ANXIETY, EXPECTATIONS, MATHEMATICAL COMPETENCIES AND PHYSICS PROBLEM SOLVING OF PRE-SERVICE TEACHERS' USING MULTI-DIMENSIONAL APPROACH

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Abstract

This quantitative study that made use of the descriptive correlational design investigated the relationship of mathematics anxiety, mathematics expectations, mathematics competencies, and understanding of physics problem solving using multi-dimensional approach among pre-service science teachers of teacher education institutions in Iloilo City. The subjects of the study were the 79 pre-service teachers' who were enrolled in the first semester of SY 2014-2015 at teacher education institutions in Iloilo city and had taken biophysics or general physics as prescribed by the course curriculum.The study utilized four sets of instruments, namely: Mathematics Competency Test (MCT), Mathematics Anxiety Rating Scale (MARS), Mathematics Expectation Rating Scale (MERS), and Force, Motion, and Energy Problem-Solving Test (FMEPST).Results revealed that the pre-service teachers had both moderately low mathematics anxiety and mathematics expectations. The level of mathematical competencies of pre-service teachers as a whole group was average; they also had average level of competencies in numbers and number sense, measurement, patterns and algebra, geometry, and statistics and probability, and moderately low level of competency in trigonometry. Their understanding of physics problem solving using multi-dimensional approach was average. However, in terms of physical representations, they had moderately low level of understanding physics problem solving and average level of mathematical representations. Significant relationships existed between pre-service teachers' mathematics competencies and understanding of physics problem solving using

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multi-dimensional approach. Mathematics anxiety and mathematics expectations were not significantly related to understanding of physics problem solving using multi-dimensional approach. Moreover, the significant relationships between mathematics competencies and physics problem solving using multi-dimensional approach implied that students with mastery in mathematics competencies scored higher in physics problem solving. On the other hand, mathematics anxiety and mathematics expectations had no bearing on students' understanding of physics problem solving.

Keywords:*Mathematics Competencies, Anxiety, Expectations, Multi-dimensional Approach, Physics, Pre-service Teacher*

Introduction

Science teaching is a lifelong learning process involving continuous acquisition of knowledge focusing on technological innovation, discovery, experimentation, collaboration, self-realization, actualization, and professional development. As a facilitator, prospective science teachers should possess the necessary skills that is, both content and process in order to facilitate instructions to the highest level. By this, they can empower the learners with the required skills that the real life situations may ask them to perform. Furthermore, students are motivated to think, act, explore, investigate and learn science when teachers encourage them to make inferences, think intuitively, and promote problem solving in the classroom. On the other hand, when necessary skills are not facilitated well, this might result to a learning gap where the other higher skills cannot be immediately acquired and may result to the low performance of the students in the above-mentioned subject. According to Tan (2012 of University of the Philippines National Institute of Science and Mathematics Education (UPNISMED), the reasons for the repeated poor performance of Filipino students in Trends in International Mathematics and Science Survey (TIMSS) shows that students who took the TIMSS test; a) have NOT taken sciences subjects, b) Not exposed to inquiry – based instruction, c) have NOT developed higher level thinking, d) have NOT retained or mastered concepts and skills, e) Not exposed to questions that show connections across disciplines , and ,f) have poor communication and comprehension skills. The absence of necessary understanding of force, motion, and energy problemsand use of mathematical language and tools are often cited as a contributory factors. Students are expected to communicate their new scientific ideas to process and interpret information and data from a variety of evidences integrating the use of mathematical skills to improve investigations.

The Philippine K-12 science curriculum envisions the development of scientifically, technologically, and environmentally literate and productive members of society who manifest skills as critical problem solvers, responsible stewards of nature, innovative and creative citizens, informed decision makers, and effective communicators, (DepEd, 2013). Bybee (2010), states that to prepare the students to the workforce; science policies, programs, and practices should develop students to acquire basic mathematics, basic science competencies, hard skills, ability to apply science and mathematics in new situations and among others. The above common denominator suggested in the practice of science teaching is mathematical competence that develops a mixture of cognitive abilities, social skills, personal motivation, conceptual knowledge, and problem solving competency.

Thus, to address the existing problems described above, the researcher was investigated the readiness of pre-service science teachers in terms of their mathematical competencies in teaching grade 8 physics (force, motion, and energy). The researcher believe that if mathematical competencies of pre- service science teachers are examined and deficient skills are constructively enhanced, prospective science teachers can deliver competent science teaching both content (what the students know), and process (what the students be able to do and understand). In return, this could results to preparedness of students to handle real life situations, communicate the results, and solve complex problem solving.

Theoretical Framework

This study is anchored on APOS theory (actions, processes, objects, and schema) of constructivism. According to this theory, mathematical knowledge consists in an individual's tendency to deal with perceived mathematical problems situations by constructing mental actions, processes, and objects and organizing them in schemas to make sense of the situations and solve the problems (Dubinsky and Mcdonald,2001).

The first essential component of the theory is action. It is a transformation of objects perceived by the individual as essentially external and as requiring, either explicitly or from memory, step-by-step instructions on how to perform the operation. When an action is repeated and the individual reflects upon it, he or she can make an internal mental construction called a process which the individual can think of as performing the same kind of action, but no longer with the need of external stimuli. Next, an object is constructed from a process when the individual becomes aware of the process as a totality and realizes that transformations can act on it. Finally, a schema for a certain mathematical concept is an individual's collection of actions, processes, objects, and other schemas which are linked by some general principles to form a framework in the individual's mind that may be brought to bear upon a problem situation involving that concept (Dubinsky and Mcdonald, 2001)

Statement of the Problem

Generally, this study aimed to investigate the contribution of mathematical competencies in the attainment of students understanding grade 8 physics problem solving using multiple-dimensional approach, and specifically sought to answer the following questions:

1. What is the pre-service teachers' level of mathematics anxiety and mathematics expectations?
2. What is the level of pre-service teachers' mathematical competencies as a whole and in terms of a) numbers and number sense? , b) measurement, c) geometry, d) patterns and algebra, e) statistics and probability, and f) trigonometry?
3. What is the pre-service teachers' level of understanding of physics problem solving using multi-dimensional approach in terms of a) physical representation, b) mathematical representation?
4. Is there a significant relationship between pre-service teachers' mathematics anxiety, mathematics expectations, mathematical competencies and understanding of physics problem solving using multi-dimensional approach?

Review of Related Studies

Characteristics of Mathematical Competency

Fostering of mathematical literacy to the learners should be the responsibility not only of mathematics educators but also of other teachers of subject areas whenever appropriate (Niss,1999; in Stacy, 2012). This is to ensure that a fair part of the responsibility are to be undertaken. When mathematical literacy is perceived to be a multi-natured endeavor and activity out of being a pure and applied mathematics, then it becomes a crucial task to find and employ new ways to define and describe mathematics curricula that focus on mathematical competence rather than facts and techniques (Niss, 1999; in Stacy, 2012). In this connection, the Commission on Higher Education (CHED) provided the framework and rationale of the revised general education as a paradigm shift in the context of the K-12 curriculum based on college readiness standards that set goals, standards , and competencies (CHED CMO.20, 2013).

At the most general level, competency in mathematics is characterized both in terms of content (what mathematics students should know) and process (how students should go about doing and understanding mathematics) which includes both content standards and process standards for students in the K-12 curriculum (Graf, 2009; NCTM, 2000, DepEd, 2012, CHED CMO 20, S. 2013). The content standards include (a) numbers and operations, (b) algebra, (c) geometry and measurement, and (d) data analysis and probability while the process standards include (a) problem solving, (b) reasoning and proof, (c) communication, (d) connections, and (e) representation. All of these standards are central to the study and practice of mathematics (Graf, 2009).

Trends in the International Mathematics and Science Study (TIMSS) 2011 outlined the appropriate range of cognitive skills across content domains in mathematics content. The first domain , knowing , covers the facts , concepts, and procedures students need to know , while the second , applying , focuses on the ability of students to apply knowledge and conceptual understanding to solve problems or answer questions. The third domain, reasoning, goes beyond the solution of routine problems to encompass unfamiliar situations, complex contexts, and multi– step problems.

Without access to a knowledge base that enables easy recall of the language and basic facts and conventions of number , symbolic representation, and spatial relations , students would find purposeful mathematical thinking impossible. Facts encompass the factual knowledge that provides the basic language of mathematics , and the essential mathematical facts and properties that form the foundation for mathematical thought. The second domain involves the application of mathematical tools in a range of contexts. Problem solving is central to the applying domain, but the problem settings are more routine than those aligned with the reasoning domain, being firmly in the implemented curriculum. Problems may be set in real-life situations, or may be concerned with purely mathematical questions involving numerical expressions, functions, equations, geometric figures, or statistical data sets. The last domain is reasoning which involves the capacity for logical, systematic thinking. It includes intuitive and inductive reasoning based on patterns and regularities that can be used to arrive at solutions to non-routine problems (TIMSS, 2011).

Core Content

Mathematics education depends mainly on the mathematics curriculum offered by different respective institutions. This perspective is similar to the idea that mathematics curricula may vary with respect to the coverage of topics, the sequence in which topics are taught, and the extent to which mathematics instruction is integrated with instruction in other subject areas (Graf, 2009). However, there could be similarities that are fundamental to any mathematics curriculum at a particular level. These similarities are found in the Philippine K-12 mathematics curriculum such as Numbers and Number Sense, Measurement, Geometry, Patterns & Algebra and Statistics and Probability (DepEd, 2012).In addition, CHED provided an explanation of general education courses in a memorandum to include mathematics in the modern world as an additional course which emphasizes on the nature of mathematics, appreciation of its practical, intellectual, and aesthetics dimensions; and application of mathematical tools in daily life (CHED CMO.20, s.2013).

Relationship of Mathematics Proficiency to Understanding Science

Mathematics is the universal language of science. It is a language of patterns and relationships as well as a discipline that explores relationships among abstractions. Students must perceive mathematics as part of the scientific endeavor. They must comprehend the nature of mathematical thinking, they must become familiar with how mathematical knowledge is constructed, and they must understand what drives mathematical inquiry (Marshall, 2000).The present ideas conform that mathematics, science, and technology have long been intrinsically linked, and their evolution as well as their internal dynamics reflect their synergistic relationship (Quebec Education program, 2004). This relationship exists in the mathematics language of symmetry and interconnection, specifically on the form of abstraction, of symbolic transformation and application (Marshall, 2000). Hence, the product of this inevitable connections are the design or representation of certain technical objects and the development of mathematical models or the representation of scientific phenomena (Quebec Education Program, 2004); however, students should not view this as a linear and discrete process of memorization and computation (Marshall, 2000).

Research Design and Methodology

This study used the descriptive – correlational method of research. This research method combines both descriptive and correlational designs.The paradigm of this combined method of research ensured maximum insights and understanding to describe and characterize pre-service teachers mathematical competencies and understanding of physics problem solving . Specifically, the study aimed to determine the level of pre-service teachers mathematical competencies and their relationship on the pre-service teachers understanding on physics problem solving in the accredited teacher education institutions (TEI's) in Iloilo city.

The Participants

The participants of the study were the senior pre-service Bachelor of Secondary Education students major in Physics, Physical Science, General Science, and Biology from the accredited state universities and colleges teacher education institutions (TEI's) in Iloilo city during the first semester of school year 2014-2015. They were randomly chosen based on certain year level, course, and school's accreditation status using cluster sampling. According to Fraenkel and Wallen, (2003), cluster sampling is similar to simple random sampling except that groups rather than individuals are randomly selected.

Data Collection Procedure

Permission to conduct the study was secured from the administrator of the TEI's who were selected as participants during the first semester of SY 2014-2015 from October 20-21, 2014.The participants were given validated and reliable instruments , namely: personal information sheet coupled with given 30 items-4 point likert rating scale on mathematics anxiety anchored from Camarista (2012) ; a researcher- made 30 items- 4 point rating scale on mathematics expectations ; researcher-made 60 -items multiple choice test on mathematical competencies broken down as follows: 10 items for number and number sense, 10 items for measurement, 10 items geometry, 10 items patterns and algebra , and 10 items statistics and probability ; Finally, 12 items on problem solving on grade 8 physics (force, motion and energy) researcher- made instrument. They were given at least two hours to answer all the instruments in the same day and on different day in other schools. Thereafter, the test papers were collected and checked and scores were recorded. The data were encoded through the Statistical Package for the Social Science (SPSS) software for analysis.

Findings

The results of pre-service teachers' mathematics anxiety and expectations are shown in Table 1. By inspection of the mean scores, the pre-service teachers had a moderately low anxiety (*M* =2.50 ,*SD* =0.55), and the SD implies the homogeneity of scores. It can be inferred that pre-service teachers are quite uncomfortable in dealing with activities that require rigorous calculations. It further suggests that they feel a quite nervous when they think of their mathematics classes. Thus, the moderately low anxiety shown by the students reflected to their low articulations in learning mathematics.

Table 1

Pre-service Teachers' Mathematics Anxiety and Expectations

Category	SD	Mean	Description
Mathematics Anxiety	0.55	2.50	Moderately low
Mathematics Expectations	0.24	1.93	Moderately low

Note. 3.51 - 4.00, Very high; 2.51 -3.50, High; 51 - 2.50, Moderately low; 1.00 - 1.50, low

The mathematics expectations of pre-service teachers is also moderately low (*M* =1.93, *SD*=0.24). As reflected by the *SD*, the dispersion of scores are nearly the same. This implies that the pre-service teachers' beliefs in learning mathematics are not well– articulated in terms of their participation in mathematics class. It can be inferred further that their beliefs towards mathematics was contributed by their inability to focus on performing calculations, thus resulted to low attitude and lack of confidence in mathematics.

In terms of level of pre-service teachers' mathematical competencies, theresults of the study showed that pre-service teachers have average mathematics competencies (*M*=36.76, *SD*=10.18) and moderately low anxiety about their ability to do and apply mathematics. As reflected, the SD implies the variations of scores. This suggests the heterogeneity of scores of pre-service teachers in the mathematics competency test. Many surpassed the mean but there were students whose scores were also below the mean. It can be inferred further that pre-service teachers are most likely capable of doing mathematics; however, they still have difficulty managing mathematics activities especially when the concepts and principles are used in problem solving.

Table 2 further shows that for specific competencies like numbers and number sense, measurement, patterns and algebra, geometry, and statistics and probability, pre-service teachers have average competency with a slight dispersion of scores in the distribution (*SD*=1.67, 2.13, 2.44, 2.52 and 2.29; *M* =6.84, 6.19, 6.52, 5.94 and 6.87), respectively. However, the pre-service teachers have moderately low competency in trigonometry (*M*= 3.76, *SD* = 1.81). The SD for trigonometry suggests that most of the students got low scores. It can be inferred that pre-service teachers have difficulty in trigonometry.

Table 2

Pre-service Teachers' Mathematical Competencies

Category	SD	Mean	Description
Mathematics Competencies	10.18	36.76	Average
Numbers and number sense	1.67	6.84	Average
Measurement	2.13	6.19	Average
Patterns and algebra	2.44	6.52	Average
Geometry	2.52	5.94	Average

Statistics and probability	2.29	6.87	Average
Trigonometry	1.81	3.76	Moderately low

Note. Mathematics Competencies: 48.55 – 60.00, High; 29.55 – 48.54, Average 10.55 – 29.54, Moderately low; 0.00 – 10.54 Low,
Specific mathematics competency: 8.55 – 10.00, High; 5.05 – 8.54,Average; 1.55 – 5.04, Moderately low; 0.00 – 1.54, Low

The results of pre-service teachers' understanding of physics problem solving using multi-dimensional approach are reflected in Table 3. The mean scores reveal that the pre-service teachers had an average physics problem solving performance (*M* =63.53 ,*SD* =22.33).Moreover, when classified in terms of physical representation and mathematical representation, the pre-service teachers had moderately low (*M*= 22.23, *SD* = 7.82) and average (*M* = 41.01 , *SD* = 16.29) performance, respectively. Also, the *SD*s suggest that for both understanding of physics problem solving using multi-dimensional approach and classifying in terms of physical representations, the scores of pre-service teachers were varied although there are slight variations in their scores in mathematical representations. This implies that pre-service teachers had heterogeneity of ideas especially when it comes to providing solutions to the problems and supplying the given and the required variables and then representing these in a diagram or in specific illustrations. Furthermore, it can be inferred that the variations of their scores are likely associated with their specific background knowledge and specific techniques employed in solving the problems.

Table 3
Pre-service Teachers' Understanding of Physics Problem Solving

Category	SD	Mean	Description
Physics Problem Solving	22. 33	63. 53	Average
a. Physical representation	7.82	22. 23	Moderately low
b. Mathematical representation	16. 29	41. 01	Average

Note. Physics Problem Solving: 105.00 – 120.00, High; 75.00 – 104.99, Moderately High; 45.00 – 74.99, Average; 15.00 – 44.99, Moderately Low; 1.00 – 14.99, Low, Physical Representation: 37.80 – 48.00, High; 23.20 – 37.99 Average; 8.60 – 23.19, Moderately low; 0.00 – 8.59, Low; Mathematical Representation: 55.00 – 72.00, High; 35.00 – 54.99, Average;15.00 – 34.99, Moderately low; 0.00 – 14.99, Low

The mathematics competencies of the pre-service teachers' were positively and significantly related to physics problem solving with (r =.258, p = 0.022). This finding is in agreement with the results of the study of Bolte (1993) and Sadler, and Tai (2001) wherein they found positive correlations between grades earned by students in their college physics courses and their previous experiences and/or grades in either high school, college mathematics courses, or high school physics courses.

In terms of mathematics anxiety and physics problem solving (r = -.290, p = .798);expectations and physics problem solving(r = .162 ,p = .153) mathematics expectations and mathematics anxiety, (r=.031, p=.784) ;mathematics anxiety and mathematics competencies, (r= -.156, p=.170); and mathematics competencies and mathematics expectations, (r=.011, p= .926), the results were not significantly related.

Table 4

Correlations of Pre-service Teachers' Physics Problem Solving and Anxiety, Expectations, and Mathematics Competencies

		Physics Problem Solving	Anxiety	Expectations	Mathematics Competencies
Physics Problem Solving	Pearson's r	1.00			
	Sig				
	N	79			
Anxiety	Pearson's r	-.029	1.00		
	Sig	.798			
	N	79	79		
Expectations	Pearson's r	.162	.031	1.00	
	Sig	.153	.784		
	N	79	79	79	
Mathematics Competencies	Pearson's r	.258*	-.156	.011	1.00
	Sig	.022	.170	.926	
	N	79	79	79	79

*p<.05 Significant

Conclusions

The pre-service teachers' have moderately low mathematics anxiety and moderately low expectations, respectively. This shows that the pre-service teachers relatively have inhibitions towards mathematics. It further implies that activities related to mathematics learning causes discomfort for them. Their moderately low mathematics expectations signifies their low outlook towards mathematics. One of the possible reasons for this is their poor preparation that makes them counterproductive in terms of performance.

The average level of mathematics competencies entails their insufficient background in K-12 mathematics as a whole and in terms of numbers and number sense, measurement, patterns and algebra, and statistics and probability. Moreover, their moderately low level of competencies both in trigonometry indicates that they have experiencing difficulties of the skills needed to perform the required tasks.

The average understanding of the pre-service teachers' in physics problem solving using multi-dimensional approach implies that they lack competencies needed to demonstrate understanding specifically in the mathematical operations and skills. These are not fully acquired as a part of the requirements of grade 8 science curriculum. Also, other attributes such as physical representations and mathematical representations need to be explored deeply to ascertain if understanding of physics problem solving improves.

The significant positive relationship of mathematics competencies and understanding of physics problem solving using multi-dimensional approach indicates that grade 8 mathematics competencies are related to pre-service teachers' understanding of grade 8 physics problem solving, thus acquiring and developing mathematics competencies leads to the conceptualization and improvement in the student's understanding of physics problem solving.

Mathematics anxiety and expectations of pre-service teachers have no significant relationship to understanding of physics problem solving. This implies that these two variables have no bearing on students understanding of physics problem solving.

Recommendations

On the basis of the findings and conclusions in this study, the following recommendations are advanced:

Pre- service students may strengthen their beliefs and attitude towards mathematics, and mathematical background as aid of understanding science problem solving by creating good study habits that promotes positive cognitive and affective outlook in learning mathematics. Consequently, science teachers may employ problem solving strategies that would give students opportunities to develop mathematical knowledge and use by the students in different perspectives or orientations of learning science. In addition, teacher educators can make themselves available for students orientation programs, dynamic activities, trainings, or lectures to prevent or lessen Students Mathematics Anxiety and raise Mathematics Expectations high.

They are also encouraged to formulate and support interventions/activities that would help students reduce mathematics anxiety. Moreover, they may strengthen their own understanding of the mathematical knowledge by attending seminars, conferences, and mathematics training for science teachers to reinforce the science courses they teach in order to challenge and engage students in an interdisciplinary or problem-based learning.

Teacher education institutions and curriculum and policy makers may review or revisit the alignment of both mathematics and science education courses being offered in their respective institution to counter balance the needs of the new K-12 curriculum of the Department of Education. They may formulate learning intervention that would prevent or lessen mathematics anxiety and develop student's expectations. Furthermore, curriculum and policy makers may design a formative and accountability assessment to track student's progress and promote self-reflection which highlights the K-12 science and mathematics competencies.

Parents and other stakeholders may be tapped of the intervention activities undertaken in classrooms or schools so that they could give proper support to such endeavors.

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