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ANALYSIS OF PATH MODEL EFFECT OF BELIEFS ABOUT THE NATURE OF MATHEMATICS ON BELIEFS ABOUT TEACHING AND TEACHER PROFESSIONAL CHARACTERISTICS USING PLS-SEM

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Abstrak

Beliefs about Beliefs about the nature of mathematics can impact teachers' confidence in teaching math and their professional development. A study with 187 elementary school teachers in Banda Aceh showed that these beliefs have a significant direct effect on increasing beliefs about teaching math but only a minimal direct effect on improving teachers' professional character. Beliefs about teaching act as an indirect-only mediation variable between beliefs about the nature of mathematics and teacher characteristics, suggesting a high and significant indirect effect. Further research is needed to confirm these results.

INTRODUCTION

Testing the data using the Structure Equation Model Partial Least Square (SEM-PLS) method is a data analysis method that aims to see the influence between variables presented in the form of a path model (Hair et al., 2017). PLS-SEM is a data analysis method using linear regression which predicts the relationship between variables in the resulting path diagram. The PLS method can be used in multivariate analysis involving many variables (Hair. et al., 2017).

The variables that are connected in the path diagram constructed in PLS are called latent variables which consist of exogenous latent variables and endogenous latent variables. Exogenous latent variables, hereinafter referred to as exogenous variables, are variables that influence other variables, while endogenous variables are variables that are influenced by exogenous variables. Each latent variable then has several indicators that represent a desired condition or criterion in the latent variable.

The path model in PLS is predictive which is built based on existing theory (Leguina, 2015). The predictive nature of PLS provides an opportunity for researchers to develop path models based on existing theory. One pathway model that is still open to development is a pathway model that describes beliefs about the nature of mathematics (BNM) with teacher professional characteristics (KG). BNM is one aspect of mathematics teacher beliefs that is very important for teachers who teach mathematics (Ernest, 1994; Jackson, 2017) because it can affect teachers' beliefs in teaching mathematics/BTM) (Alkhateeb, 2019; Clark et al., 2014; Felbrich et al., 2008; Forgasz & Leder, 2008; Ren & Smith, 2018; Xie & Cai, 2021; Zakaria, 2010). KG is the attitude displayed by teachers regarding their profession as a teacher, in this case as a mathematics teacher (Yaratan & Muezzin, 2016). KG is closely related to BTM.

The interrelated relationships between BNM, BTM, and KG can be explained using the PLS-SEM path model. Research related to the effects of mathematics teacher beliefs, especially on the BTM aspect, has often been carried out (Aydın et al., 2010; Beswick, 2012; Çiftçi & Karadag, 2019; Corkin, 2015; Maass, 2009; Siswono et al., 2019; Stipek et al., 2001; Xie & Cai, 2021). The research related to BNM, particularly the development of path models that explain the relationship between BNM and KG, is limited. Additionally, there has been no discussion of the role of BTM as a mediating variable between BNM and KG. According to Hair et al. (2017), a mediating variable is a variable that intervenes between exogenous variables and endogenous variables in PLS-SEM. Changes in exogenous variables lead to changes in mediating variables, which, in turn, affect changes in endogenous variables. There are three types of mediation (Hair, 2017): 1) Complementary mediation occurs when the direct effects and indirect effects are significant and have the same direction; 2) Competitive mediation happens when the direct and indirect effects are significant but in opposite directions; 3) Indirect-only mediation occurs when the direct effect is not significant, and the indirect effect is significant.

The author has not found a discussion or path analysis in PLS-SEM that uses BTM as a mediating variable between BNM and KG. This prompted the author to research to find out this information. Understanding the type of mediation that MTB plays in analyzing the influence of BNM on KG can be valuable for future related research and could also be considered in the development of teacher education curricula and mathematics teacher competency.

RESEARCH METHODS

This study uses a quantitative approach. Data was collected from 187 samples who were elementary/MI teachers in Banda Aceh City who taught mathematics in class. BNM and BTM data collection uses a questionnaire that has been developed by Purnomo (Purnomo, 2017). For KG using a questionnaire that has been developed by Yaratan (Yaratan & Muezzin, 2016). The questionnaire uses a Likert scale with 5 choices: 1) very strongly disagree; 2) strongly disagree; 3) Agree; 4) strongly agree; 5) very strongly agree.

BNM comprises 9 indicators related to teachers' beliefs in mathematics, such as: 1) Mathematics is a tool to solve problems; 2) Mathematics is formed from human culture; and 3) Mathematical concepts. BTM includes 11 indicators, such as the confidence to 1) link mathematics with the real world; and 2) choose a mathematical learning model. KG encompasses 12 indicators, including 1) the character of the knowledge sources used in learning; 2) commitment to the profession; and 3) professionalism in carrying out duties.

In this study, the path model design involves BNM as an exogenous variable that influences KG as an endogenous variable. Additionally, BTM acts both as an exogenous variable affecting KG and as a mediation variable between BNM and KG. The path model design was developed with the assistance of Smart PLS 3 software, as illustrated in Figure 1

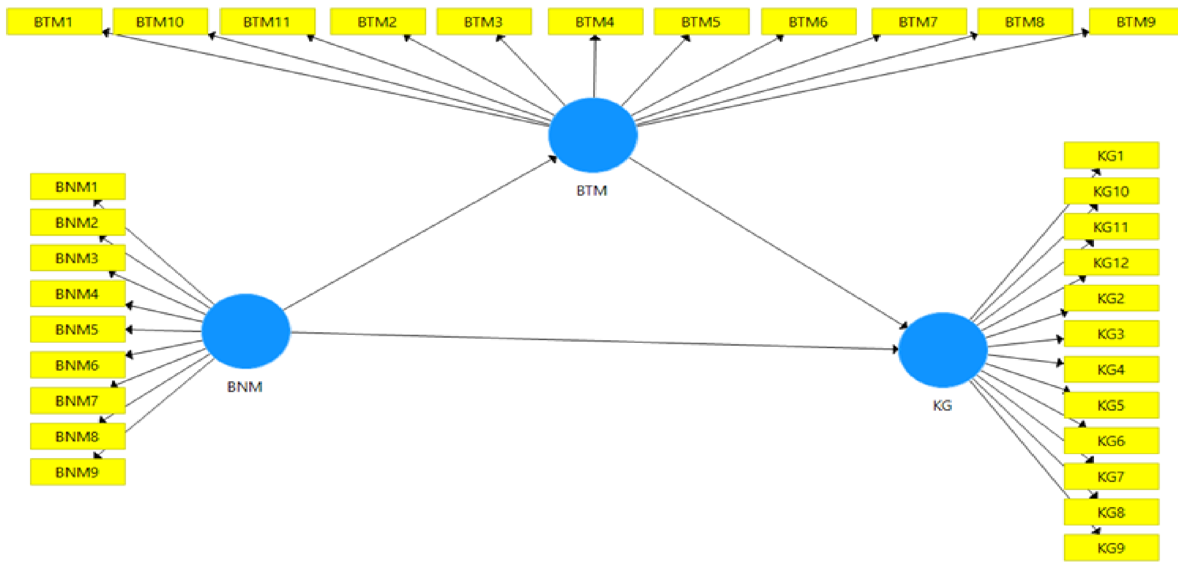


Figure 1.
Path Model BNM Relations with BTM and KG (image from Smart PLS 3)

Based on the information presented in Figure 1, the path model will examine four relationships. These include the direct impact of BNM on KG, the direct effect of BNM on BTM, the direct effect of BTM on KG, and the indirect effect of BNM on KG through the analysis of BTM's role as a mediating variable. In my data analysis, I will be using Smartpls 3 software and conducting two main stages of analysis: Outer Model Analysis and Inner Model Analysis. During the Outer Model Analysis phase, I will be focusing on assessing the reliability and validity of the indicators used in the study. This will involve examining how well the indicators measure the constructs they are intended to represent. Moving on to the Inner Model Analysis, my main objective will be to analyze the magnitude of the BNM effect on KG. Additionally, I will be testing the significance of the author's effect using bootstrapping analysis, which will help me assess the robustness of the findings. To evaluate the results, I'll be using model testing criteria specifically tailored for Partial Least Squares Structural Equation Modeling (PLS-SEM). (Hair et al., 2013; Hair & Alamer, 2022; Sarstedt et al., 2021; Shmueli et al., 2019) as presented in Table 1

Al Khawarizmi, Vol. 8, No. 2, Desember 2024 (123-133)

Table 1. Model testing criteria

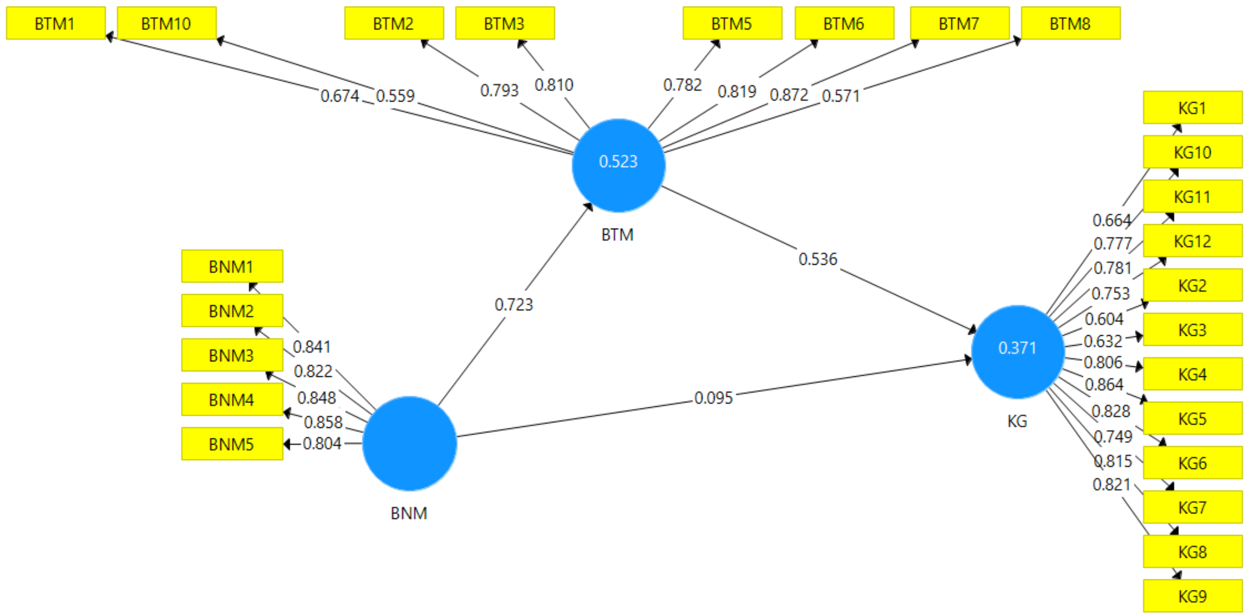
No	Criteria	Description
		Outer model
1	Reliability (outer loading)	> 0,5.
2	Composite Reliability (p_c)	Nilai ≥ 0,6
3	*AVE*	Nilai > 0,5.
		Inner model
4	*Coefficient of Determination* (R^2)	Nilai R^2 > 0,25
5	*Effect size* (f^2)	< 0,02 no effect 0,02 < f^2< 0,15 (low) 0,15 < f^2< 0,35 (moderate) > 0,35 high
6	*Predictive Relevance* (Q^2)	Nilai Q^2 > 0
7	*Bootsrapping*	*p-value* pada *path coefficient* < 0,05

RESULT AND DISCUSSION

Result

The author conducted an outer Loading analysis and found that certain indicators (BNM6, BNM7, BNM8, BNM9, BTM9, and BTM11) had Outer Loading values < 0.5. According to the analysis, indicators with outer loading values < 0.5 are considered less valid as they are unable to explain the relationship with the variables. Therefore, these indicators should be eliminated in further model analysis (Hair et al., 2017. The indicators eliminated in BNM pertain to the formation of mathematics and mathematical concepts. Upon analyzing the questionnaire values, it was found that the average value for these indicators was < 3.5 out of a maximum value of 5. Indicators with an average of < 3.5 were found to have an outer loading value > 0.6. This suggests that the variance of respondents' choices for these indicators is low, with most of them choosing the value of 2 or 3. This implies that respondents were undecided about the statement. The path model with the removed indicator is presented in Figure 2.

Al Khawarizmi, Vol. 8, No. 2, Desember 2024 (123-133)



Picture 2.
Illustration of a path model with indicators > 0.5 (image form Smart PLS 3)

In the path model presented in Figure 2, the outer model analysis includes an examination of the outer loading values, which describe indicator validity, composite reliability, and Average Variance Extracted (AVE). Indicator validity assesses the indicator's capability to explain the variables. Composite reliability is used to determine the ability of the construct or model to elucidate the relationship between variables. On the other hand, AVE represents the diversity of variables within the model. A summary of the results of the outer model analysis is presented in Table 2 below.

Table 2.
Summary of the results of the outer model analysis

No	Criteria	Description	Details
	Outer model (Model Reflektif)		
1	*Indikator Reliability (outer loading)*	Nilai > 0,5.	All remaining indicators are valid in describing the relationship with the variables.
2	Composite Reliability (p_c)	BNM = 0,920 BTM = 0,907 KG = 0,943	The path model has high reliability in describing the relationship between latent variables.
3	*AVE*	BNM = 0,697 BTM = 0,529 KG = 0,581	With an AVE value > 0.5, the latent variable is considered to be able to measure more than half (50%) of the indicators.

Based on the test results summarized in Table 2, it is evident that the constructed path model is highly reliable and can be used to analyze the impacts of BNM and BTM on KG. The next step involves inner model analysis, which aims to examine the influence of BNM as an endogenous variable on BTM and KG as endogenous variables. During this stage, the inner model analysis is combined with bootstrapping tests to identify significant influences between the variables. Bootstrapping was conducted using 3000 subsamples, and a summary of the test results is provided in Table 3.

Table 3. Summary of Inner Model Test Results

No	Criteria	Description	Details
	Inner model (Model Struktural)		
1	*Coefficient Determinasi (R^2) (bootstrapping)*	BNM → BTM = 0,523 BNM → KG = 0,371	*p Value* = 0,000 *p Value* = 0,000
2	*Effect size (f^2)* *(Direct)*	BNM → BTM = 1,098 BNM→KG = 0,007 BTM → KG = 0,218	*p Value* = 0,000 *p Value* = 0,651 *p Value* = 0,002
	(Indirect) (dengan variabel mediasi)	BNM → KG = 0,388	*p Value* = 0,000
3	*Predictive Relevance* (*Q^2*)	BTM = 0,275 KG = 0,207	The model has good observational value in mapping the influence between connected variables.

Discussion

The analysis results presented in Table 3 indicate that the R^2 value, which represents the relationship between the BNM and BTM variables, is 0.527. This value suggests that BNM has a direct correlation of 52.7% in increasing BTM. With a p-value of 0.000, this effect is found to be significant. The 52.7% correlation falls within the category of strong correlation. Additionally, the magnitude of the influence of BNM on BTM as a mediating variable, represented by KG of 0.371, indicates a notable level of correlation. In other words, BNM through BTM has a 37.1% influence on increasing KG. This correlation is further clarified Regarding the direct and indirect effects of BNM on BTM and KG, the analysis of the effect size value helps to determine the magnitude of the influence of one variable on the others. A predictive relevance (Q^2) value greater than 0 indicates that the relevant path model is suitable for measuring the effect of BNM on both BTM and KG.

a. Direct effect of BNM on KG

The direct impact of BNM on KG is evident in Table 3, which shows an effect size value of 0.007 with a p-value of 0.651. This implies that BNM does not have a significant direct effect on KG. With a value of 0.007, we can infer that BNM does not directly influence KG significantly. This indicates that an increase in BNM does not have a significant direct influence on KG. In the path model analysis depicted in Figure 2, the direct influence of BNM on KG is 0.095, signifying a very low value. The author has not come across any articles discussing the direct relationship between BNM and KG in a study. This could present an opportunity for future research to explore the factors causing a direct effect of BNM on low KG. Research about the impact of BNM on KG is often associated with its application in learning or BTM.

b. Direct effect of BNM on BTM

The direct effect of BNM on BTM is indicated in Table 3, with an effect size value of 1.098 and a p-value of 0.000. The effect size value of BNM on BTM into the category of a very strong effect or high effect, suggesting that the direct influence of BNM on increasing BTM is highly significant. Therefore, it can be concluded that an increase in BNM has a very significant impact on increasing BTM, indicating a significant influence of BNM on increasing teacher confidence in teaching mathematics in the classroom. This is further supported by the correlation value of BNM to BTM in Table 3.

Although there is not much research discussing the relationship between BNM and BTM, several studies state that BNM significantly influences teacher-managed mathematics learning practices (Aljaberi & Gheith, 2018; Dede & Uysal, 2012; Presmeg, 2002). This concept is based on Ernest's (1994) description, which suggests that teachers' beliefs about the nature of mathematics influence the learning models they use. Therefore, when designing teacher competency curricula, it is important to consider these beliefs about the nature of mathematics to encourage improvements in learning practices in mathematics education programs.

c. Direct effect of BTM on KG

The direct effect of BTM on KG, as indicated by the effect size BTM → KG in Table 3, is 0.218. This size effect value is smaller than the size effect of BNM on BTM directly. However, it is still larger than the effect size of BNM on KG directly. The effect of BTM on KG wich in the moderate category but it is significant. These results support the idea that belief in mathematics learning can guide the future development and professional growth of mathematics teachers (Lloyd, 2016; Timmerman, 2004).

The author has not found any research discussing the effects of BTM on increasing KG. There has not been a strong discussion for researchers to compare the results of this analysis. The author assumes that because BTM is closely related to teachers' competence in teaching mathematics as part of their professional role, it is understandable that BTM has a significant impact on teachers' professional attitudes and behavior, thus strengthening the assumption that changes in teachers' beliefs can be reflected in their professional changes. (Schueler et al., 2015).

d. BTM contribution as a mediating variable for BNM and KG

In addition to directly affecting KG, BTM also serves as a mediating variable between BNM and KG. This section analyzes the indirect effects given by BNM to KG. Based on the values in Table 3, the direct effect of BNM on KG is found to be very weak and not significant. However, the indirect effect of BNM on KG is greater, at 0.388. This effect is included in the high category, which means that the function of BTM as a mediating variable is very important. By paying attention to the significance of the direct effect and indirect effect of BNM on KG, it can be concluded that BTM has a role as an indirect-only mediating variable, which means that BTM as a mediating variable provides a very important role in increasing KG because without being mediated by BTM, BNM is unable to significantly increase KG. Comparing the direct and indirect effect values, it can be concluded that BTM as a mediating variable provides a positive influence that strengthens the effect of BNM on KG. Therefore, an increase in BNM will directly and significantly increase BTM, which in turn substantially impacts the professional characteristics of mathematics teachers in managing their learning. By focusing on the importance of both the direct and indirect effects of BNM on KG, we can infer that BTM serves as an indirect-only mediating variable. This implies that BTM plays a crucial role in increasing KG, as without being mediated by BTM it is understandable that BNM cannot significantly increase KG.

The implementation of the beliefs about teaching mathematics (BTM) has shown a significant impact on enhancing the professionalism of teachers in teaching mathematics. The role of BTM can be a crucial consideration for the development of educational curricula and mathematics teacher training. Improving teacher professionalism should begin with enhancing teachers' beliefs in the essence of mathematics (BNM). Increasing a teacher's belief and knowledge about the essence of mathematics, convincing that mathematics originates from human life, and believing that mathematics is a tool that can help humans solve everyday problems, provides teachers with the confidence to teach mathematics more effectively. According to the analysis in this study, it has a significant effect on increasing teachers' confidence in what they teach in the classroom (BTM) and has a significant effect on improving their attitudes, behaviors, and classroom management practices as part of the teaching profession (KG).

At present, there is a lack of research on the role of BTM as a mediating variable to assess the impact of BNM on KG, making it challenging to compare the findings of this study with previous research. Nevertheless, several studies suggest that teachers who embrace a more open-minded view of mathematics and its real-life applications demonstrate a more positive approach to teaching mathematics compared to those who view mathematics purely as a set of knowledge (Güven Akdeniz & Gürefe, 2021; Maphutha, 2012). Altering a teacher's beliefs regarding mathematics also influences their teaching behavior, leading to positive impacts on their professionalism in managing the mathematics classroom (Oksanen & Hannula, 2013).

CONCLUSION

The analysis results conclude that belief about the nature of mathematics (BNM) has a high and significant direct effect on beliefs about teaching (BTM), but BNM has a very weak and insignificant direct effect on teachers' professional characteristics in managing mathematics learning (KG). The indirect effect of BNM on KG is high and significant when mediated by BTM. The results show that belief about teaching mathematics plays a role as a mediating variable with an indirect-only mediation type, which means that without beliefs about teaching mathematics, BNM cannot directly enhance the professionalism of teachers. These findings provide recommendations for the development of an education curriculum and mathematics teacher training curriculum. Relevant parties should consider increasing confidence in mathematics as an initial step to improve the professionalism of mathematics teachers. However, these research findings still need strengthening, and it is hoped that they will motivate further research in the future, especially in the development of the path model used and testing with various related instruments.

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