PROFESSIONAL PROFILE AND PEDAGOGICAL CONTENT KNOWLEDGE OF GEOMETRY TEACHERS IN MATHEMATICAL PROOFS IN THE CONTEXT OF PUBLIC SECONDARY HIGH SCHOOLS

[1]Jessie C. Pasigna and [2]Miraluna L. Herrera

Abstract

The study was undertaken to determine the pedagogical content knowledge of secondary schools geometry teachers in mathematical proofs and the influence of their professional profile controlling learning environment. It utilized descriptive survey and descriptive correlational research designs. Analysis of the data revealed a significant moderate positive association between the pedagogical content knowledge (PCK) of the Geometry teachers in the public high schools and their professional profile in terms of the number of subjects taught or the diversity of subjects handled and number of years in teaching. Further, the learning environment in terms of class size and class interaction significantly influenced the association between the variables of the study.

Keywords: *professional profile, pedagogical content knowledge in mathematical proof, learning environment*

1.0 Introduction

Teachers' competence and proficiency in teaching the subject is indeed complex and is made of several aspects (Chick, Baker, Pham & Cheng, 2006). In fact, the Professional Teaching Standard mandates teachers to demonstrate excellence in their knowledge of the subject content and how to teach that content to students (NSWIT, 2007). They must effectively "design accurate explanations that are comprehensible and useful for students, and interpret and make pedagogical judgments about the students' questions, solutions, problems and insights both predictable and unusual" (Ball, Bass, and Hill 2004). The manner in which teachers relate their subject matter (what they know about what they teach) to their pedagogical knowledge (what they know about teaching) and how subject matter knowledge forms part in the process of pedagogical reasoning are seen as integrants of pedagogical content knowledge or PCK (Cochran, De Ruiter & King, 1993). In mathematics education literature, PCK has emerged as a critical component of teacher quality that is strongly linked to student achievement (Ngo, 2013). Thus, this study will look into some factors on the development of the PCK of high school teachers in relation to their professional experience and actual teaching condition.

Although pedagogical content knowledge (PCK) was not clearly defined in the beginning, the very notion of content-related knowledge for teaching caught the field's imagination and opened up significant new areas for both research and practice. PCK gained renewed emphasis through the works of Shulman (1986). Schoenfield (2005)

[1] Esperanza National High School
[2] Caraga State University

enumerated the types of knowledge that a competent and knowledgeable teacher must have; namely, content knowledge, pedagogical knowledge and curricula knowledge. In particular, an efficient and competent mathematics teacher is described as one having broad knowledge, equipped with multiple methods and deep understanding of the concepts of mathematics and also armed with the pedagogical knowledge (Schoenfield and Kilpatrick, 2008). According to the review of Kahan, Cooper and Bethea (2003), students would learn more mathematics if their teachers knew more mathematics. Nonetheless, content knowledge in the subject area does not suffice for good teaching. They also outlined that PCK is content-specific and at the same time goes beyond simple knowledge of mathematics, and a mathematician may not possess it (Kahan, Cooper and Bethea, 2003).

In the same vein, it is imperative that mathematics teachers better understand pedagogical moves that do support student justification. The National Council for Teacher of Mathematics (NCTM, 2000) emphasizes that reasoning and proof should be a standard activity in every classroom. Likewise, the Common Core State Standards for Mathematics (CCSSM, 2010) emphasizes justification as one of its key in mathematical practices. In Geometry, reasoning and proof is given more emphasis, not as an application to the concepts learned but as a main learning task.

Proof is a core idea in the discipline of mathematics, but an understanding of what proof is, how proving is carried out, and what a completed proof signifies has been shown to be lacking at all levels of education. Many national reports have called for increased and more coherent attention to proof across the K-12 curriculum (Ball & Bass, 2003; NCTM, 2000), and "constructing viable arguments" is one of the eight mathematical practices identified as standard in the CCSSM (2010). However, in practice little movement has been made toward consistently incorporating ideas about proving into the elementary grades and high school level. With little attention to proving, how one might come up with a proof, or what the significance of a proof is, elementary grades and high school level mathematics is not preparing students for their encounters with proof in later years.

Parallel to the aforementioned situation is the low performance of students in Geometry for the past three consecutive years in the National Achievement Test (NAT). Furthermore, results of item analysis of Geometry-NAT showed that the students' performance ranged from below mastery to nearing mastery only. This non-mastery of the competencies can be certainly overcome if proper intervention is implemented to improve teachers' competence in the teaching of Geometry. The main purpose of this study was to determine the teaching competence of secondary school geometry teachers in mathematical proofs. Specifically, this study sought to determine the teacher's professional profile, the quality of learning environment and the level of pedagogical content knowledge (PCK) in mathematical proof among high school teachers teaching Geometry. It further sought to determine the association between teachers' professional profile and level of competence in teaching mathematical proofs and this association when remain constant when teaching environment is controlled.

2.0 Theoretical/Conceptual Framework

This study is anchored on the Competency Framework for Teachers which was formulated by the Department of

Education and Training of Australia (DETA, 2004). The Department recognized that teachers are highly dedicated and strive to improve outcomes; hence their potentials should always be enhanced. The framework articulates competency standards for teachers which outline the varying degrees of effectiveness teachers demonstrate when applying their professional knowledge, skills and attributes to their specific teaching context. According to this framework, teachers must be life-long learners who engage in ongoing professional learning during the course of their teaching careers. This entails for the teachers to be able to be proficient both in content and pedagogical skills.

The framework thus spells out the means by which teachers become competent in content and pedagogy. Accordingly, teachers attain competence if they are able to: reflect on their professional effectiveness; determine and prioritize areas for professional growth; identify professional learning opportunities; and assist in their personal and career development plan.

In the same vein, Filipino teachers are required by the Department of Education (DepEd) to adhere to the National Competency-Based Teacher Standards (NCBTS). The NCBTS is an integrated theoretical framework that defines the different dimensions of effective teaching, where effective teaching means being able to help all types of students learn the different learning goals in the curriculum (NCBTS, 2006).

The NCBTS provides a single framework that defines effective teaching in all aspects of a teacher's professional life and in all phases of teacher development. These domains are: Social Regard for learning, Learning Environment, Diversity of Learners, Curriculum, Planning, Assessing and Reporting, Community Linkages, and Personal Growth and Professional Development. Using the NCBTS, the teacher can be aware of her strengths as a teacher and ensure that she becomes more consistent in demonstrating her strengths. At the same time, she can plan on professional development strategies so that she can improve on her weaknesses.

In the holistic view of teacher competence, the emphasis is more on process and outcomes of teaching rather than inputs, more on learning how to learn and apply knowledge than on the mere transmission of knowledge. In academic terms, the influence has moved from behavioral psychology to social constructivism, i.e. the idea that people construct understanding through interaction with others.

Based on the above frameworks on the development of teaching competence in an individual doing the practice, the conceptual framework (fig.1) provides more specific constructs and their relationship as employed in this study to address the problem aforementioned above. The teachers' professional profile, the independent variable of the study was looked into as strong inputs into PCK. The educational qualification provides the basic training for teaching the subject in school. This quality of pre-service education and training is a function of the type of institution from where these are obtained. Experience in teaching mathematics and particularly Geometry also hones the expertise of the teacher in teaching. Furthermore, exposure to training and related activities will introduce the teacher to innovations in the PCK.

Teachers' PCK, the dependent variables of the study is an important knowledge level of teachers (Shulman, 1986) and an important factor towards effective teaching (NCBTS, 2006; DETA, 2004). In this study,

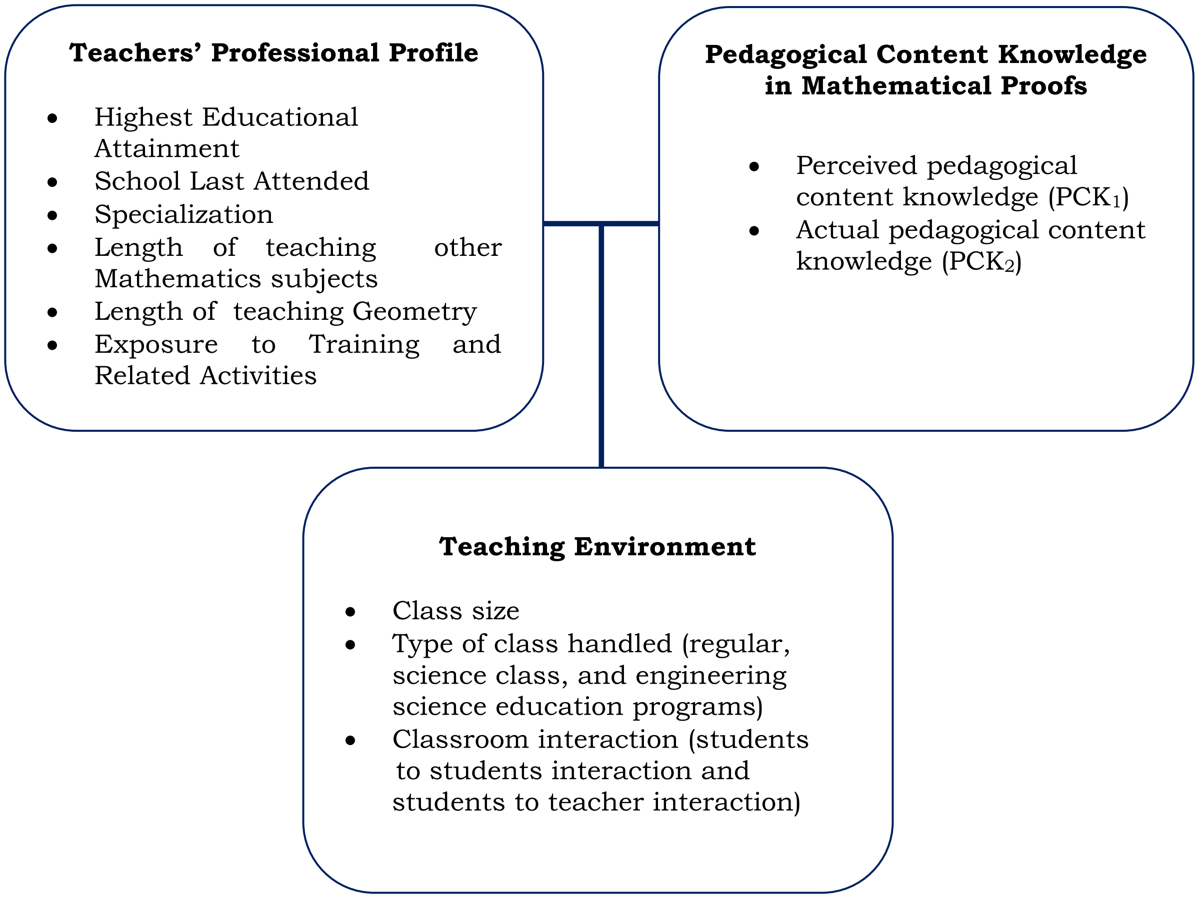

Figure 1. A schematic diagram showing relationship of the variables of the study

the teachers' PCK in mathematical proof is defined in terms of perceived pedagogical content knowledge (PCK_1) and actual pedagogical content knowledge (PCK_2). The PCK_1 includes belief and perception of the teacher on her knowledge in the teaching process of proof which is constructed and theorized by Mishra and Koehler (2006). On the other hand, PCK_2 refers to the methods and processes of teaching proof and reasoning as employed by the teacher in her/his class which includes knowledge in classroom management, assessment, lesson plan development, and student learning.

The study also investigated the nature of the learning environment that might have some bearing into the PCK of teachers in teaching mathematical proofs. It included possible effects of the class size (which are usually big) type of class handled and classroom interaction. These are realities which the teachers need to competently address (NCBTS, 2006).

3.0 Research Design and Methodology

This study utilized the descriptive research design using the survey technique. It is a descriptive and correlational research strategy because it sought to determine the levels of the teaching competence of secondary school teachers in mathematical proofs. Moreover, it also determined whether a significant association existed between the levels of competence in teaching mathematical proof and the teaching environment of teachers and their achievement on mathematical proofs in Geometry.

The study was conducted at Esperanza District I which included the following ten (10) public secondary high school: Esperanza National High School (ENHS), ENHS-Nato annex, ENHS-Salug annex, ENHS-Catmonom annex, ENHS-Santa Fe annex, ENHS-Hawilian annex, ENHS-San Toribio annex, Guadalupe National High School (GNHS), GHNS-Oro annex, and GNHS-Duangan annex, Esperanza, Agusan del Sur.

The study involved seventeen (17) mathematics teachers who were handled Geometry in the SY 2012-2013. This study used a universal purposive sampling in which all the mathematics teachers handling geometry were taken as respondents.

The study utilized a Survey Questionnaire comprised of the teacher's professional profile and his/her Geometry class profile for learning environment (part 1); the perceived content knowledge (part 2, section 1), as constructed and theorized by Mishra and Koehler (2006); the actual pedagogical content knowledge (part 2, section 2); student-student classroom interaction (part 3, section 1); and student-teacher classroom interaction (part 3, section 2). This instrument was subjected to content and logical validation by three teacher experts teaching Geometry in high school, college and graduate studies.

A letter requesting for permission to conduct the study in the District submitted to the District Supervisor for approval was accomplished prior to the actual conduct of the study. After the approval of the permission letter, a letter invitation was sent to each participating school for the focus group discussion (FGD). To ensure maximum participation, follow-ups were made for the confirmation of attendance to the FGD. In case of absence of participant teacher/s, a personal interview was conducted with the concerned teacher/s.

The data gathered were coded, summarized in spreadsheets and were treated according to the research questions and the nature of data obtained from the actual conduct of the study. The nominal data were interpreted using set of rubrics and analyzed using frequency distribution and mean as descriptive tools. An association between the independent and dependent variables and the confounding effect of learning environment were analyzed using Spearman rank correlation and partial correlation respectively using the Statistical Packages for Social Science (SPSS) software.

4.0 Results and Discussion

Table 1 shows the professional profile of the high school Geometry teachers in ENHS and its annexes. In particular, the majority of the high school teachers handling Geometry had earned units in master's degree (64.7%) or were currently enrolled in graduate programs offered in a university specializing in Mathematics (52.9%). Moreover, the majority (41.2%) of the teachers taught mathematics for five (5) years and above but with only one (1) training exposure in teaching mathematics. More precisely, majority (64.7%) of the teachers was mathematics majors but less than half of their teaching load was mathematics subjects in the sense that they were also handling other subject. Furthermore, the majority (52.9%) taught Geometry in less than three (3) years with no training in the teaching of the subject geometry.

The foregoing results show that despite substantial length of years in teaching the mathematics subjects, teachers were more loaded with teaching preparations other

Table 1. Teachers' professional profile

Indicators		Percentage
Highest Educational Attainment	Undergraduate	35.3
	With Masteral units	64.7
School last Attended	University not specializing in mathematics	47.1
	University specializing in mathematics	35.3
	University specializing in mathematics with accreditation/ COD/COE	17.7
Specialization	Math major without in-service training in teaching Geometry	64.7
	Major in allied courses with in-service training in teaching Geometry	11.8
	Math major with in-service training in teaching Geometry	23.5
Numbers of Years in Teaching any Mathematics Subjects	Less than 3 years	17.7
	At least 3 years in teaching but less than 5 years	23.5
	At least 5 years in teaching but less than 10 years	41.2
	More than 10 years	17.7
Number of Years in Teaching Geometry	Less than 3 years	52.9
	At least 3 years in teaching but less than 5 years	35.3
	At least 5 years in teaching but less than 10 years	11.8
Exposure to Training and Related Activities	1 training in teaching Math	100
Ratio of Math Subjects Handled	At least 15% subject taught but less than 30%	11.8
	At least 30% subject taught but less than 50%	41.2
	At least 50% subject taught but less than 70%	29.4
	At least 75% subject taught but less than 100%	17.7

than mathematics subject and very limited in-service training in teaching mathematics. With less experience and training in the teaching of Geometry, the teachers were experiencing difficulties in teaching mathematical proof in particular.

Figure 2 reveals that the majority (82.4%) of the teachers perceived that they had mastered content knowledge in the teaching process in Geometry. This is readily seen in the high percent rates of the indicators. Most precisely, this mastered competence level is indicated by a very high response rate in agreeing that they were knowledgeable enough in terms of teaching lessons appropriate to the students capacity and knowing how to select effective teaching approaches to guide student thinking and learning in Geometry. Another prevalent strengths as perceived by the teachers were their pedagogical content knowledge in using critical thinking in relating mathematics to real life situation and adapting teaching on what students understand or not understand (94.1%).

On the other hand, relatively low response rates (64.7%) were obtained in teachers' pedagogical content knowledge in employing various ways and strategies of developing students' understanding in geometry and sufficient knowledge about mathematical proof in geometry. The foregoing results reveal that teachers do not posses enough confidence about their knowledge to be able to impart mathematical proof to their students.

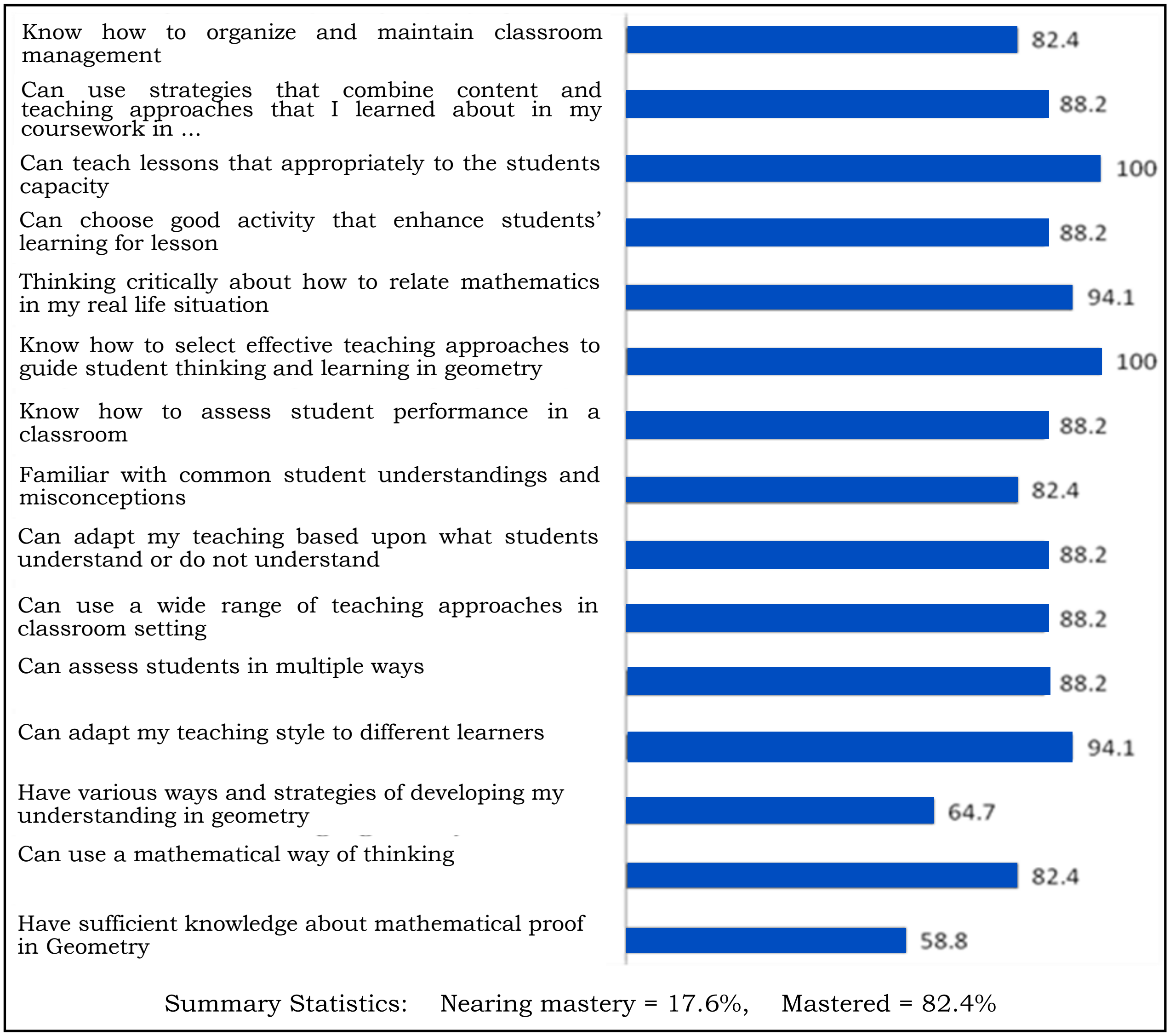

Figure 2. Perceived Pedagogical Content Knowledge (PCK_1) of high school teachers on mathematical proofs in geometry

Figure 3 on the other hand, shows the actual pedagogical content knowledge (PCK) of the secondary geometry teachers of Esperanza National High School and its annexes. Overall result shows that the teachers had a nearing mastery level (76.5%) of competence in terms of PCK_2. This can be explained by a majority (94.1%) identifying only less than 15% of the topics as least learned.

Further, analysis shows actual pedagogical content knowledge PCK_2 the actual PCK of ENHS teachers including its annexes. In particular, the majority of the teacher respondents had less than 15% of topic identified (94.1%) in proportion of least learned competencies. On the other hand, during the Focus Group Discussion (FDG) a majority of the teacher respondents (64.7%) identified only one topic to be difficult which rated very poor response. Teachers found that the construction of proof is difficult in part such as in identifying the correct assumption (64.7%) and determining

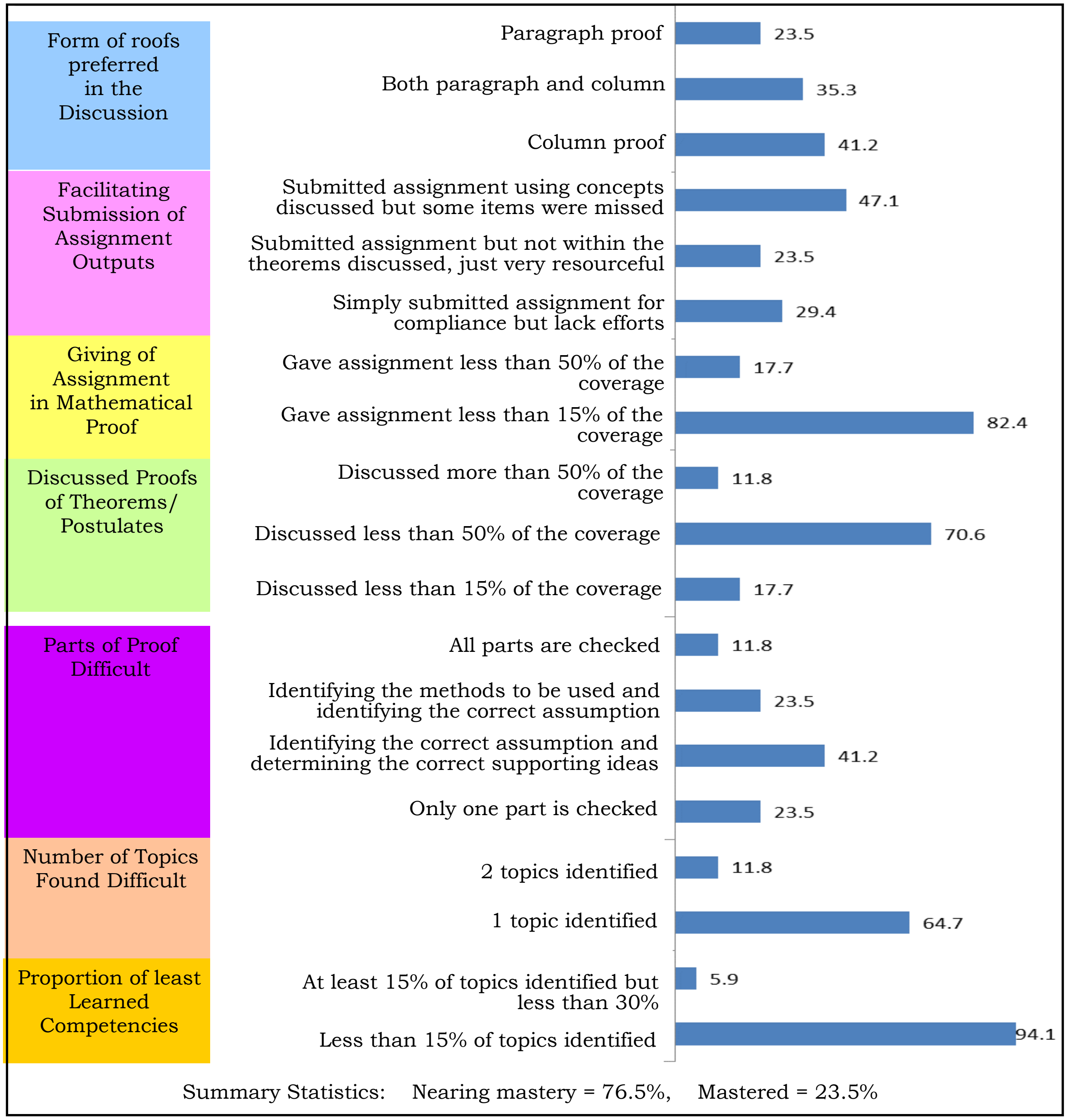

Figure 3. Actual Pedagogical Content Knowledge (PCK_2) of high school teachers on mathematical proofs in Geometry

the correct supporting ideas rated (41.2%). The figure also shows that the teachers were not able to discuss more than 50% of the coverage on proofs of theorems postulates and corollaries with the rating (70.6%). In terms of giving the assignments to students, a majority (82.4%) of the teachers had only given less than 15% of the coverage as assignments. It was also revealed by 29.5% of the teacher respondents that the students just submitted the assignments for compliance . This meant that the purpose of the assignment was forfeited because the assignment was not tackled well in class.

Moreover, this nearing mastery for actual pedagogical content knowledge (PCK_2) may be attributed to fact that the majority of the teachers were not able to discuss more than 50% of the coverage on proofs of theorems, postulates and corollaries (70.6%) but were able only to give less than 15% of the coverage of mathematical proofs as assignment to students (82.4%). Further, data reveal that teachers failed to facilitate students' submission of assignment because students did it only for compliance. A majority of the teachers (76.5%) admitted to have failed to give more efforts or missed to tackle some postulates/theorems/corollaries in class.

Figures 4 and 5 show the result in terms of teaching environment. In terms of class size it is clearly shown that the majority of the teachers have large class size (52.9%). The small class size were those classes in the school's annexes, in engineering special education program (ESEP) and the science class section. It is also shown that majority of the class handled by the respondents are regular class 88.2%).

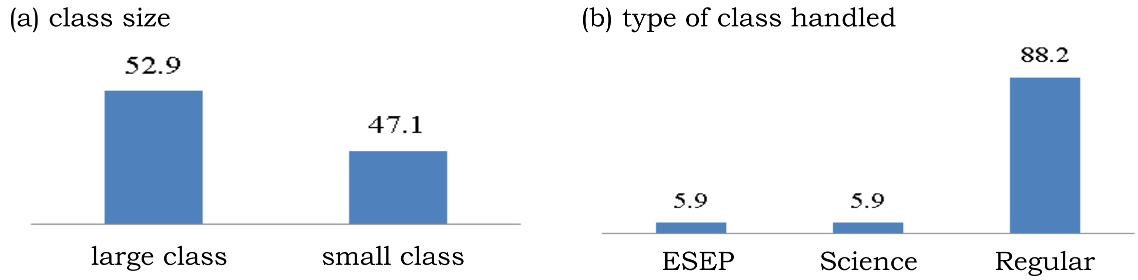

Figure 4. Learning environment of high school Geometry class in terms of (a) class and (b) type of class handled

Data in fig. 5a show that there is a maximum manifestation (100%) of student-student classroom interaction in terms of participation in board work; but relatively low (64.7%) in exhibiting enthusiasm to discuss with group mates in the Geometry class and providing help to their classmate in accomplishing tasks. Responses indicating that the class agreed to all other indicators suggest that the students had maintained good relationship with each other in their Geometry class.

The data on students-teacher classroom interaction (fig.5b) disclose that all of the respondents (100%) agreed that the teachers asked questions that motivate students to participate discussion; answered question from students that will encourage them to ask more; and calling the students at random during class recitation. Responses to all other indicators indicate that there is a good rapport between the students and the teachers in the Geometry class.

Analysis shows a significant moderate positive association between the number of subjects taught and the PCK at 10% level of significance. More precisely, a significant moderate positive association between the actual pedagogical content knowledge and the number of years in teaching any mathematics subjects at 5% level of significance and the number of subjects taught at 10% level of significance. The diverse exposure of a mathematics teacher to different learning areas or disciplines through a substantial period of time enhances his/her PCK. This may be accounted to the fact that some subject

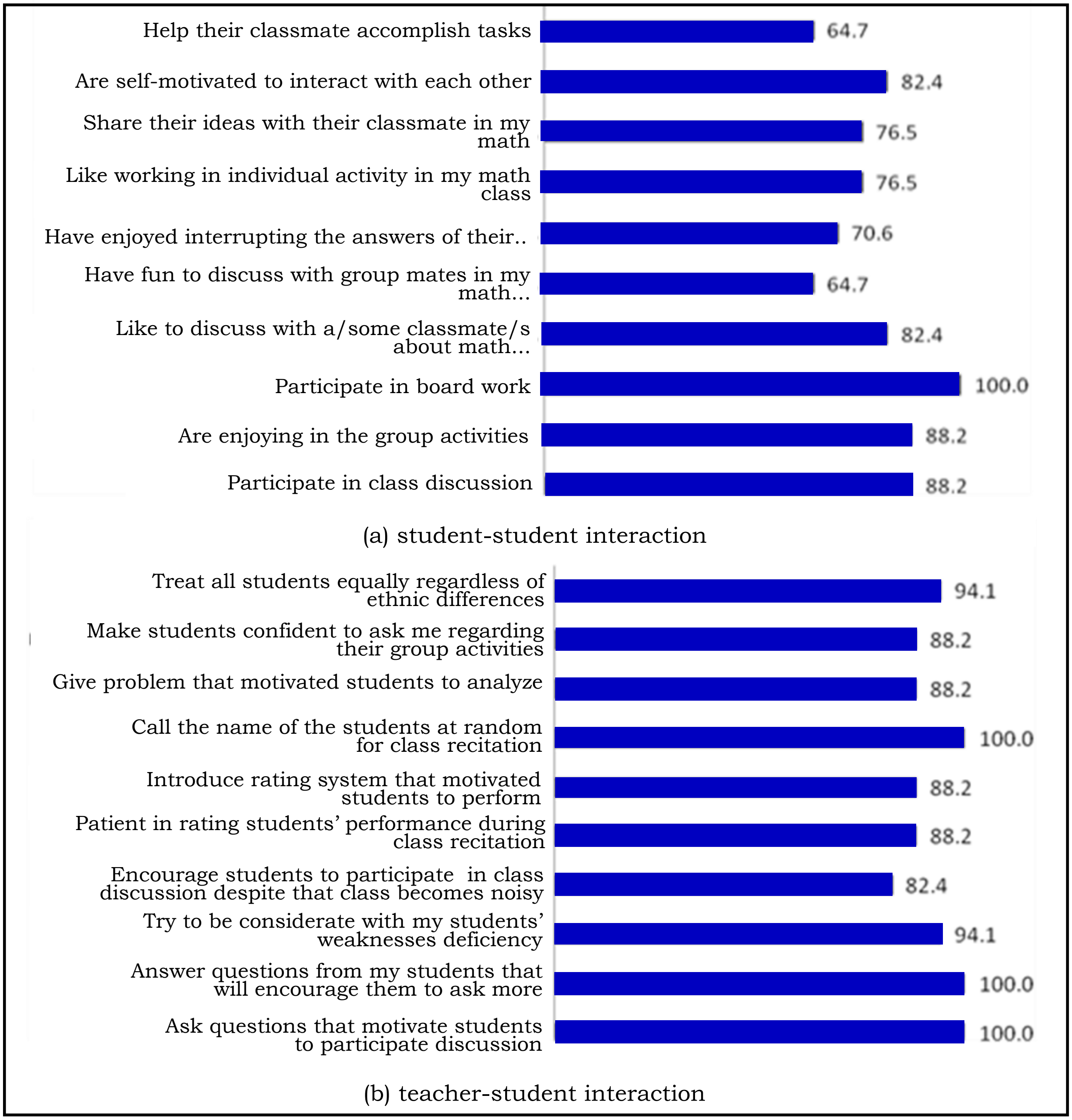

Figure 5. Learning Environment of high school geometry class in terms of classroom interaction

areas have a combination of learning competencies designed to be interpreted by teachers and implemented with variations. Moreover, learning competencies do not present teaching methods and learning activities that teachers must follow but to stimulate the creativity of teachers by the option to plan and use the appropriate teaching/learning activities independently.

Moreover, a significant moderate positive association exists between perceived content knowledge and the educational attainment of the teachers at 10% level of significance. Data revealed higher PCK among teachers with higher educational qualification or those who has earned higher degree in the

Table 2. Correlation coefficients of professional profile and pedagogical content knowledge in mathematical proof

Professional Profile	PCK_1	PCK_2	PCK_{total}
Educational Attainment	0.491[b]	-0.346	0.115
Specialization	-0.155	0.283	0.204
School last Attended	0.223	-0.132	0.138
No. of Years in Teaching	-0.254	0.551[a]	0.339
No. of Years in Teaching Math	-0.309	0.369	0.188
No. of Subjects Taught	0.204	0.440[b]	0.584[a]

PCK_1 = score in the structured PCK questionnaire; PCK_2 = score in the unstructured PCK questionnaire; PCK_{total} = PCK_1 + PCK_2; PCK is the pedagogical content knowledge. Superscripts *a* & *b* to the correlation coefficients that are significant at 5% and 10%, respectively.

Table 3. Association between professional profile and pedagogical content knowledge in mathematical proof when learning environment variables are controlled

Professional Profile	Learning Environment	PCK_1	PCK_2	PCK_{total}
Educational Attainment	Controlling: Class Size	0.438[b]	-0.346	0.097
	Class Size & interaction	0.274	-0.276	0.011
	Class interaction	0.244	-0.209	0.024
Specialization	Controlling: Class Size	-0.114	-0.116	-0.009
	Class Size & interaction	-0.174	0.145	-0.026
	Class interaction	-0.261	0.334	0.049
School last Attended	Controlling: Class Size	0.028	-0.01	0.014
	Class Size & interaction	0.012	0.00	0.008
	Class interaction	0.129	-0.223	-0.064
No. of Years in Teaching	Controlling: Class Size	-0.096	0.427[b]	0.202
	Class Size & interaction	0.126	0.377	0.32
	Class interaction	-0.01	0.507[a]	0.338
No. of Years in Teaching Math	Controlling: Class Size	-0.187	0.17	-0.027
	Class Size & interaction	0.033	0.065	0.063
	Class interaction	-0.048	0.201	0.105
No. of Subjects Taught	Controlling: Class Size	0.404[b]	0.454[b]	0.579[a]
	Class Size & interaction	0.449[b]	0.460[b]	0.589[a]
	Class interaction	0.452[b]	0.393[b]	0.575[a]

field. The educational qualification provides the basic training for teaching the subject in school. When competence profiles work well they can be a highly effective tool for talking about and evaluating the quality of teachers and guiding their professional development. Competence profiles can and should allow for a gradation of competences to match different stages in a teacher's career, and can be linked to levels of qualification. This can be especially helpful for improving the professional quality of less qualified teachers working in difficult contexts. Schoenfield and Kilpatrick (2008) has described the qualities of an efficient and competent mathematics teacher as having broad knowledge, equipped with multiple methods and deep understanding of the concepts of mathematics and also armed with the pedagogical knowledge. This can only be attained through professional upgrading or pursuing advanced studies.

Table 3 shows an increase in the effect size resulted in the association between teachers' number of subjects taught and level of perceived PCK when learning environment was controlled. Foregoing result implies a negative effect of class size on the influence of a teacher's diverse on the enhancement of his/her perceived PCK. A large class size is a negative factor of an effective teaching, distracting the creativity of teaching the subject. In addition, when class size and class interaction were both controlled, a decrease in the effect sizes in the association between the number of years in teaching Geometry and the actual PCK. This implies that class size and interaction, jointly, have a positive effect on the influence of teacher's teaching experience on the development of his/her actual PCK. When classroom interaction in large class weakens, the influence of the teaching experience on a teacher's PCK consequently decreases.

5.0 Conclusions

The mathematics teachers of ENHS and its annexes have the qualifications to teach Geometry but have to enhance their competence in the teaching of the subject considering the benefits that teachers, students and the schools will derive from improved student performance.

The teaching environment in ENHS and its annexes are typical of the usual scenario in many public secondary schools where teachers handle large classes; have more than one preparation; and are hardly able to find time to hone their potentials. Despite these conditions, the teachers are still able to maintain a good classroom environment.

The nearing mastery level in the teaching mathematical proofs is indicative of a wanting condition that needs to be addressed if ENHS and its annexes aim to keep abreast with teacher standards. More precisely, the high school teachers of ENHS and its annexes teaching Geometry need appropriate tools to compensate for their inadequate pre-service training and in-service practices in order for them to bring out their latent skills in teaching proof and reasoning. Their native creativity with awareness of their inadequacy in teaching mathematical proof can be utilized as a driving force for them to be responsive with the tools designed to improve their competence in teaching mathematical proof.

The teachers' competence of teaching mathematical proof is determined by experience and exposure. Their competence in the teaching process or pedagogical content knowledge (PCK) of proof and reasoning is directly determined by both amount of time and venues in which she/he develops her/his framework or strategies in ushering students to understanding and appreciating the concept of proof and reasoning. Moreover, the dimension of the learning environment facilitates this process of developing a teacher's PCK; that is, more effective PCK is exhibited in a large class.

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