Academic Article

USING PRINCIPAL COMPONENT REGRESSION ANALYSIS TO EXPLORE PROFESSIONAL COMPETENCE OF MATHEMATICS TEACHERS

Received: May 12, 2022 **Revised:** June 22, 2022 **Accepted:** July 18, 2022

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Abstract

Professional competence of secondary mathematics teachers is measured in terms of cognitive abilities and affective-motivational characteristics. There are many items which attribute to cognitive abilities and affective-motivational characteristics of teachers. Thus, this study wanted to reduce these items into components using principal component analysis. From the extracted components, develop a model using principal component regression. This study employed multi-stage cluster sampling where secondary mathematics teachers are clustered according to the municipal level, division, and school. Simple random sampling was used to determine clusters. Results showed that the kaiser-meyer-olkin yield good result and bartlett's test for sphericity are significant, which implied that it already suits to test for principal component analysis. Findings showed that there were 27 extracted components and from these components have component loadings less than 0.300; thus, they need to be eliminated. The components with component loadings greater than 0.300 are used in principal component regression. The model generated yielded two insignificant regressors.

Keywords: Professional competence, Principal Component Regression Analysis, Mathematics, Kaiser-Meyer-Olkin, Bartlett's Test

Introduction

Professional competence is the ability and proficiency of a teacher utilize in teaching and learning through mastery of the subject taught, choosing appropriate pedagogy, professional education, and motivation to improve oneself. Teachers have a crucial role in classroom management; they nurture students through mentoring and coaching, set the classroom to build an environment conducive for learning, control, and teach students the knowledge. Many extensive types of research are focused on teachers' professional knowledge, more particularly the study of Baumert and Kunter (2013), which conceptualized mathematical knowledge for teaching developed in terms of content knowledge (CK) and pedagogical content knowledge (PCK). The k-12 basic education program of the Department of Education (DepEd) shifts from teacher-centered instruction to student-centered instruction. The program uses

the spiral progression approach, a form of the curriculum where learners are exposed to an extensive variety of concepts/topics, skills, and character formation that are considered a continual concern of every learner until they are mastered. In this approach, the scope and sequence of the content are carefully developed from one grade level to the next grade level, and the concepts/skills are revisited at each grade level to the next grade level. The program centered on exposition, practical work, discussion, problem-solving investigation, cooperative learning, and Information Communication Technology (ICT) is integrated with the instruction. Quality education in mathematics is simply the sum of having strong national government support, a good curriculum, well-trained teachers, and private organization support (Department of Science and Technology, 2011). The Philippine Educational System places a premium on holistic growth through the transformation of knowledge and the development of skills, values, and attitudes. In the Philippines, the education policy directions seem to define competencies and skills as non-cognitive talents. Thus, this study aims to model the professional competence of secondary mathematics teachers.

Successful teaching depends on teachers' professional knowledge and his/her values, professional beliefs, and self-regulation (Blomeke et al., 2012; Blömeke & Delaney, 2012). A framework on the professional competence of mathematics teachers was developed focusing on the cognitive abilities of the teachers or the teachers' knowledge and skills to effectively teach mathematics and the professional beliefs of the teachers in the affective-motivational aspects, which is considered to be the most important attribute in the success of teaching (Ball et al., 2008; Blomeke et al., 2012). Southeast Asian Ministers of Education Organization (2010) have identified general area competencies of Southeast Asian teachers in the 21st century. These competencies include facilitating the progress of the life and career skills of the learners, create an environment contributing to student learning, which facilitates learning, prepare lesson plan suits to the vision and mission of the school, and develop higher-order thinking skills (HOTS) and utilize teaching and learning resources. It also contains enhancement of ethical and moral values and assessing and evaluating the performance of the learners. Lastly, it involves engagement in professional development, networking with stakeholders, and managing students' welfare and other tasks.

The teachers' pedagogical content knowledge, capacities, and professional beliefs, self-regulation or his/her skills values as well as their interpersonal skills, and motivation about work are aspects of the teachers' professional competence (Sengottuvel & Aktharsha, 2015; Kunter et al., 2013). There are 79 items known as aspects of cognitive abilities in this study, while 68 items are known as aspects of affective-motivational characteristics. These aspects are reduced into components using principal component analysis. This study evaluates the influence of the identified components of cognitive abilities and affective-motivational characteristics in predicting the professional competence of the teachers. Using these principal components generated, regression analysis is employed to develop a model for predicting the professional competence of the teachers.

Conceptual Framework

This study enhances the teachers' professional competence model of Döhrmann et al. (2012). According to Dohrmann et al. (2012), teachers' competencies depend on their professional knowledge and professional beliefs, motivation, and self-regulation.

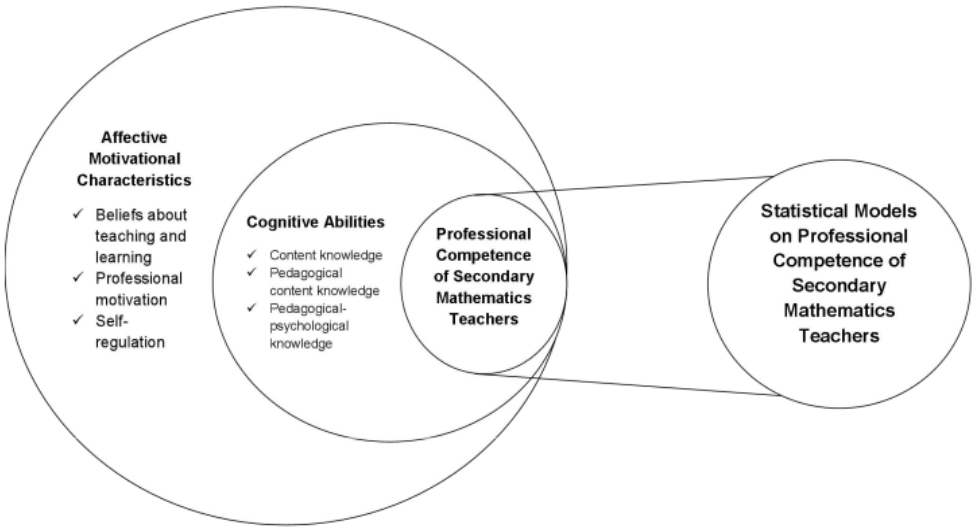


Figure 1 Conceptual Framework

The researcher prefers to consider the development of teachers' professional competence as layered circles leading to the development of statistical models of professional competence of secondary mathematics teachers. The innermost layer or the foundation of the layered circles is the teachers' professional competence developed through the teachers' cognitive abilities (professional knowledge) and the affective, motivational characteristics in the outer two-layer circles. The elements of the layers are descriptors of the major focal points of knowledge, thinking, skills, and character that aim to develop teachers' competence.

In the present model, the layering of circles is used in the framework showing various elements in the outer two layers and the teachers' professional competence in the innermost layer, which serves as the foundation of the layered circles. One of the elements in cognitive abilities will be changed from general pedagogical knowledge (GPK) of Dorhmann et al. (2012) to pedagogical-psychological knowledge (PPK) of Baumert and Kunter (2013) model. The gathered data on teachers' professional competence of secondary mathematics teachers were used in developing statistical models.

Teachers' professional competence is developed in terms of cognitive skills (professional skills/ knowledge skills) and affective, motivational characteristics (Dorhmann et al., 2012; Epstein & Hundert, 2002; Kane, 1992; Weinert, 2001; Blömeke & Delaney, 2012; Baumert & Kunter, 2013), professional values, beliefs and goals (Baumert & Kunter, 2013).

The notion of mathematical knowledge for teaching is categorized into content knowledge (CK) and Pedagogical knowledge (PCK) (Baumert & Kunter, 2013; Ball et al., 2008; Ball et al., 2001; Hill et al., 2008; Shulman, 1987), pedagogical-psychological knowledge (Baumert & Kunter, 2013), curricular knowledge (Shulman, 1987), and general pedagogical knowledge (Shulman, 1987). Ball et al. (2008); Ball et al. (2001); and Hill et al. (2008) further classified content knowledge into common content knowledge, specialized content knowledge, and horizon content knowledge, while pedagogical content knowledge is categorized into the knowledge of content and students, knowledge of content and teaching, and knowledge of content and curriculum.

Objective

This study evaluates the influence of the identified components of cognitive abilities and affective-motivational characteristics in predicting the professional competence of the teachers.

Research Questions

1. What is the suitability of the data for reduction?
2. What are the principal components extracted from the data?
3. What is the value estimate of a response variable at the basis of selected principal components of the explanatory variables?

Methodology

This study employed a cross-sectional survey design. The researcher chose the cross-sectional survey design because it suits the purposes of the study. The survey research is a design in which a group of people/items of interest is studied by collecting and analyzing sample data representing the entire population.

Research Subject

The subjects of this study are the secondary mathematics teachers of public schools, and the target population includes secondary mathematics teachers in all public national high schools in the Philippines.

Sampling Technique

This study employed a cluster sampling procedure for selecting the respondents in this study. It was employed to reduce the amount of geographic dispersion of the sample. Sampling was employed in a particular multi-stage cluster since a large population is divided into clusters to make the sampling process more practical—a technique used as a combination of simple random sampling and cluster sampling. There were three groups in the sampling, i.e., municipal classification of settlement comprising 40 municipalities with 105 national high schools, city classification of the settlement consisting of two cities with 19 national high schools, and a highly urbanized city classification of settlement with seven national high schools.

Cluster sampling was applied in each group for the selection of sample respondents. All mathematics teachers in the selected national high school were the subjects of the study.

Research Instrument

In this study, an instrument is a tool designed to measure secondary mathematics teachers' professional competence. The instrument asked how the respondents perceived the competence of math teachers. The study's research instrument is an enhanced instrument used by other researchers and indicators were identified based from literature reviews. The instrument composed of two parts; part I measured the cognitive competency of the respondents and part II measured the affective-motivation characteristics. Cognitive competency consists of 80 indicators as well as the affective-motivational characteristics with 80 indicators. The research instrument's reliability and validity were done in this study since the researcher originally constructs the research questionnaire. The Cronbach alpha of the instrument of this study is greater than 0.70, which is the minimum assumption that has to meet before using the instrument. Therefore, there should be no item to delete from the survey questionnaire. Cronbach alpha values beyond 0.70 were considered satisfactory for inclusion (Bland & Altman, 1997).

Data Analysis

The Kaiser-Meyer-Olkin (KMO), which measures for each variable, and Bartlett's Test of Sphericity to test the suitability of the data for reduction were measured in this study to test the assumptions of Principal Component Analysis. Once the assumptions are met, proceed with the analysis of principal components. Principal component analysis is tested to extract components from many items attributed to teachers' competence, and the extracted principal components are used for principal component regression analysis. The extracted components depict items from the instruments which attribute to teachers' competence. The principal component regression generates a model which regresses the principal components.

Results and Discussions

The discussion below is the results of the analysis using the principal component. The Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity were tested to test principal component analysis and communalities' assumptions. Then principal component analysis was done to extract principal components from the items. Lastly, regressions were done using the components as regressors.

KMO and Bartlett's Test of Sphericity

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.780, above the commonly recommended value of 0.600. According to Glen (2016), the rule of thumb for KMO states that KMO values less than 0.600 indicate the sampling is not adequate. At the same time, Bartlett's test of sphericity (a test that the correlation matrix has an identity matrix) was also significant (χ^2 (10731) = 31035.106, $p < 0.01$). The communalities were all above 0.300, further confirming that each item shared some common variance

with other items. Given all these indicators, principal component analysis was suitable for all the items/questions.

Extracted Components

The total number of items/questions which attribute to teachers' professional competence were 147 items. These items are aspects of both cognitive abilities and affective-motivational characteristics of teachers. There are 27 extracted components from 147 items/questions, but it was down to 13 components since the 14 components had components loadings of less than 3. The rule of thumb for component loading depends on the choice of the researcher. According to Rahn (n.d.), at least a |0.40| is considered important, but those researchers relax the criteria they consider at least |0.20|. The researcher chose to have at least |0.30| components loading as important components in this study.

Among 147 items, items 64, 65, 66, 109, and 121 are highly associated with a principal component (PC) 1 with component loadings 0.734, 0.719, 0.733, 0.721, and 0.726, respectively. For item 64, 53.88% of its variance is explained by component 1. In item 65, 66, 109 and 121 with 51.70%, 53.73%, 51.98%, and 52.71%, respectively, its variance is explained by principal component 1. Further, items 92, 107, 109, 127), and 141 are moderately associated with principal component 2 with component loadings 0.5000, 0.479, 0.494, 0.484, and 0.463, respectively. About 25% of its Variance for item 92, 22.94% of its Variance for item 107, 24.40% of its Variance for item 109, 23.43% of its Variance for item 127, 21.44% of its Variance for item 141 is explained by component 2. Items 2, 7, 13, and 136 are associated with principal component 3 with component loadings 0.362, 0.388, 0.411, and 0.383, respectively. About 13.10% of its Variance for item 2, 15.05% of its Variance for item 7, 16.89% of its Variance for item 13, and 14.67% of its Variance for item 136 are explained in component 3.

Moreover, items 96, 99, and 146 are associated with component 4 with component loadings 0.552, 0.426, and 0.462, respectively. About 30.47% of its Variance for item 96, 18.15% of its Variance for item 99, and 21.34% of its Variance for item 146 are explained by component 4. Items 18, 68, and 92 are associated with principal component 5 with component loadings -0.308, 0.311, and 0.320, respectively. About 9.49% of its Variance for item 18, 9.67% of its Variance for item 68, and 10.24% of its Variance for item 92 are explained by component 5. However, item 8 is uncorrelated with component 5. Items 96, 99, and 101 are associated with component 6 with component loadings 0.415, 0.474, and 0.512, respectively. About 17.22% of its Variance for item 96, 22.47% of its Variance for item 99, and 26.21% of its Variance for item 101 are explained by component 6. Items 32, 36, and 50 are associated with component 7 with component loadings 0.446, 0.474, and 0.478, respectively. About 19.89% of its Variance for item 32, 22.47% of its Variance for item 36, and 22.85% of its Variance for item 50 are explained by component 7. Items 24 and are associated with component 8 with component loadings 0.355 and 0.332, respectively. About 12.60% of its Variance for item 24 and 11.02% of its Variance for item 99 is explained by component 8. Items 23, 103, and 122 are associated with component 9 with component loadings 0.343, 0.322, and 0.382, respectively. About 11.76% of its Variance for item 23, 10.37% of its Variance for item 103, and 14.59% of

its Variance for item 122 are explained by component 9. However, items 23 and 122 are inversely associated with component 9.

In addition, items 100 and 141 are associated with component 11 with component loadings 0.358 and -0.330, respectively. About 12.82% of its Variance for item 100 and 10.89% of its Variance for item 141 is explained by component 11. Item 4 is associated with component 12 with component loading -0.340, which means it is uncorrelated with the component. For this item, 11.56% of its Variance is explained by component 12. Item 97 is associated with component 14, with component loading 0.336. For this item, 11.29% of its Variance is explained by component 14. Item 12 is associated with component 16, with component loading 0.359. For this item, 12.89% of its Variance is explained by component 16.

All items associated with components 10, 13, 15, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, and components 27 have component loadings less than 0.3, which are not good loadings. They were all eliminated because they do not meet the minimum criteria of having a component loading of at least 0.3. Thus from 27 extracted components, only 13 components were retained for the regression analysis of principal components. Moreover, component 16 has an attribute to teachers' competence which belongs to content knowledge. Components 3, 5, 7, and 12 have attributes to teachers' competence which belong to pedagogical content knowledge (See Table 1).

Components 1 and 2 have attributes to teachers' competence which belong to pedagogical-psychological knowledge. Components 4 and 11 have attributes to teachers' competence which belong to beliefs about teaching and learning. Component 9 has an attribute to teachers' competence which belongs to professional motivation. While components 6, 8, and 14 have attributes to teachers' competence which belong to self-regulation. The content knowledge, pedagogical content knowledge, and pedagogical-psychological knowledge are elements of cognitive abilities, while beliefs about teaching and learning, professional motivation, and self-regulation are elements of affective-motivational characteristics.

Table 1 Principal Components According to Teachers' Professional Competence

Principal Components	Elements on Teachers' Competence
PC 1	Pedagogical-Psychological Knowledge
☐ Uses different types of evaluation techniques.	
☐ Identifies learning difficulties of pupils.	
☐ Adopts appropriate remedial measures.	
☐ The training as a teacher made him/her more focused.	
☐ Calls students by name.	

Principal Components	Elements on Teachers' Competence
PC 2	Pedagogical-Psychological Knowledge
☐ The training as a teacher made him/her more focused.	
☐ Do react impulsively to situations.	
☐ Adjusts to new thinking.	
☐ Shows relevance of geosciences to their everyday lives.	
☐ Increases the difficulty of the material as the semester progresses.	
PC 3	Pedagogical Content Knowledge
☐ Writes educational objectives in behavioral and procedural way which could be measured and observed.	
☐ Identifies ways and methods of teaching.	
☐ Integrates and analyze relations between variables.	
☐ Strengthens students' self-motivation.	
PC 4	Beliefs about Teaching and Learning
☐ Keeps his/her judgments within the limits of my competence.	
☐ Have positive expectations of people.	
☐ Gives students feedback as quickly as possible.	
PC 5	Pedagogical Content Knowledge
☐ Provides scientific information that allows me to gain a better a deeper understanding of the subject matter	
☐ Attempts to keep students alert and enthusiastic are fruitful.	
☐ Do react impulsively to situations.	
PC 6	Self-Regulation
☐ Keeps his/her judgments within the limits of my competence.	
☐ Have positive expectations of people.	
☐ Do things at the expected/appropriate time.	
PC 7	Pedagogical Content Knowledge
☐ Innovates technological and educational aids and use them in self-learning.	
☐ Easily accessible (tutorials, e-mails, etc.).	
☐ Incorporates and employs ICTs (Information and Communication Technologies).	

Principal Components	Elements on Teachers' Competence
PC 8 Have positive expectations of people. Takes into account not to mention more than one learning point of at the same time.	Self-Regulation
PC 9 Draws students attention using verbal and non-verbal language. Possesses the ability to teach. Uses humor	Professional Motivation
PC 11 Leaves things wherever. Increases the difficulty of the material as the semester progresses.	Beliefs about Teaching and Learning
PC 12 Distinguishes between objectives areas and levels (cognitive - psychomotor - emotional).	Pedagogical Content Knowledge
PC 14 Gets angry when people make jokes about me.	Self-Regulation
PC 16 Depends on access to information and modern concepts, which are linked to modern scientific sources and references.	Content Knowledge

Principal Component Regression Analysis

The model using ordinary least square takes all variables/items as its independent variables and the model is

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots + \beta_n x_n \quad (1)$$

In this study, if ordinary least squares are applied, all variables or items are considered the predictors or independent variables. Since this study used principal component analysis from 147 items/variables, it reduces to 27 extracted principal components. However, some extracted components are less than 0.300, which are not good loadings; it only retains 13 components. The model that will generate from principal component regression is

$$y = \beta_0^{'} + \beta_1^{'} Z_1^{'} + \beta_2^{'} Z_2^{'} + \beta_3^{'} Z_3^{'} + \ldots + \beta_{13}^{'} Z_{13}^{'} \quad (2)$$

The predictors or variables in the principal component regression are the extracted components with component loadings greater than 0.300. The predictor *Z1* refers to PC 1, *Z2* refers to PC 2, *Z3* refers to PC 3, *Z4* refers to PC 4, *Z5* refers to PC 5, *Z6* refers to PC 6, *Z7* refers to PC 7, *Z8* refers to PC 8, *Z9* refers to PC 9, *Z10* refers to PC 11, *Z11* refers to PC 12, *Z12* refers to PC 14, and *Z13* refers to PC 16.

The regression analysis of the principal components is significant *(F (13,23.81), p<0.001)*. There are 11 components which are significant regressors to principal components. These components are PC 1, PC 2, PC 3, PC 4, PC 5, PC 7, PC 8, PC 9, PC 11, PC 12, and PC 16 *(p < 0.05)* while the components PC 6 and PC 14 *(p > 0.05)* are not significant regressors (See Table 2).

Table 2 Regression Analysis on Extracted Principal Components

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	.053	.010		5.525	.000
Z1	-.048	.016	-.227	-3.104	.002
Z2	.035	.003	.517	10.796	.000
Z3	.023	.006	.187	3.618	.000
Z4	.016	.007	.124	2.234	.027
Z5	.024	.008	.163	3.264	.001
Z6	.011	.009	.068	1.217	.226
Z7	.024	.008	.150	3.037	.003
Z8	.032	.008	.188	3.923	.000
Z9	.036	.009	.198	4.155	.000
Z10	.032	.009	.167	3.501	.001
Z11	.028	.010	.141	2.932	.004
Z12	.018	.010	.089	1.766	.080
Z13	.021	.011	.099	1.998	.048

The principal component regression model is written below:

$$y = 0.53 - 0.048Z_1 + .035Z_2 + 0.023Z_3 + 0.016Z_4 + 0.008Z_5 + 0.011Z_6 + 0.024Z_7 + 0.036Z_9 + 0.032Z_{10} + 0.028Z_{11} + 0.018Z_{12} + 0.021Z_{13} \quad (3)$$

The model explains that *Z1* (PC 1) has an inverse relation with the principal components, and it has the greatest contribution to the model since it has the largest numerical coefficient *($\beta 1 = -0.048$)*. However, the rest of the regressors have a direct relation with the principal components. The regressors *Z2* (PC 2) and *Z9* (PC 9) are next to *Z1,* having a greater contribution to the principal component regression model since they have larger numerical coefficients *($\beta 2 = 0.035$, $\beta 9 = 0.036$)*. The regressor *Z5* (PC 5) has the least contribution to the model since it has the lowest numerical coefficient *($\beta 5 = 0.008$).*

Conclusion

This study suits principal component analysis since the KMO and Bartlett's test for sphericity met the assumptions of PCA. From 147 items/questions which attribute to the teachers' professional competence, there were 27 extracted principal components. However, 14 of 27 extracted components have component loadings less than 0.300. Thus, only 13 components were subjects to principal component regression. The model generated from principal component regression yielded two regressors that are not significant to principal components.

Recommendation

Based on the analysis of the findings, this study suggests increasing the study subjects and the respondents. Then, apply the direct oblimin method for its rotation. This study also suggests doing factor analysis to measure the model of latent variables.

Acknowledgement

The author wishes to thank the almighty God for the wisdom and strength to finish this paper, her family for the support and to her employer, Palompon Institute of Technology Tabango, for allowing her to conduct this research.

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