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Assessment of Pedagogical Content Knowledge of Math Teachers: Basis for Professional Development Program

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Abstract*: This study aimed to evaluate the pedagogical content knowledge of mathematics teachers and its relationship to students' achievement level and to develop a Professional Development Program that will further enhance their content knowledge and pedagogical skills in teaching Mathematics. The respondents of the study were 365 Grade 10 students, 26 Grade 10 Mathematics teachers and 14 Math Coordinators including the Head Teachers and School Heads whose specialization is Mathematics in the Schools Division of Lipa City. The Pedagogical Content Knowledge (PCK) was measured in terms of Learning Competencies, Content Knowledge and Teaching Approaches of Mathematics mentors/teachers. The study utilized two sets of research instrument, one is for Grade 10 students to determine their achievement level and the other one is for mathematics mentors to determine their level of competence on PCK. Out of 14 national high schools 5 or 36% of them achieved an MPS equivalent to Moving Towards Mastery level, and 8 or 57% of them got an MPS matching to Average Mastery level. Unfortunately, only one school obtained an MPS corresponding to Low Mastery level. Pedagogical Content Knowledge of Math Mentors in terms of Learning Competencies obtained an overall mean score of 3.29, interpreted as Expert, Learning Competencies on the following areas, such as:(a) Measurement and Sequence having the highest average rating of 3.5; (b) Polynomials and Polynomial Functions; and (c) Circles and Plane Geometry obtaining a weighted mean of 3.35 and 3.37, respectively, had obtained an overall rating equivalent to Expert. Only in Probability and Statistics that teachers were rated 2.95 equivalent to Experienced. In term of Content Knowledge, all content areas such as: (a) Measurement, Sequence and Number Sense; (b) Geometry; (c) Patterns and Algebra; and (d) Probability and Statistics were given rating equivalent to Experience with an overall mean of 2.85. In terms of Teaching Approaches, math mentors had an overall mean score of 2.57 which described the teachers as Experienced. On the following teaching approaches: (a) Reflective; (b) Collaborative; and (c) Constructivist, mentors were rated Experienced. On the other hand, mentors were rated equivalent to Developing on Inquiry-Based and Integrative Approaches. More so, there was no significant difference between the PCK rating of teachers and administrators in terms of Learning Competencies and Content Knowledge. However; there was a significant difference on the rating of two groups of respondents in terms of Teaching Approaches. On the other hand, there was a significant relationship on the PCK of Mathematics teachers and student's achievement level. PCK has vital contribution to quality teaching which means the higher teacher's pedagogical content knowledge; the higher student achievement level is expected. As a result, a proposed Professional Development Program was developed to equip teachers with necessary skills to enhance their content knowledge and pedagogical skills in teaching Mathematics.

***Keywords*: Approaches, Content, Competencies, Knowledge, Pedagogical.**

1. Introduction

There are many challenges that mathematics teachers face today. Many of our teachers are unprepared or inadequately prepared to meet these challenges. Top of these is the amount and depth of mathematics content that teachers ought to know. At the heart of effective content teaching is the teachers' pedagogical content knowledge. According to Shulman (as cited by Hilderbrandt, 2010), pedagogical content knowledge is a form of practical knowledge that is used by teachers to guide their actions in highly contextualized classroom settings. Likewise, pedagogical knowledge means the "how" of teaching acquired through education course work and personal experience, while content knowledge is the "what" of teaching. Teaching, by its nature, cannot be deemed effective unless significant learning takes place.

Many educators like the idea that the primary measure of teaching effectively relies on students learning outcomes. The Third International Math and Science Study (TIMSS) is a series of international assessments of the mathematics and science knowledge of students around the world. TIMSS is one of the studies established by the International Association for the Evaluation of Educational Achievement (IEA) aimed at allowing educational systems to compare students' educational achievement and learn from the experiences of others in designing effective education policy. This study was first conducted in 1995, and has been performed every 4 years thereafter. In 2003, the Philippines ranked 34th out of 38 countries in High School II Math. In 2008, even with only science high schools participating in the Advanced Mathematics category, the Philippines ranked lowest among 10 countries. Filipino students are still weak in math and science,

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according to results of the Third International Mathematics and Science Study-Repeat (TIMSS-R)(http://nces.ed.gov/timss).

The poor performance in mathematics is brought about by the kind of mathematics instruction currently followed in most of our mathematics curriculum (Tan). Students' low scores in the National Achievement Test and Trends in International Math and Science Study are a reflection of the current quality of education in the country. (K12Philippines, 2015).

Most mathematics educators consider the development of Mathematics framework for the Enhanced Basic Education Curriculum timely and strategic with the current trends brought by the reforms and innovations in the curriculum and policies which are all cored to education today. The majority of upcoming trends in K-12 education relate to fostering 21st century skills by using technology in new and innovative ways (2014 Hanover Research). Thus, math programs are based on the current and future needs of students making them as functions on their life situations. This is seen very vividly as the challenges and hurdles in the modern times are at most met and triumphed by the learners through teachers' persistent and indefatigable thrust for quality education.

2. Statement of the Problem

This study was an attempt to determine the Pedagogical Content Knowledge of mathematics teachers in the Division of Lipa City.

The study sought answers to the following questions:

1. What is the achievement level of Grade 10 students in Mathematics?
2. To what extent do mathematics teachers' Pedagogical Content Knowledge (PCK) rated by Grade 10 mathematics teachers and coordinators/ head teachers/ school heads in terms of the following:
   1.1. Learning competencies;
   1.2. Content; and
   1.3. Teaching Approaches?
3. Is there a significant difference between the PCK rating of Grade 10 math teachers and the PCK rating of mathematics coordinators/ head teachers/school heads?
4. Is there a significant relationship between the pedagogical content knowledge of Mathematics teachers and students' achievement level?
5. Based on findings of the study, what Professional Development Program can be developed for mathematics teachers?

3. Significance of the Study

A country's vision of inclusive growth and development entails investment in human capital, particularly through the provision of quality basic education. In light with the reforms in the Philippines, it is imperative to take actions which promote programs that would help teachers to become effective and efficient mentors of learners.

The findings of the study may give significance to the following:

Schools Division Superintendents: The results of this study may guide them on the realization of the root cause of the achievement gaps in mathematics and implement appropriate development plan to ensure quality standard for basic education.

Curriculum and Implementation Division: The identified strengths and weaknesses may provide an avenue to look at the effectiveness and sustainability in the implementation of the proposed program.

Division and District Supervisors: The findings of this study may lead them to strengthen the professional and instructional advice and support they render to school heads and teachers on curricula supervision in the course of raising the mathematical achievement of students.

School Heads: The results of the study may provide directions to the school heads in implementing the school's curricular and instructional processes in mathematics in the desire to achieve excellence. They too, could provide assistance to teachers on the execution of effective teaching

Faculty/Teachers: The study may provide direction and guidance to the teachers in ensuring the quality they provide to meet curricular standards. This may serve as a motivation to improve their teaching. This may also be a tool for continuous improvement and development and may help them to appropriately align instructional decisions and activities as well as teaching styles and techniques within the level of students' understanding and competence.

Students: The programs, instructional practices and activities of the teachers may be more responsive to the students and may focus on the students' priority and needs. Also, students may be the direct beneficiaries of this study since teachers may be more competent and the learning process may be facilitated pedagogically.

Parents: With a better instructional practices and more efficient delivery of educational services to the students, the parents may have the assurance that their children are acquiring quality education

Educational System: This study may set a standard on assessing teachers' instructional competence. Public high schools may be able to set a benchmark against the result of evaluation using the instrument, thereby assisting them in their improvement and continuous growth and development as institution of learning.

Other Researchers: The study may also serve as a source of useful insights on the need for their studies of this kind in the future.

4. Research Design

In this study, a descriptive method of research was used. The study entailed mixed method data analysis with phase one being quantitative and the other is qualitative. The quantitative method was used to measure the level of students' performance and the rating for mathematics teachers. Quantitative and qualitative data processing was done to arrive at precise analysis and interpretation of results.

A. Research Instrument and Technique

The study utilized two sets of research instrument, one is for

Grade 10 students to determine their achievement level and the other one is for mathematics mentors to determine the Pedagogical Content Knowledge of mathematics teachers

The researcher developed an assessment tool for grade 10 students comprising the learning competencies from first quarter up to third quarter of school year 2016-2017. The content of the assessment tool was based on the learning competencies as prescribed by the Department of Education for Grade 10 learners. The content of the test was purposively studied and identified. The Budget of Work (BoW) for Grade 10 was considered in making the Table of Specification (ToS). A ToS is a plan that provides an assurance that the test will measure the desired competencies. In this study, a ToS was made for the 50-item multiple choice test. The researcher used various textbooks as references for the test items.

Likewise, the researcher devised Part 1 of the questionnaire for the rating of PCK of Mathematics teachers as to the level of mastery of the Learning Competencies and Content of Mathematics under the Enhanced Basic Education Curriculum. For Part 2 of the questionnaire, the researcher asked permission from the author of a study, "Towards Developing a Pedagogical Based Training Design for Public Secondary School Teachers in a City Division" (Morcilla 2013), to use part of her instrument in the present study to rate the mathematics teachers knowledge on teaching approaches.

Three master teachers, five head teachers and a school head whose area of specialization is Mathematics were consulted and approved the test.

B. Validity and Reliability of the Instrument

The research instruments for students and teachers were presented to five instructional leaders whose area of specialization is Mathematics. The items were evaluated and validated by these experts. Their comments and suggestions were considered in the final making of questionnaire. On the other hand, Part 2 questionnaire for PCK of Mathematics teachers had already been validated and used in previous study.

The pilot testing of two sets of instrument was tried out to Grade 10 students, mathematics teachers and school head of the Lipa City National Science High School, a high school in the Division of Lipa City which was not part of the respondents. The questionnaires were retrieved and tabulated the results using Microsoft excel. The tabulated result was then submitted to the statistician for the computation of the internal consistency using Cronbach's Alpha.

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5. Summary of Findings

A. Achievement Level of Grade 10 Students

Out of 14 national high schools 5 or 36% of them achieved an MPS equivalent to Moving Towards Mastery level, and 8 or 57% of them got an MPS matching to Average Mastery level. Unfortunately, only one school obtained an MPS corresponding to Low Mastery level.

Pedagogical Content Knowledge (PCK) of Mathematics Teachers

1) In terms of Learning Competencies

1.1. Sequence

Math teachers were rated as Expert under the category Sequence in 9 out of 10 learning competencies. For this result, it was concluded that both respondents had almost the same assessment that teachers were competent on numbers 1 to 9 indicators. Only in the indicator to Solve real-life problems involving geometric sequence, that Math teachers were rated average mean of 3.05, interpreted as Experienced. As a whole, teachers got an overall rating of 3.45, interpreted as Expert in

the Learning Competencies under Sequence.

1.2. Polynomials and Polynomial Functions

Out of 7 learning competencies, 4 were rated as Expert, among these were Apply the Remainder Theorem and the Factor Theorem having the highest average weighted mean of 3.55; followed by Perform Division of Polynomials using Long Division and Synthetic Division with 3.48 rating; and Factor Polynomials and Solve Polynomial Equations both with 3.44 rating. This assessment revealed that teachers were on high level of competencies with respect to these indicators. On the other hand, the remaining 3 learning competencies, solve problems involving Polynomial Equations and Graph Polynomial Functions acquired an average weighted mean of 3.24 and Solve problems involving polynomial functions got 3.13 weighted mean which described as Experienced. As a whole, this category obtained an overall mean of 3.36 which described that Math teachers are experts on these field. They have almost all the competencies at high level for effective teaching.

1.3. Circle and Plane Geometry

Teachers were rated Expert in the 5 learning competencies, namely: Illustrate tangents and secants of circles; Find the center and the radius of a circle given the equation; Determine the center and radius of the circle given the equation and vice versa, with weighted mean of 3.55, 3.48 and 3.44, respectively; and Solve for segments and sector of a circle; and, Use and apply the Distance Formula to prove some geometric properties with both 3.36 weighted mean. Meanwhile, teachers were rated Experienced on the following learning competencies: Solve problems involving chords, arcs, central angles and inscribed angles of a circle; Solve problems involving tangents and secants of a circle; having weighted mean of 3.28 and 3.20, respectively, while; Prove theorems on tangents and secants of a circle; and Solve problems involving geometric figures on the coordinate plane had the lowest rating of both 3.01. An overall mean of 3.30 which give a description of Expect was achieved.

1.4. Probability and Statistics

Teachers were rated as Expert on 4 out 12 learning competencies. Three of these competencies had similar weighted mean of 3.4, such as: Find the permutations of n objects taken r at a time; Find the combinations of an object taken r at a time Calculate quartile, decile, percentile of ungrouped data. On the other hand, calculate quartile, decile, percentile of grouped data acquired 3.32 weighted mean. The learning competency with the lowest weighted mean of 2.69 is Calculate quartile, decile, percentile of grouped data. Illustrate and find probability of mutually exclusive events and Illustrate independent and dependent events had the same weighted mean of 2.93. Solve problems involving permutations and combinations and Identify conditional probability had consecutive weighted mean of 2.96 and 2.97, respectively. The overall weighted mean for Probability and Statistics was 3.11 which means mathematics teachers are Experienced teachers.

Pedagogical Content Knowledge (PCK) of Mathematics Teachers

1) In terms of Content

1.1. Number and Number Sense

Math teachers were rated Experienced in all indicators except in indicator No. 1, *Describing correctly the structure and properties of real numbers that obtained a highest rating of 3.38 and described teachers as Expert on this field. Among the indicators, proving fundamental theorems involving numbers had the lowest mean of 2.84. The next indicators with the lowest mean were *Making correct conjectures based on observed numerical patterns and relationships; *Posting problems involving these numbers; *Solving problems involving real numbers, with weighted mean of 3.05, 3.09 and 3.24, respectively. The overall rating achieved by Math teachers was 3.10, meaning they were categorized as Experienced teachers.

1.2. Measurement

The second group of administrators had common rating of 3.33 in three indicators. However, on the part of the math teachers, *Converting of units of measurement had the highest rating of 3.31. This indicator also described math teachers as Expert having a mean of 3.32. Teachers were rated Experienced in the last two indicators, *Solving problems involving measurements ideas; *Formulating problems involving measurements having weighted mean of 3.17 and 3.13.

1.3. Geometry

The two sets of respondents rated Math teachers as Experienced teachers in this skills except in * Drawing geometric figures based on a given description, wherein teachers were rated 3.33 meaning Expert on the eyes of the administrators. It was observable that the lowest indicators that need to be prioritized are the following: * Making conjectures about properties of shapes which includes transformation and combination of shapes, obtaining an average mean of 2.52; * Proving theorems involving geometric concepts; and * Solving problems involving congruent and similar figures having 2.56 and 2.89 average mean, respectively.

1.4. Patterns and Algebra

The indicator * Solving linear and quadratic functions was confidently rated as Expert by both groups of respondents. However, other indicators were rated as Experienced by both respondents. The indicator with the lowest average mean of 2.68 was *Making conjectures based on the observed patterns using functions. Other indicators, *Proving properties of equations and inequalities, *Constructing mathematical problems based on real life situations and *Recognizing patterns based on observed patterns using functions obtained an average mean of 2.80, 2.93 and 3.01, respectively. This content area had an overall rating of 2.96, meaning teachers were assessed as Experienced.

1.5. Patterns and Algebra

Indicators that quite alarming were *Applying probability concepts in making decision in real-life situations and * Making predictions about outcomes, having means of 2.36 and 2.43 and described as Developing. The result of these two indicators revealed the weaknesses of Math teachers in terms of content. Although the first two indicators: *Analyzing and interpreting data and *Solving problems involving probability achieved rating of 2.96 and 2.8, equivalent to Experienced.

Pedagogical Content Knowledge (PCK) of Mathematics Teachers

1) In terms Teaching Approaches

1.1. Reflective Approach

Indicators No. 9. Takes time to reflect on his own during and after classes; No. 7, Transforms every day classroom life and No. 3, Helps students develop analysis of feelings, evaluation of experience, should be prioritized in designing professional program for teachers since these indicators got the lowest rank of 7th, 8th and 9th, respectively.

1.2. Inquiry-Based Approach

The lowest assessed five indicators which were all given Satisfactory rating were the following: No. 2, Requires to seek out knowledge as well as apply historical skills to determine why events occurred and what motivated the people to take the action they took; No. 11, Collaborates within and beyond the classroom; No. 14, Draws out and work with students pre-existing understandings and make student 'thinking' visible and central to the learning; No. 15, Classroom activities were designed to develop understanding through in-depth study of curriculum topics and No 7, Engages learners and researchers with the foundational belief that the topics they teach are rich, living and generous places for wonder and exploration; having rank 15, 14,13, 12 and 11, respectively. It was noted that Indicator No.2 ranked lowest for the teachers; on the contrary it ranked highest for the administrators. Both showed different views in this indicator that need to be clarified. As a whole, the overall average rating was 3.45 which interpreted Very Satisfactory for the pedagogical skills of mathematics teachers in terms of Inquiry-based approach.

1.3. Integrative Approach

The consolidated result of responses of two groups on the PCK of Mathematics Teachers in terms of Integrative Approach of Teaching. Indicator 7b, Teaches the students to direct their own learning so they become self-regulated learners had the highest in the average ranks with a Very Satisfactory interpretation. On the contrary Indicator 7a, Teaches the students to monitor their own learning so they become self – regulated learners obtained the lowest in the average ranks with Satisfactory interpretation. Likewise, Indicator 1, Develops the ability to discover and create, integrate and interpret knowledge from different disciplines, applying knowledge through real-world engagements was rated the same interpretation of Satisfactory. There were indicators which obtained similar average mean of 3.56, Anchors teaching in students' diverse life-contexts and Emphasizes problem-solving. Indicators 2a, leads students to synthesize learning from a wide array of sources, learn from experience; 2b, makes significant and productive connections between theory and practice and 3, Recognizes the need for teaching and learning to occur in a variety of contexts such as home, community and work sites had similar average mean of 3.44 interpreted as Very Satisfactory.

1.4. Collaborative

Indicator 1b, provides a place where teachers become learners at times, and learners sometimes teach was rated highest average mean of 3.79. This was followed by Indicators 4, Develops interpersonal relationship and 2, Allows the students to broaden their perspectives to an issue based on their cultural differences which obtained average mean scores of 3.69 and 3.46, respectively. These top 3 ranking categories were interpreted Very Satisfactory. On the other hand, the remaining 2 categories obtained an average mean scores of 3.39 and 3.23 which interpreted Satisfactory.

1.5. Constructivist Approach

Indicator 1, Acknowledges individual differences had the highest average mean of 3.89. This indicator ranked 1 for both respondents. On the contrary, indicator 6, Sees to it that learning situations, environments, skills, content and tasks are relevant, realistic, authentic and represent the natural complexities of the 'real world' had the lowest rank of 15 having a mean of 3.33 and Satisfactory interpretation. Aside from this category 6, all other categories obtained Very Satisfactory interpretation except for the following indicators which have also Satisfactory rating: 4 a. Activities are provided to encourage metacognition, self-analysis -regulation, -reflection & -awareness; b. Opportunities are provided to encourage metacognition, self-analysis -regulation, -reflection & -awareness; d. Environments are provided to encourage metacognition, self-analysis -regulation, -reflection & -awareness and 12, Errors provide the opportunity for insight into students' previous knowledge constructions. The results revealed an overall weighted mean of 3.54 which could be interpreted as Very Satisfactory.

B. Significant Difference between the Pedagogical Content Knowledge (PCK) Rating of Mathematics Teachers and the PCK Rating of Mathematics Coordinators/ Head Teachers/ School Heads

Learning Competencies obtained a significant value of .221 which was greater than .05 level of significance. This result revealed that there is no significant difference on the responses of the two sets of groups. Likewise, both respondents had a weighted mean of 3.30. This is an indication that both teachers and administrators have common assessment on the level of PCK in terms of Learning Competencies and the position or designation in the school does not affect the rating of teachers. On the other hand, PCK in terms of Content yielded a computed p value greater than .05 which was .296. This result revealed that there is no significant difference on the responses of teachers and administrators. This could be attributed to the fact that administrators are also knowledgeable in terms of content in Mathematics. The result of computed P value for PCK of Math Teachers in terms of Teaching Approaches was -.215. The p value was less than .05 level of significance which indicates that null hypothesis should be rejected that there is a significant difference between the rating of teachers and administrators. This was also seen in the overall means of the two groups of respondents, 3.35 rating of mathematics teachers and 3.79 rating of administrators. It was also noted that there was a difference of 0.44 on the average means of the two groups of respondents.

C. Significant relationship between the pedagogical content knowledge of mathematics teachers and students' achievement

Learning Competencies reached a significant value of .159

which indicates that there was a very low significant relationship. But then, the computed P-value for the Content Knowledge as predictor variable is .746 which denotes that there is a strong significant relationship to student's achievement level. Likewise, it was also found out that Teaching Approaches had strong significant relationship to student's achievement level with a calculated significant value of .877. The strong results of significant relationship of the last two predictors indicate that improvements on teacher's knowledge of content and teaching approaches may predict an increase on student's achievement level. In totality, the significant value computed was .409 which indicates that there was a moderate significant relationship between the Pedagogical Content Knowledge of teachers and student's achievement level.

6. Conclusion

From the findings, the following conclusions are drawn.

1. Only one school exceeded the 75% MPS standard of rating in the assessment given to Grade 10 students.
2. Pedagogical Content Knowledge of Mathematics teachers in terms of Learning Competencies are almost at high level. Only in Probability and Statistics that teachers still need improvement. In term of Content Knowledge, majority of the competencies were at high level but necessary to be enhanced. In terms of Teaching Approaches, teachers had a very satisfactory rating in the five pedagogical approaches.
3. There is no significant difference between the rating of teachers and administrators in PCK in terms of Learning Competencies and Content, however; there is a significant difference in terms of Teaching Approaches. Besides, the rating of administrators was higher than the rating of teachers. Perhaps, administrators were confident that teachers were well-informed on this approaches since these were mandated by the Department of Education.
4. There is a significant relationship on the PCK of Mathematics teachers and students achievement level. Pedagogical Content Knowledge has important contribution to effective teaching which means the higher teacher's pedagogical content knowledge; the higher student achievement level is expected. The teachers' Pedagogical Content Knowledge have an impact on student's learning.
5. Professional Development Program is needed to enhance teacher's PCK based on the result of the study.

7. Recommendations

1. Teachers should analyze the result of the assessment given to students for them to identify the least mastered skills of students. They should also provide necessary intervention to address the gap on basic knowledge of students that hinders their understanding of the lesson. In addition, constant practice of basic knowledge through Drills to help students master the competencies.
2. The Education Program Supervisor In-Charge of Mathematics should conduct trainings/ seminars/ workshop for teachers to improve their knowledge on content and pedagogy
3. School heads and other instructional leaders should provide technical assistance to teachers to improve their teaching performance and teaching practices. Intensive instructional supervision may give school heads the idea of the kind of assistance needed by teachers.
4. Assessment of teachers PCK can be done to identify the need-based priority area and include those needs in the next Professional Development Program for teachers.
5. Professional Development Program for Teachers should be done regularly to achieve the desire level of competency or mastery on the Pedagogical Content Knowledge.

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