in a systematic way through careful analysis.	+2

representative of the class demographics and at least one of them had to be a female student. All students had taken physics at high school and had to have a minimum of 60% pass at the National Senior Certificate (grade 12) examination to be considered for admission in their chosen field of interest. The purpose of the study was to judge students' epistemological beliefs whilst they were engaged in solving different kinds of problems in physics. This research took place in the students' spare time during the course of the semester. We choose to use the interview/observation method as a way to judge the students' written and verbal responses. Students' responses were rated according to the rating scale as highlighted in the table below. The rating score ranged from -2 to +2, for all beliefs and done purposefully

because of the fourth belief had four categories in its dimensional structure.

(a) Interview /observation method

Two staff members from the physics department (one of them myself), who were unfamiliar to the students, interrogated the selected cohort of students independently for an hour whilst they were engaged in problem solving in physics. The session was audiotaped to ensure factual and authentic information. During the interview, students were made to feel comfortable and were initially asked general questions about their background knowledge in physics. In the interview, they were asked about their performance in their grade 12 examinations as well as their current physics performance at the university. The students were given three kinds of problems to be solved, on separate

occasions during the semester. These students were required to think aloud whilst using various strategies in solving the problems. They were regularly interrupted and asked questions such as ‘how’ and ‘why’ certain steps were undertaken. Unfortunately, they were not told whether their explanations were right or wrong. Results of their responses were compiled according to criteria indicated.

(b) Judged assessment of Beliefs

The analysis of the results was done by observing the students’ behaviour in respect to their verbal and written responses to the three different kinds problems in physics. In respect to the scoring mentioned in Table 1, a range from -2 to +2 was considered. For dimensions one to three, a further demarcation was implemented to include 0 as an intermediate range value. In this respect, the intermediate dimensions such as weak coherent structure, apparent concepts and weak independence were added to the three dimensions in Table 1, to be consistent with dimension four of the modified epistemological beliefs of Hammer (1990).

(c) Reliability of scores

An independent assessor was assigned to judge the students’ epistemological beliefs when engaged in solving different kinds of problems in physics.

(d) Verbal and written responses

Both verbal and written responses were correlated to get a holistic picture about the students’ epistemological beliefs. An average score was obtained from these scores.

The Names of the Students and their Physics Background

The names of the students that were used for this research had been changed to protect their identity, and we proposed their changed names to: Peter, Roger, Simelane, Cindy, Tommy, Thandi and James.

The Nature of the Physics Questions and the Students’ Problem Solving Strategy Session

The three questions that were given to the students in the interview/observation session were taken from different sources. The first two questions were taken from the National Senior Certificate (NSC) Examination (grade 12) of the Department of Basic Education (DBE), while the third question came from the Serway and Beichner (2000) textbook, entitled Physics for Scientists and Engineers. Permission was sought from the directors of the Department of Basic Education for use of their questions. We choose some questions from the 2015 final grade 12 examinations paper that were challenging in nature compared to previous examinations papers. In particular, the performance of the students for Problem 2 (see below) was a mere 47% and was poorly answered by grade 12 students. Students are competent when solving a one-body physics problem but once two bodies

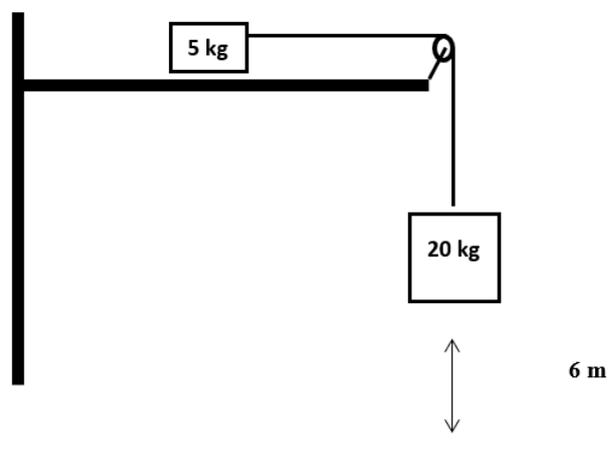
are incorporated in the same question, they faced insurmountable challenges. The first 2 problems consists of 2 bodies in different contexts. Our interest is to see how students figure out these problems. The three questions that were chosen for interrogation with the students during the interview/observation session were:

Students were given the following equations of motion:

$$v_f = v_i + a\Delta t, v_f^2 = v_i^2 + 2a\Delta t, \text{ and}$$

$$\Delta x = v_i\Delta t + \frac{1}{2} a\Delta t^2$$

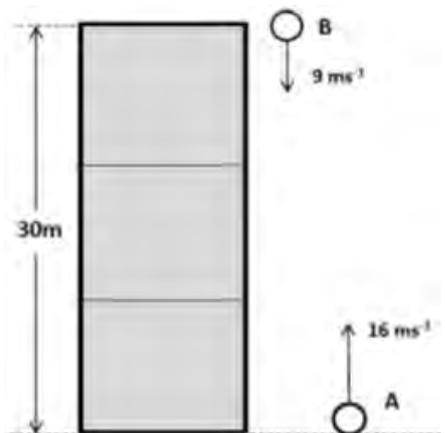
Problem 1: A light inextensible string, which passes over a light frictionless pulley, connects a 5kg mass and a 20kg mass. Initially, the 5kg mass is held stationary on a horizontal surface, while the 20 kg mass hangs vertically downwards, 6m above the ground. (For this problem, students use Newton’s second law of motion for each body separately and then solve these equations simultaneously to find the acceleration of the system, and once the acceleration is determined, they then use one of the equations of motion to determine the speed at which the body strikes the ground. Common errors: Some students used linear equations of motion instead of Newton’s laws of motion to determine the acceleration of the system of the both masses. They were unable to accurately use the equation of motion for the second part of the problem)



1. Calculate the acceleration of the 20kg object.
2. Calculate the speed of the 20kg object as it strikes the ground.
3. At what minimum distance from the pulley should the 5 kg mass be placed initially, so that the 20 kg mass just strikes the ground?

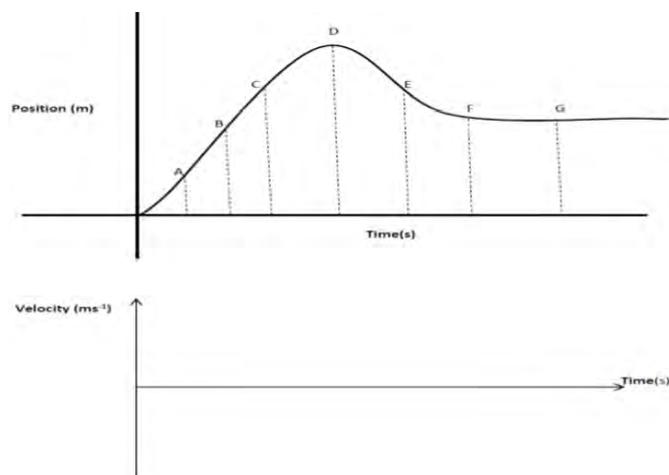
Problem 2: Ball A is projected vertically upwards at a velocity of 16 m.s⁻¹ from the ground. Ignore the effects of air resistance. Use the ground as zero reference. One second later after ball A is projected upwards, a second ball B is thrown vertically downwards at 9 m.s⁻¹ from a balcony 30 m above the ground. (For this problem, the student is expected to find Δy for each ball and equate the displacements when the balls meet after a time delay

of 1 second, bearing in mind that one displacement is positive and the other negative. They determine the time when the balls meet and they use that time to determine the displacement of ball A. Common errors: Students were unable to incorporate the time delay accurately in the displacement equations. Further, they failed to accurately link the two displacement equations to determine time).



Calculate how high above the ground ball A will be at the instant the two balls pass each other.

Problem 3: The following graph represents the position of an object moving along the x-axis with time. Represent the velocity versus time and acceleration versus time graph for the same motion in the graphs below. (For this problem, students are expected to determine the velocity vs time graph by taking the gradient of the position vs time graph. For the acceleration vs time graph, the student is expected to find the acceleration by taking the gradient of the velocity vs time graph. Common errors: Inaccurate determination of gradients of the graphs during separate intervals of motion for both the velocity vs time and acceleration vs time graphs).



FINDINGS

The students' epistemological beliefs towards problem solving in physics has been judged by myself (X) and a colleague (Y) in the department. An average score was then compiled from our judged rating of the students' beliefs according to the rating scale in Table 1. Students appear to use a variety of epistemological strategies in seeking solutions to the physics problems. From Table 2, we see similarities in students' epistemological beliefs when engaged in problem solving in physics.

The epistemological beliefs of students towards problem solving is quite similar for Roger and Peter with respect to Beliefs 1 and 2 of Table 2. Results reveal that students' knowledge appears to be fragmented and show a high dependence on formulas in the way they have solved problems 1 and 2. Both Roger and Peter displayed a weak conceptual understanding of the given problems basically because of their approach in problem solving. For example, when Roger was solving problem 1, he used the correct equations of motion: $T - f = ma$ and $T - W = ma$ for bodies 1 and 2, respectively to determine the acceleration of the system but then proceeded to determine the speed of the system by use of the equation: $v = \frac{\text{distance}}{\text{acceleration}}$. Peter on the other hand determined the acceleration of the system by only focussing on the 5 kg object, with no due consideration in the presence of the 20kg object. In respect to problem 2, Peter used appropriate equations of motion for the 2-body problem but made one mistake in changing the sign of "g" when a second body is projected in the opposite direction to the first. Roger struggled to interpret the 1-second delay in the projection of the second ball and presented the following equation as part of his solution:

$$30 = a(t + 1) + \frac{1}{2}(-9.8)(t + 1)^2$$

he then struggled to find a solution to this quadratic equation. Peter initially followed a similar approach but had no clear problem solving strategy and then proceeded with a structured plug and chug method in solving problem 2. In the case of Roger, there was scientific merit in the initial part of his solution but that faded when he tried to solve problem 2. The knowledge revealed by Roger was that from authority with little modifications made on his side.

Table 2. An evaluation of the students’ epistemological beliefs according to the rating scale in Table 1. The table also includes the overall average as well as the combined classification of beliefs.

Names of students	Belief 1: Beliefs about the Structure of Physics knowledge		Belief 2: Beliefs about the Content of Physics knowledge		Belief 3: Beliefs about the Learning of Physics		Belief 4: Beliefs about Problem solving approaches in Physics	
	X	Y	X	Y	X	Y	X	Y
	Peter	-2	-2	-2	0	0	+2	-2
Cindy	-2	0	-2	0	0	-2	0	+1
Tommy	0	0	-2	-2	-2	0	+1	+2
Roger	-2	-2	-2	-2	-2	-2	+1	+2
Simelane	0	0	0	+2	-2	0	-1	+1
James	0	0	-2	-2	0	0	+1	+1
Thandi	0	0	-2	-2	0	0	0	+1
Overall classification	Fragmented/weak coherence		Formulas		Apparent authority		Structured plug and chug	

Cindy and Tommy have had a similar belief about their learning in physics (belief 3). For these students it appeared that the knowledge that they received from their teachers is taken as the absolute truth with no modifications and therefore their knowledge structures could be classified as knowledge from authority. This can be seen from the way they have presented their answers to problems 1 to 3. For example, Simelane might have remembered a similar problem in class of an object accelerating upwards and without modifying his knowledge to this problem; he decided to replicate it likewise. In this sense, he has used the equation $T - W = ma$ to solve for the acceleration of the 20 kg object. In his attempt to solve this problem, he obtained a negative value for the acceleration. At that point I asked him: “What does the negative sign mean?” and he replied: “The object is accelerating in the opposite direction” and my follow-up question was: “What will you do about it?” and he replied: “Will go back to verify”. Likewise, for Cindy who obtained a negative value for the acceleration but did not find meaning to such an answer. Both Cindy and Tommy appear to have used stock type of methods to find solutions to problems 1 and 2. Cindy’s problem solving strategy is similar to that of Roger in that it was highly fragmented with a plug and chug formula driven approach. She has a weak conceptual understanding of the concepts required to solve these problems. Her knowledge was similarly dependent on authority with little modifications. On the other hand, the approach of Tommy is slightly different, in that he had some kind of scientific approach in the way he had presented his answers (employing a structured plug and chug method). In the case of Simelane, he appears to have employed an unstructured plug and chug method in his manipulation of the formulas. Peter appears to have had no clear approach in the way he had gone about solving his problems. Thandi and James, like Tommy and Simelane have used standard formulae from mechanics to solve problems 1 and 2. In the case of Thandi, she proceeded to solve problem 1 by first drawing free body diagrams for the two masses and then solved it by applying Newton’s second law of motion to

the problem. She, however made one fundamental mistake when solving for the 20 kg object, she unintentionally added the mass of the 5 kg to the 20 kg in solving the problem. This can be seen by the equation below:

$$\Sigma F_y = ma \text{ then } \Sigma F_y = (20 + 5) a$$

On the other hand, James merely treated the two body mass-systems to be in static equilibrium and then proceeded to solve the two equations simultaneously to find the acceleration of the system. In respect to problem 2, both students treated the problem as a two-body system but totally ignored the 1-second delay to the projection of body 2. Hence, the approach by these two students appears to display a weak degree of coherence and with a structured plug and chug method of solving these problems.

Many of these students had a poor conceptual understanding of graphs, as will be revealed from their description of the graphs.

(a) Peter has a very poor conceptual understanding of graphs. His velocity versus time graph description between the origin (O) and the end (G) is as follows: an increase in velocity between O and D, with D representing a break in motion (like a bouncing ball) and a decrease in velocity in the regions between D and F. The only region that Peter correctly interpreted was the region between F and G. His acceleration versus time graph for the region between A and D was a negative constant value, as well as the region between D and F. The only section of the graph that he correctly interpreted was the region between F and G for the acceleration versus time graph.

(b) Simelane’s velocity versus time graph shows a uniform increase in velocity in the region between O and D and a constant value of velocity in the region between F and G. His acceleration versus time graph was poorly interpreted, achieving a constant value in the region between F and G.

(c) Cindy has struggled to interpret the position versus time graph, obtaining only a correct description

in the regions between C and D as well as the region between F and G, with the rest of the regions incorrectly described. She obtained the correct interpretation of the acceleration versus time graph between the regions O to A, D to F and F to G.

(d) Roger, like Cindy has got certain regions of the velocity versus time graph correctly described (sections O to B), but had the rest of the sections of the velocity versus time graph and the acceleration versus time graph to be a picture representation of the position versus time graph.

(e) Tommy is the only student who had a better idea of describing the velocity versus time graphs but failed in describing the acceleration versus time graph. His entire velocity versus time graph was almost perfect, except for some regions (O to A and D to F), where his graphs were curved instead of straight lines.

(f) Thandi simply has a poor understanding of graphs. She only got a correct description of region O to A correct and assumed the linearity of the curve to continue up to point D without a change in curvature. She also left sections from D to G blank. Her description of the acceleration versus time graph was a picture description of the displacement versus time graph.

(g) James, like Thandi drew a similar linear-like line for the regions from A to D and then proceeded with a picture description of the rest of the regions. His acceleration versus time graph was similar to his velocity versus time graph. He too has a poor conceptual understanding of graphs.

It is most likely that students have guessed their answers in each of the regions of the graph. This stems from a lack of practices of graphical problems in class. In most cases their interpretation of the graphs is a picture representation of the motion, with no scientific merit in their approach and a lack of sound conceptual understanding.

DISCUSSION

Students' epistemological beliefs maybe effected when they try to solve complex problems. In this sense it can be said that such epistemological beliefs are related to cognition, study skills, and learning strategies (Erdamar & Alpan, 2013). Based on the above, this study has revealed that students have displayed a novice-like approach (unsophisticated) in their problem solving strategies, and this is related to their underdeveloped epistemological beliefs about problem solving. Further, they lack the problem solving strategies and higher order thinking skills that are required for problem solving. Novices tend to solve problems through manipulation of formulas (Hammer, 1994) and this is none so with the approaches undertaken by majority of these students. Their intuitive beliefs about problem solving remains largely fragmented. These students are of the belief that knowledge is absolute, consisting of

unconnected parts and transmitted from authority to them (Erdamar & Alpan, 2013). Most students have manipulated the formulas without a sound conceptual understanding and an incoherent approach in their strategies of finding solutions to problems 1 and 2. These findings also concurs with the research done by Hammer (1990) in many domains of epistemological beliefs for American students. Further, it is similarly found that students' content knowledge appears to be lacking in their solution presentations. In the case of Tommy and Roger, there appears to be glimpses of a scientific approach in their problem solving strategies but they failed to resolve the misconceptions to the given problems. The performance of the students in the graphical section was very poor, with not one really getting grips of it. This may be attributed to the lack of foundational knowledge in kinematics. In respect to knowledge received from authority, it can be mentioned that only Peter showed some evidence of independent approach to problem solving in physics. A common feature amongst all the students is the plug and chug method without a deeper insight of understanding of the dynamics of the problems. An overall description of the students' beliefs can be categorised as having a fragmented knowledge structure, formula driven approach in their beliefs about the content of physics knowledge, a weak authority in respect to their beliefs about the way they learn physics and their approach to problem solving is largely plug and chug into the relevant equations. The 2-body problem was most poorly done. This is because they are fluent in solving kinematic equations only for a one body diagram but struggle once a second body is incorporated into the motion. In this, instance students then change the sign of "g" and then treat the second body as an independent body. For this problem, they lacked the content knowledge of physics and a deeper understanding of a 2-body problem dynamics. Whilst the same problem was given to grade 12 learners with appalling results, a similar pattern was emerging at the university level when the same problem was given, with them retaining similar misconceptions from high school. According to Erdem (2005), these students have based their knowledge on existing knowledge or the knowledge from authority (their high school teachers) without making sense of it.

CONCLUSION

This report was an exploratory study of epistemological beliefs of a small group of students engaged in problem solving in physics. It was found that students have distinctive personal epistemological beliefs in ways they learn and understand physics. There also appears to be inconsistencies in their beliefs of how different problems in physics are solved. Mostly, their intuitive knowledge beliefs appears to be fragmented with a weak organised knowledge structure. This stems

from previous ingrained misconceptions that were embedded in their knowledge structures from early years in high school. Such structures leaves little or no room for modification of their understanding or intuition. These students have persisted in trying to find possible solutions to the given problems, despite their misconceptions. It is evident that their problem solving strategies were characterised by superficial manipulation of formulas (Redish & Steinberg, 1999), without a deep conceptual understanding of the physics, and largely by the plug and chug method. They fail to associate a meaning to the answers they obtained from their calculations. This kind of working is reminiscent of how novices tend to solve problems by manipulation of formulas (Hammer, 1994). Research alludes to a correlation between epistemological beliefs and academic success (Hofer & Pintrich, 1997 & Hofer, 2001). In this research, it was found that such belief maybe weak and disorganised and definitely not a recipe for success. For the other beliefs, there appeared to be glimpses of good conceptual understanding of the knowledge and independent reasoning by some of the students, but that fades once they try find a solution to their problems. In respect to problem solving, most students are solving problems in physics by using equations from the manual. Their approach to problem solving was based on the recognition of surface features and with a lack of a scientific approach. Therefore, in order for these students to become good problems solvers, they need to have a sound knowledge of physics and have the necessary skills and strategies to solve problems (Wampler, 2013). Students tend to focus on searching for relevant equations that fit the given variables. In most cases our characterisation of student's beliefs were found to be in an intermediate range of the beliefs structures in Table 1. None of these students have displayed an independent approach to problem solving. In majority of the cases, they have resorted to plugging the equations with numerical numbers and then solving the problems without giving any cognisance to the value of the answers they obtained. In future, it will be worthwhile to focus our research on a larger cohort of students to get some sense of generalisation of their problem solving epistemology.

In summary, it can be said that as far as the beliefs about the structure of physics knowledge is concerned, they are largely fragmented and with low levels of coherence in some instances. On the aspect of beliefs about the content of physics knowledge, all students in one way or the other were dependent on the plug and chug method in their manipulation of their formulas. Mostly students have relied heavily on the knowledge cascaded down from their teachers without making meaningful assimilation of the knowledge before applying them to new problems. In respect to beliefs about problem solving, most students had some kind of strategy in solving while others had no clear approach in

their problem solving strategies. Thus, understanding students' beliefs can provide insight into how students develop their conceptual knowledge and how they understand that knowledge and this could provide a clearer indicator into the developments of their beliefs (Hammer, 1994).

Implications for Teaching

It was observed that students have had considerable difficulty in solving these problems in physics. It might be that some of the concepts that they have learnt in school may be contributing to the misconceptions that we were observing. Teachers need to confront and expose these misconceptions head-on by re-teaching and re-enforcing the concepts (Hammer, 1994) before they become part of their knowledge belief structure. Two of the given problems highlights such misconceptions in their understanding:

1. The 2-body problem has proved to be daunting task for the students. They may be fluent in a 1-body problem but struggle if the problem is modified. This could be a casualty of a traditional mode of instruction, where learning is only for examination purposes and focus on surface features of the curriculum. Students should be taught to think scientifically. Examples of real life scenario would help them to understand the concepts better. In the case of problem 2, students likewise have treated the each mass as an independent system. In most cases, they have determined the acceleration of the system by working with one body only.
2. In problem 3, students have struggled to represent a velocity versus time graph and acceleration versus time graph from a position versus time graph. The answers they give is "picture" representation of a position versus time graph. Teachers need to emphasise the importance of gradients and areas in these problems. Students lack a physical description of kinematics in graphical form.

REFERENCES

- Angeli, C., & Valanides, N. (2012). Epistemological Beliefs and Ill-structured Problem-solving in Solo and Paired Contexts. *Educational Technology & Society*, 15(1), 2-14.
- Bromme, R., Pieschl, S., & Stahl, E. (2009). Epistemological beliefs are standards for adaptive learning: a functional theory about epistemological beliefs and metacognition. *Metacognition and Learning*, 5(1), 7-26.
- Ekinci, N. (2017). Examining the Relationships between Epistemological Beliefs and Teaching and Learning Conceptions of Lower-Secondary Education Teachers. *Inonu University Journal of the Faculty of Education*, 18(1), 344-358.

- Erdamar, G., & Alpan, G. (2013). Examining the epistemological beliefs and problem solving skills of preservice teachers during teaching practice. *Teaching in Higher Education, 18*(2), 129-143. <https://doi.org/10.1080/13562517.2012.694101>
- Faber, C. J. (2015). Epistemic Cognition During Problem Solving. *All Dissertations*, Paper 1789.
- Hammer, D. (1994). Epistemological beliefs in introductory physics. *Cognition and Instruction, 12*(2), 151-183. https://doi.org/10.1207/s1532690xc1202_4
- Hofer, B. K. (2001). Personal epistemology research: Implications for learning and teaching. *Educational Psychology Review, 13*(4), 353-383. <https://doi.org/10.1023/A:1011965830686>
- Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research, 67*, 88-140. <https://doi.org/10.3102/00346543067001088>
- Kizilgunes, B., Tekkaya, C., & Sungur, S. (2009). Modeling the relations among students' epistemological beliefs, motivation, learning approach, and achievement. *The Journal of Educational research, 102*(4), 243-256. <https://doi.org/10.3200/JOER.102.4.243-256>
- Kuhn, D., & Weinstock, M. (2002). What is epistemological thinking and why does it matter? In B. K. Hofer & P. R. Pintrich (Ed.) *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 121-144). Mahwah, NJ: Erlbaum.
- Leder, G. C. (2008). Beliefs: What lies behind the mirror? In B. Sriraman (Ed.), *Beliefs and mathematics* (pp. 39-54). Charlotte, NC: Information Age Publishing.
- Lising, L., & Elby, A. (2005). The impact of epistemology on learning: A case study from introductory physics. *American Journal of Physics, 73*(4), 372-382. <https://doi.org/10.1119/1.1848115>
- Mason, C. T. (1999). *Psikolojiye giris* (13 Ed.). H. Arici & S. Karakas (Trans.). Ankara: Meteksan Yayincilik.
- May, D., & Etkina, E. (2002). College physics students' epistemological self- reflection and its relationship to conceptual learning. *American Journal of Physics, 70*(12), 1249-1258. <https://doi.org/10.1119/1.1503377>
- Mudd, H. (1997). How to Solve Physics Problems: Physics. In D. Gabel (Ed), *Handbook of Research of Science Teaching & Strategy*. New York: MacMillan Publishing Co.
- Muis, K. R., & Franco, G. M. (2009a). Epistemic beliefs: Setting the standards for self-regulated learning. *Contemporary Educational Psychology, 34*(4), 306-318. <https://doi.org/10.1016/j.cedpsych.2009.06.005>
- Muis, K. R., & Franco, G. M. (2009b). Epistemic profiles and metacognition: support for the consistency hypothesis. *Metacognition and Learning, 5*(1), 27-45. <https://doi.org/10.1007/s11409-009-9041-9>
- Ozturk, T., & Guven, B. (2016). Evaluating Students' Beliefs in Problem Solving Process: A Case Study. *Eurasia Journal of Mathematics, Science & Technology Education, 12*(2), 411-429. <https://doi.org/10.12973/eurasia.2016.1208a>
- Perry, W. G. (1970). *Forms of intellectual and ethical development in the college years: A scheme*. New York, NY: Holt, Rinehart, and Winston.
- Redish, E. F., Saul, J. M., & Steinberg, R. N. (1998). Student expectations in introductory physics. *American Journal of Physics, 66*(3), 212-224. <https://doi.org/10.1119/1.18847>
- Redish, F., & Steinberg, R. N. (1999). Teaching Physics: Figuring Out What Works. *American Institute of Physics, 52*, 24-30. <https://doi.org/10.1063/1.882568>
- Sahin, M. (2009). Correlations of Students' Grades, expectations, Epistemological Beliefs and Demographics in a Problem-Based Introductory Physics course. *International Journal of Environmental & Science Education, 4*(2), 169-184.
- Schoenfeld, A. H. (1983). Beyond the purely cognitive: Belief systems, social cognitions, and metacognitions as driving forces in intellectual performance. *Cognitive Sciences, 7*, 329-363. https://doi.org/10.1207/s15516709cog0704_3
- Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension, *Journal of Educational Psychology, 82*, 498-504. <https://doi.org/10.1037/0022-0663.82.3.498>
- Schommer, M. (1998). The influence of age and education on epistemological beliefs. *British Journal of Educational Psychology, 68*, 551-562. <https://doi.org/10.1111/j.2044-8279.1998.tb01311.x>
- Schommer, M. (1994). Synthesizing epistemological belief research: Tentative understandings and provocative confusions. *Educational Psychology Review, 85*(3), 293-320. <https://doi.org/10.1007/BF02213418>
- Schommer-Aikins, M. (2002). An evolving theoretical framework for an epistemological belief system. In B. K. Hofer & P. R. Pintrich (Ed.) *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 103-118). Mahwah, NJ: Erlbaum.
- Schommer-Aikins, M., Duell, O. K., & Hutter, R. (2005). Epistemological beliefs, mathematical problem-solving beliefs and academic performance of middle school students. *The Elementary School Journal, 105*(3), 289-305. <https://doi.org/10.1086/428745>

Serway, R. A., & Beichner, R. J. (2000). *Physics for Scientists and Engineers* (5th Ed.), Saunders College Publishing, page 32.

Stathopoulou, C., & Vosniadou, S. (2007). Exploring the relationship between learning between physics-related epistemological beliefs and physics understanding. *Contemporary Educational*

Psychology, 32, 255-281. <https://doi.org/10.1016/j.cedpsych.2005.12.002>

Wampler, W. N. (2013). *The relationship between students' problem solving frames and epistemological beliefs* (Unpublished PhD thesis). Purdue University, West Lafayette, Indiana.

<http://www.ejmste.com>