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Probing the Graduate Students' Conceptual understanding in Mechanics

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Abstract

Spiral progression in Science and Mathematics subjects under the K-12 curriculum have been implemented in the Philippines wherein teachers should teach Physics subject even if it was not their field of specialization. Deficient knowledge of teachers and students in science still evident as based from several researches. This study aimed to explore the understanding of Teachers' concept in Physics specifically in mechanics. Qualitative data gathering was done through content analysis of the respondents' written answers on the problem sets given to them. Fifteen graduate students who were enrolled in Master of Arts in Education major in Science and Technology, LSPU Sta. Cruz Campus, were the respondents of the study. Results revealed that most respondents have misconceptions on the selected topics in Mechanics specifically in acceleration and constant velocity. It was also found that 14 out of 15 of the respondents have lack of conceptual understanding in at least one of the conceptual questions given to them.

Keywords: Probing, Conceptual Understanding, Misconception.

Introduction

One of the reasons why concepts in Science are difficult to learn is the misconception or lack of conceptual knowledge that occurs among students[1]. Research results reveals that most students commonly had deficiency in the conceptual understanding on some topics in Physics whether these are future teachers, high school students, engineering students or even teachers[2]. The traditional method of teaching has shown inadequacy in developing a deep learning and long term retention of important concepts. In a traditional way, high school Physics teachers equate students understanding to the ability of the students in solving formula-based problems correctly without acknowledging its conceptual side[3]. This results to inadequate understanding of concepts in Physics even if those are already discussed. Few teachers give some conceptual problems due to the deficiency of their knowledge to teach the concepts[4] considering that understanding of concepts is a prerequisite for expert problem solving and a meaningful learning[5].

In the Philippines, based on the K-12 curriculum, spiral progression is being implemented. The approach is that concepts and skills are revisited at each grade level with increasing depth. In this sense, all Science teachers, whether or not they are Physics major, have to teach the said subject for all grade levels. Within the Science, Technology Engineering and Mathematics (STEM) Strand in K-12 curriculum, teachers should also be highly qualified in teaching higher Mathematics and Physics for the Senior High School. But several studies show that the country lacks scientists because of the lack of qualified Science teachers[6,7]. This implies that a regular teacher's competence evaluation is required to determine their strengths and weaknesses in Science particularly in Physics. In this context, probing the conceptual understanding of teachers is one way of attaining this goal.

This study is about examining the conceptual understanding of selected topics in Mechanics of Graduate students majoring in Science and Technology at LSPU - Sta. Cruz Campus enrolled during Summer 2015, by giving them conceptual problems in Mechanics extracted from the instrument made by Antwi V., Hanson R., Savelsbergh E.R. and Eijkelhof H.M.C.[3]. There are numerous studies about exploring the conceptual understanding in Physics but none so far with the study of understanding the concept of current or in-service teachers in selected topics in Physics specifically Mechanics. Assessing the high school teachers in their Physics concepts may give the researcher and other Science professors in the graduate and undergraduate level an idea to what Physics concepts will they give emphasis in teaching. This will also become a basis to develop methodologies and strategies in teaching. It also will help the graduate students to revisit their concepts in teaching Physics. In addition, it can be an eye opener for the administration to train these teachers who are not specializing in Physics to develop more comprehensive understanding of Physics concepts.

Statement of the Problem: This study tried to answer the following questions: i. How do the graduate students understand selected concepts in Mechanics? ii. What topic/s do the graduate students mostly have misconceptions?

Literature Review: In the preparation of implementation of spiral progression approach in the Philippines, it was assessed that majority of teachers in both public and private schools in Cavite province have Biology as their specialization[8]. This means that these teachers and other teachers in the country with the same situation would make much effort to master Physics for the implementation of spiral progression and for the preparation of senior high school wherein the STEM will be introduced.

One of international assessments that aim to determine the level of students' knowledge in Science is the Trend in International Mathematics and Science Study (TIMSS), this assessment shows that Philippines scored lowest in Science as compared with neighboring countries. The low TIMSS results can bring about low level of Science careers, and may eventually result to a few numbers of journal articles and level of Industrial competitiveness[9]. Several studies have identified that facilities and lack of competent Science teachers[10] are the reasons for students' low scores in Science in the country as compared with other neighboring countries. Lack of competent teachers can be attributed with their deficiency in understanding of Science concepts, even if the subject is practical in nature but commonly taught in a theoretical approach[11].

This study is based on the constructivist approach wherein students actively engaged to learning by constructing knowledge to make sense of the world. Constructivist understanding is a central model for learning in Science that focuses on an individual learner as an active agent of conceptual development[12]. Students are given opportunities to process a high level of reflection on some cognitive structures that serve in determining its central ideas, concepts, and facts and apply the concept to new situation. The sole responsibility of teachers is to diagnose students' interpretations and may help them to change, edit or enrich these concepts. But if teachers have anticipated that students already learned the concepts in their previous grade level, communication gap between teachers and learners arises. Students encountering difficulties in Science lies not on accounting for their preconceived ideas before teaching[13]. Hence, identifying students' misconception through assessing their conceptual understanding is very essential in the process of teaching and learning.

Further, this study is also anchored on the Cognitive Learning Theory which stated that what has already been learned is carried over and affects the ability to master the learning tasks; it may aid in learning another task or it may hinder its learning[14]. Teachers as the agents of learning process through transferring of learning may cause misconception that affects students learning.

One important branch of Science is Physics – considered by many students as a difficult subject. But, Physics has shown its importance in the development and improvement of human civilization. So, it is essential to build firmly the foundational part of Physics in order to truly understand the physical world, otherwise students cannot answer even simplest questions about the world[15]. Several studies, however, have shown that misconceptions in Physics still exist in students[16-18]. Ozmen synthesized the meaning of misconception from the views of Science educators as much as the students' concept about facts or events that are not coherent with the concept in Science. These misconceptions may come from the students' personal experiences, textbooks, language used, and the teachers[19].

There are three important aspects of learning as based from the research in education. These are conceptual understanding, transfer of information, and basic beliefs about physics[20]. Conceptual understanding is defined as the comprehension of scientific theories, systems and relationship between various disciplines. It is particularly relevant because few fundamental concepts can explain a vast range of phenomena. Hence, teachers in this context should understand scientific facts or terms as well as have a deeper conceptual knowledge in order to become effective[21]. But several researchers have found out that most teachers focused on problem solving method of teaching in Physics than concepts. This can be due to the fact that teachers still need to polish their own concept to overcome their own misconceptions[22]. As a result, students have less conceptual understanding in the subject making their ideas inconsistent with scientific concept (misconception), further confirmed with the findings of several studies regarding misconception[23-25] that observations regarding respondents conceptual understanding in Physics manifested shortcomings in their scientific concepts. Initial step to help students or teachers to correct their misconception is to identify their inaccurate scientific conception then adjust the teachers' methodology in the teaching and learning situation.

A great part in making students understand the subject lies on the teachers' hands, how teachers teach the subject will bring either correct scientific concept or misconception about them. Science teachers should be aware of the examples they give to students because these may not match what the students need. In addition, there should be an adjustment in the way of teaching through helping the students identify their misconception and eventually correct it.

Writing strategy is proven to be effective in discovering misconception of students[26]. Knipper and Duggan and Tessier (as cited in Hillaire)[27] depicted that writing has been widely used to facilitate learning, because it can engage students, extend thinking and deepen understanding. It can also promote students' understanding in connecting scientific issues to other components of their lives. Opps and Otfinowski[28] used analytical writing that aims to enhance retention of Science learning, and found out that analytical writing increase students' confidence in their scientific writing. McDermott and Kuhn[29] studied the application of writing-to-learn activities in a College Science integrated course and the strategy manifested that students clarified their own understanding in the concept before communicating to audience. Similarly, writing strategy in this study is also used to evaluate the understanding of the respondents in concepts in Mechanics, and at the same time attempt to probe the graduate students' misconceptions.

In this study, the researcher tried to dig deeper on the Science teachers' understanding on some topics in Mechanics, not to belittle them but to help the Physics educators to develop or design pedagogical tools making Physics less difficult to understand.

Methodology

This study employed qualitative research design through content analysis on the part of method used during the process of gathering data and information. Researchers used content analysis to analyze on how people communicate, usually in a form of written communication.

It also employed quantitative on the part of what topic/s in Mechanics do the respondents have most misconception at by utilizing frequency. The instrument used was derived from the study of , R. Hanson, E.R. Savelsbergh and H.M.C. Eijkelhof[3] but with modifications in the process of answering the question. In this study, the part of analysing conceptual and reasoning questions on how these questions were given was different. A problem set was given to them that contain conceptual questions, the graduate students had enough time to think of their answers and write their answers on a bond paper, handwritten and submitted for next meeting. This method of allowing the respondents to reflect their views through writing on concepts was a way of acknowledging what conceptual problems the respondents have. It was also a way of determining to what specific concepts the teachers can give emphasis in discussion the next meeting.

After submitting their answers, the researcher checked and analyzed the content of their answers; each concept was carefully scrutinized with the aid of textbooks and other materials to validate if the respondents' answers were correct. After sometime the papers were returned to them and had a discussion on the topics found to have misconception/s. They were allowed to explain their thoughts or reasons in each item. The questions were sometimes in the form of cartoon expressing some concept, conversation of two people talking about some concepts or a thought provoking question about a concept. There were only 10 items extracted from the instrument made by Antwi, et al.[3].

Frequency was used to determine how many teachers have misconceptions on a certain topic. Respondents of this study were fifteen (15) graduate students taking up Master of Arts in Education major in Science and Technology, eleven (11) were female and four (4) were male. Eleven (11) were teaching in public schools under the Department of Education, three (3) were employed in private schools, and one (1) was part-time instructor in a State University. Twelve (12) of them have been teaching Science for 1 to 5 years now, and three (3) of them teaching for more than 6 years already. Only four (4) teachers were Physics majors.

Results and Discussion

There were ten (10) questions given to the respondents taking up Master of Arts in Education major in Science and Technology. However, there were only eight (8) questions reflected in the discussion because these were the only items found by the researcher to have misconceived answers. Each table below showed the answer of the graduate students, identified as misconception/s in specified topics in Mechanics. There were no modifications on the answers given by the respondents; these were literally transcribed verbatim to the data table below. The item which was not reflected meant that there was no misconception seen.

Q1. *Listen to the conversation between a girl and a boy and comment on it.*

Image Source: https//www.google.com
Figure-1
Conversation of a Boy and a Girl

Girl: I went to the North Campus of LSPU from South Campus and back. So I got a long way
Boy: You went nowhere so your distance is zero (0) km

Table-1
Concept of Distance and Displacement

Teacher 1	"The boy is right because the distance and displacement is the same."
Teacher 2	"The boy because displacement and distance are the same thing."

The two persons talking are referring to two different concepts, the girl referred to distance while the boy referred to displacement. Although the two characters are right in their explanation, it seemed that they are not clear on the concept of distance and displacement. They meant distance and displacement as the same thing. Taken from the Physics texts, "distance" is the path length covered from one point to another, so when a person goes to north from south and returned to south he/she would not attain zero distance. Now since "displacement" involved direction and a vector quantity, it is zero in that instance. This implied that there is lack of understanding of the concepts of distance and displacement considering that they mean distance and displacement as the same thing.

Question number 2. *Listen to the conversation between a policeman and a driver who was charged with over Speeding.*

Image source: www.google.com

Figure-2
Conversation between a man and a Woman

Police: You drove 80km/h while 50km/h was allowed
Woman: You see my house on the hill there at Los Baños is less than 1km (by the odometer) away and I have been driving for over 10 minutes. So I drove 6km/h.

Table-2
Concept on Instantaneous and Average Speed

Teacher 12	"Based on the time of travelled and speed of travelled that explained and justified by the driver it indeed the driver was telling the truth."
Teacher 15	"The woman did not violated, because she travels 1 km for 10 minutes therefore it is not over speeding."

In the conversation made by the policeman and woman, they meant two different concepts, the police man is referring to "instantaneous speed" defined as the speed travelled at an instant time while the woman refers to "average speed" or the total distance travelled divided by time.

The two characters in the situation are both correct with their explanation though they are pointing out on two different concepts in one situation. In this question, teacher 12 and 15 both answered correctly only one of the conversant, teacher 12 chose the driver while teacher 15 chose the woman. The totality of concept of average and instantaneous speed is lacking in their answers. The situation required analysis that made teacher 12 and 15's answers incomplete.

Question number 3: If an object has an acceleration of 0 m/s2, one can be sure that the object is not (a) moving (b) changing position (c) changing velocity. Explain your answer.

Table-3
Concept on Acceleration

Teacher 1	"The object must not have change on its velocity because it is at rest."
Teacher 2	"The object does not change its velocity because it is at rest because the object has 0 acceleration."
Teacher 4	"All of it could be possible answers. An object that has a constant velocity on a given period of time will have zero acceleration. An object that is not moving is definitely not accelerating. Also an object with a constant velocity could accelerate if it will change its position, because acceleration is a vector quantity."
Teacher 5	"All of the choices, $0m/s^2$ mean zero acceleration, and it means no changes in velocity, and if there's no change in velocity definitely the object is not moving."
Teacher 12	"The object is not moving and probably not changing its position because of zero acceleration. When we say acceleration it is a change in velocity either speed or in direction. Let say, if an object is not accelerating, then the object is moving at constant speed and maintaining a constant velocity."
Teacher 15	"The object is not changing its position because it is zero acceleration."

"Zero acceleration" does not always mean the object is not moving; the object may move or change its position but only at "constant velocity." Teacher 1, 2, 5, 12 and 15 have the same concepts of acceleration that if it has zero acceleration the object is not moving. They meant that the object with constant velocity did not change its position.

But in the concept of constant velocity, the object is possibly moving or changing its position provided that it maintained its velocity. Although teacher 4 is right that all choices might be possible answers but the question has the term *"one" can be sure,* and the only sure answer is that the object did not change its velocity whether the changes can result to rest or just moving at constant velocity.

Teachers find difficulty in understanding the concept of acceleration and constant velocity. In this sense, there is a need to polish these topics since teachers have misconception or there is inconsistency with the said topics. They should really understand and be able to explain them right to their future students.

Q4. What is the acceleration of a car which moves at a constant velocity of 30 m/s for 5 s?

Table-4
Concept on Acceleration and Constant Velocity

Teacher 4, 5, 6, 7, 8, 10, 11	They all computed the acceleration using the formula $\frac{Vf - Vo}{T}$ $6 m/s^2$

Another question that most respondents were not clear about was again the concept of constant velocity. They did not realize that the car moves at constant velocity meaning that the initial and final velocity are the same, they considered initial velocity as zero.

Teachers found a hard time analysing the question when they computed for the value of acceleration when in fact it was very clear from the question that the object moved at constant velocity. Again the question is tricky yet simple.

Question 5: Which of the following statements is/are true of a free-falling object? An object in a state of free fall; (a) falls with a constant speed of -10 m/s (b) falls with varying acceleration (c) falls under the sole influence of gravity (d) falls with downward acceleration which has a constant magnitude (e) motion which falls under the influence of air resistance. State your reason.

Table-5
Concept on freely falling bodies

Teacher 4	a free-falling object that motion falls under the influence of air resistance
Teacher 7	falls with varying acceleration
Teacher 9	I chose letters a c and e

The answer for this question was letter c – "it falls solely under the influence of gravity" which meant that air resistance or any other force did not affect it from falling. Table 5 showed that teachers 4, 7 and 9 are not really that aware of the concept of freely falling bodies since teacher 4 conceptualized that it is air resistance that affected the falling of object.

Teacher 7 thought that acceleration changed as the object fell where in fact it is the speed that changed, since there is constant acceleration in a freely falling body. Teacher 7 interchanged the understanding of velocity and acceleration of object as it fell. This particular data showed that these teachers are not sure on the concept of freely falling bodies and needed to re-examine their knowledge in this topic. Again, inconsistency of the scientific concept was seen.

Question 6. A ball is thrown horizontally from a height above the earth. Neglect air resistance. Which of the forces provided will act on the ball after it is thrown. (a) The force of throw from the thrower (b) force of gravity (c) force from speed (d) none of them. Explain

Table-6
Concept on Freefalling Body

Teacher 2	It will fall at the same rate of the air resistance as it falls.
Teacher 3	The force of throw from the thrower and the force of gravity.
Teacher 4	The force of throw from the thrower and the force of gravity. There are two forces acting on a projectile motion. Horizontal motion and vertical motion. For an object to gain speed there must be a force acted on that object. That force must be initially coming from the thrower The vertical motion coming solely from the force of gravity.
Teacher 9	The forces provides/act on the ball after it is thrown is the force of throw from the thrower and the force of gravity. Both forces will act on that object which is horizontal direction, because in the projectile motion it is the combination of horizontal and vertical component. While the object is moving forward because of the force applied by the thrower, it is also moving forward because of the force acted by the thrower, it is also moving downward because of the influence of the gravitational force of the earth.
Teacher 13	And it also depends on the initial force applied.
Teacher 15	The force of throw from the thrower. This force helps the ball move forward.

After the object is thrown into the air, the only force that acted on it is the pull of gravity, but based on the situation described, teacher 3, 4, 9, 13 and 15 seemed to have misconception regarding it. They tended to believe that there is still force of the thrower acting on the object once it is released.

On the other hand, teacher 2 seemed to explain that the object falls with the same rate as air resistance, if that so, it will have a constant velocity and not a constant acceleration. Again, this is another proof that there are still misconceptions on the part of Science teachers when it comes to some concepts in Physics.

Question-7. To dislodge ketchup from the bottom of a ketchup bottle, it is often turned upside down and thrusted downward at high speeds and then abruptly halted. Which of Newton's laws of motion explains this phenomenon? Explain.

Teachers 6 10, and 12 seem to be confused on the situation stated, when the ketchup turned upside down and thrusted downward at a high speed manifested the law of inertia, it explains that ketchup is state of inertia in motion wherein it will continue to move after a force is acted on it.

Table-7
Concept on Law o Inertia

Teacher 6	The action there is when you poke the bottle of the ketchup upside down and the reaction is when the liquid inside comes down.
Teacher 10	For me it is the 2nd law of motion. The direction of the acceleration is the direction of the net force acting on the object.
Teacher 12	Different forces may not cancel each other, because they acted or not the same bodies. This situation explained law of interaction. The action is when the bottle turned upside down and thrusted downward at high speed then the reaction will be movement of ketchup inside.

They tend to explain the situation in terms of third law of motion and misunderstood that the bottle is the action and the ketchup is the reaction. There is also a misconception on third law in which only two bodies acted on each other because they always acts in pairs.

Question 8. A group of physics teachers are taking some time off for golf. The Golf Course has a large metal rim which putters must use to guide their ball towards the hole. Mr. Boakye's guides a golf ball around the metal rim. When the ball leaves the rim, which path (1, 2, or 3) will the golf ball follow? (note: the ball follow a circular path)

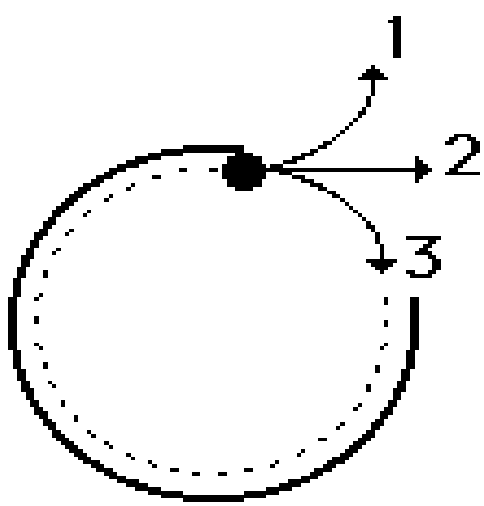

Image source: http//www.gogle .com

Figure-3
Ball follow a circular path

Table-8
Concept on Law of Inertia

Teacher 2	Path 2 is the path of the golf ball, because the centripetal force provided by the circular tube is the reason why the golf ball move in a circle.
Teacher 3	The golf ball will follow path no 3 because in circular motion the movement is always perpendicular to the radius of an object.
Teacher 6	Number 2. It explains that the circular tube was providing the centripetal force to cause the golf ball to move in a circle.
Teacher 7	Path no 2, because when you observe the three paths only path 2 has a straight line while the two other paths has different direction
Teacher 9	If the motion of the ball is clockwise and when the ball leaves the rim it follows the 3rd path, but if it is in the counter clockwise direction it follows the 1st path.

Teachers 2, 6 and 7 are correct with their answers but they could not discuss the reason why it followed path number 2 so there is lack of scientific knowledge on the concept. It means that if they teach this to their students, they would tend to have a hard time explaining to them.

On the other hand, teacher 3 and 9 have a misconception on the first law of motion when they answered that it will follow path number 3. They are not able to ascertain that when no outside force acts to an object, this will continue to move in straight direction.

Table-9 presented the summary of teachers who have identified misconception as inconsistent with scientific concepts. In this study, misconception is identified when a graduate student has a correct response with unscientific explanation or incorrect response with unscientific explanation[22].

The table shows the number of teachers who have misconception on some topics in Physics. The highest number of teachers who have misconception is on the concept of acceleration and constant velocity wherein seven (7) teachers are found to have misconception. Then, six (6) teachers have misconceptions on both topics on acceleration and situation *b* of freely falling body. Next in rank is topic number 8 which is the law of inertia situation *b* wherein five (5) teachers are found to have misconception. Three (3) teachers have misconception on both law of inertia situation *a* and freely falling body situation *a,* while only two (2) teachers misconceived the topics of distance and displacement and instantaneous and average speed.

Table-9
Summary Table on the Conceptual Understanding of Graduate Students in Selected topics in Mechanics

Topic	**Teacher**															**Total # of Teachers with Misconception**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	
1. Distance and Displacement	+	+														2
2. Instantaneous and Average Velocity												+			+	2
3. Acceleration	+	+		+	+							+			+	6
4. Acceleration and Constant Velocity				+	+	+	+	+		+	+					7
5. Freefalling body (situation a)				+			+		+							3
6. Freefalling body (situation b)		+	+	+					+				+		+	6
7. Law of Inertia(situation a)						+				+		+				3
8. Law of Inertia (situation b)		+	+			+	+		+							5
Total # of Misconceptions per Teacher	2	2	2	4	2	3	3	1	3	2	1	3	1	0	3	

Legend: Identified Misconception +

On the other hand, of the fifteen (15) respondents, only one (1) teacher is found to have no misconception in her answers to all the questions. But, most of the teachers have found misconception ranging from one to four topics in Mechanics. This study is just a confirmation of the findings of Handhika J[2]. et al., Brown[1], Martín-Blas[3] et al. and Larkin L.[30] that there are still gaps in understanding concepts in Physics. But since the respondents are already teachers, the result has a big impact on the part of the academe in higher education for they are the ones who mold and build the comprehensive understanding of future and progressing teachers.

Conclusion

The study seems to be simple yet it digs deeper on the teachers' concept of Mechanics in certain topics. It made the researcher realize that to anticipate that these teachers already know much concepts in Physics really doesn't follow even if many of them are already teaching high school for about 3 to 5 years now. The issue needs to be addressed especially in their graduate and post-graduate studies simply because they will be teaching thousands of students with these misconceptions if left unclarified. In this data, the researcher chose simpler and commonly discussed topics in Physics classes, and realized that if teachers are found to misconceive even the simpler topics how much more of complicated lessons spelled out in DepEd content standards. This also served as a realization on the part of the instructors/professors teaching the subject in tertiary level to always make probing tasks regardless of the nature of the respondents in order to determine the conceptual understanding of the learner. Hence, it would lead the teachers to adjust with their teaching style or techniques that can attribute in the understanding of the concepts deeply.

Recommendations: Teachers are encouraged to make a balanced teaching between the concepts and mathematical problems. Science faculty teaching in Graduate or Undergraduate programs are suggested not to anticipate that their students already understand the subject. It is suggested that they conduct probing test to identify the students' preconceived ideas and prior knowledge of the topics, and should adjust their teaching to help learners effectively confront their misconceptions. Since spiral progression exists, Science Supervisors or School Administrators in a particular should conduct a regular intervention program for Science teachers to keep them updated and eventually master their Science subjects.

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