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ASSESSING MATHEMATICAL MODELING PROFICIENCY IN K-12 EDUCATORS: INSIGHTS FROM THE MATHEMATICAL MODELING KNOWLEDGE SCALE (MMKS) IN ASIA

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Abstract

The primary objective of this research is to examine the level of mathematical modeling proficiency among K-12 educators in Asia. This will be accomplished by creating and employing the Mathematical Modeling Knowledge Scale (MMKS). The Mathematical Modeling Knowledge Scale (MMKS) is a reliable measure ($\alpha = .80$) with strong validity, making it a valuable tool for evaluating instructors' understanding of mathematical modeling. The significance of customized professional development is highlighted by the gender-based disparities in teachers' expertise, as female educators exhibit a more advanced comprehension of the subject matter. The qualitative study reveals a range of reactions, highlighting the necessity of focused interventions to address mistakes and improve conceptual understanding. The research, utilizing a cross-sectional survey methodology involving a sample of 71 teachers, offers a complete examination of various viewpoints and personal encounters. The aforementioned findings provide a substantial contribution to the continuing academic discussion over the significance of research and quantitative methodologies in furthering the pedagogy of mathematical modeling. The consequences have a broad reach, encompassing the education of prospective teachers as well as the ongoing professional development of current educators. Furthermore, the research underscores the importance of implementing policies tailored to specific regions in order to enhance the standards of mathematical education throughout Asia, while also highlighting their wider implications. The study not only demonstrates the effectiveness of the MMKS in assessing teachers' understanding of mathematical modeling, but also emphasizes the importance of implementing focused interventions and region-specific initiatives to improve the overall standard of mathematical education in the Asian environment.

Keywords: mathematical content knowledge, mathematical modeling, scale development, teacher preparation, professional development.

1. Introduction

The field of mathematics education plays an important part in the development of knowledge in academia, as the effectiveness of teaching relies heavily on instructors' deep understanding of mathematical concepts. This preliminary investigation explores the fundamental

relationship between teachers' mathematics content understanding and their professional ability.
The importance of high-quality mathematics instruction is emphasized by the global educational environment. In the pursuit of improving educational systems, it is crucial to prioritize the comprehension of teacher knowledge dynamics (Hill et al., 2022). An in-depth understanding of mathematical modeling is of utmost importance in cultivating students' proficiency in mathematics and their ability to solve problems, hence enhancing worldwide competitiveness in the fields of science and technology (Tattoet, al 2023).

The present study focuses on the particular context of teachers' mathematical modeling expertise within the Asian educational environment, which is characterized by a variety of pedagogical techniques and cultural intricacies (Li &Schoenfeld, 2022). Asia, renowned for its extensive educational heritage and diverse range of educational institutions, offers a distinctive context for exploring the fundamental elements of mathematics comprehension among educators (Blömekeet, al 2023).

Although the significance of teachers' content knowledge is widely recognized, there is a lack of empirical instruments particularly designed to assess their comprehension of mathematical modeling (Cho &Ahn, 2023). The present study aims to bridge this existing research gap by proposing a novel scale specifically tailored for Asian educators, which aims to provide a focused evaluation of their understanding of mathematical modeling ideas.

The study holds importance in its capacity to provide valuable insights for teacher training and professional development programs (Remillard& Heck, 2022). By identifying specific areas in which instructors excel and areas in which they may improve their comprehension of mathematical modeling, educators and policymakers can develop targeted interventions to strengthen teaching practices. This, in turn, adds to the larger objective of enhancing mathematical education and, as a result, students' mathematical ability. The primary objective of this study is to create a scale that can be used to measure teachers' comprehension of mathematical modeling in Asian educational settings.

Mathematical Modeling: Mathematical modeling is a strong teaching strategy that involves the production of mathematical representations for the purpose of comprehending, analyzing, and finding solutions to problems that occur in the real world. According to Lesh and Doerr (2019), it acts as a connection between theoretical mathematical concepts and their practical applications, hence encouraging critical thinking and the ability to solve problems (Blum et, al 2019).In educational settings, mathematical modeling functions as a potent instrument for engaging students in real-world mathematical practices and motivating them to apply mathematical ideas to a wide variety of circumstances. (Kaiser et, al 2018)

Knowledge of Mathematical Modeling Among Teachers A teacher's knowledge of mathematical modeling covers not only their comprehension of mathematical topics but also their capacity to direct students through the modeling process. According to Blum and Leiß (2019), it requires pedagogical content knowledge (PCK) that is particular to modeling, a comprehension of the cognitive processes that are involved, and an ability to anticipate student challenges. In order for educators to effectively teach mathematical modeling, they need to manage the balance between mathematical rigor and relevance to the real world. This helps to ensure that students develop both strong mathematical skills as well as a profound awareness for the ways in which mathematics can be applied (Ball et, al 2022)

2. Methodology

Research Design: This study, conducted in 2023, focused on K–12 mathematics teachers in Asia, employing a survey research design. The chosen approach was a descriptive survey design, specifically cross-sectional in nature, to investigate teachers' knowledge of mathematical modeling. This design allowed for a snapshot of participants' perspectives and experiences at a specific point in time.

Participants: The study involved K–12 mathematics teachers in Asia, and a total of 71 teachers self-selected to participate. Among the 60 teachers from whom demographic data was collected, 77% were 35 years or older, and nearly 60%. The participants comprised 36 grades K–5 teachers, nine grades 6–8 teachers, and 17 grades 9–12 teachers, with teaching experiences ranging from one to 32 years. The sample was predominantly female, with 85% identifying as such.

Measures: The research utilized a Mathematical Modeling Knowledge Scale (MMKS) developed based on various sources, including the Common Core State Standards, NCTM standards, and relevant research articles. The initial 22-item scale underwent refinement through cognitive interviews, expert reviews, and item analysis, resulting in a final 13-item scale. The survey included true or false items and an open-ended question, providing a comprehensive assessment of teachers' understanding of mathematical modeling.

Data Collection: For this study in Asia, purposeful sampling targeted potential participants who responded to the online survey. The data collection method involved an online self-administered survey, facilitated through Qualtrics—an online survey software. Invitations were sent to potential respondents via Qualtrics, and the collected responses were downloaded for subsequent statistical analyses.

Data Analysis: Both quantitative and qualitative analyses were employed for the study's data. Quantitative analyses included univariate analysis, Cronbach's alpha reliability analysis, and exploratory factor analysis (EFA) to demonstrate the reliability and construct validity of the MMKS. Cronbach's alpha assessed internal consistency reliability, while an independent t-test explored potential differences between teachers' gender and their knowledge of mathematical modeling. The SPSS statistical software facilitated these analyses, with statistical significance set at $p < .05$.

3. Result and Discussion

The Item–Total Correlations (ITC) in Table 1 reflect the strength and direction of the relationship between each individual item and the overall score on the MMKS (Metacognitive Monitoring Knowledge Scale). Higher ITC values suggest a stronger association between an item and the total score, indicating that the item effectively contributes to measuring the construct of metacognitive monitoring knowledge.

Table 1: Item–Total Correlations and Reliability Measures on the MMKS

Items	M	SD	SE	ITC	α-if item deleted
Item 1	.82	0.28	0.02	0.17	0.70
Item 2	.80	0.30	0.04	0.49	0.67
Item 3	.70	0.40	0.03	0.38	0.68
Item 4	.62	0.45	0.06	0.18	0.70
Item 5	.76	0.35	0.03	0.33	0.69

Item 6	.76	0.35	0.05	0.44	0.68
Item 7	.67	0.42	0.07	0.37	0.70
Item 8	.80	0.30	0.08	0.44	0.89
Item 9	.72	0.39	0.06	0.53	0.87
Item 10	.84	0.23	0.02	0.49	0.89
Item 11	.83	0.26	0.01	0.41	0.70
Item 12	.67	0.42	0.04	0.59	0.66

Total Correlation=∑Item–Total Correlations Total Correlation=4.82

Reliability Measures (α-if item deleted): The alpha (α) values represent the internal consistency or reliability of the scale if a particular item is deleted. A high alpha value indicates that the item contributes significantly to the reliability of the scale. Items 8, 9, 10, and 11 show high alpha values (above 0.80), suggesting that they play a crucial role in maintaining the reliability of the MMKS.

Mean (M), Standard Deviation (SD), and Standard Error (SE): These descriptive statistics provide insights into the central tendency, variability, and precision of each item's scores. Consistent mean values across items (around 0.70 to 0.80) suggest a balanced distribution of responses.

Item 4's Low ITC and Reliability: Item 4 stands out with a low ITC (0.18) and alpha value (0.70), indicating a weaker association with the overall scale and potential impact on the reliability. Further investigation into the content and wording of Item 4 may be warranted to enhance its contribution to the measurement of metacognitive monitoring knowledge.

Table 2: Teachers' Responses on Mathematical Modeling

Categories	**Number of Teachers**
Excellent	4
Misconceptions	33
Others	17

The robust reliability (α = .80) of the MMKS underscores its utility in assessing teachers' knowledge of mathematical modeling in the Asian context. The unidimensional factor, "knowledge of modeling," aligns with established theoretical frameworks, providing validity to the scale.

The significant gender-based difference in teachers' knowledge suggests potential variations in professional development needs. Female teachers, on average, exhibited a more nuanced understanding of mathematical modeling. This finding emphasizes the importance of tailored interventions to bridge gender-specific gaps in knowledge.

The qualitative analysis revealed a spectrum of responses, highlighting both promising understanding and prevalent misconceptions. The majority of teachers associated mathematical modeling with concrete manipulations, indicating a need for targeted professional development to enhance conceptual clarity. The relatively low percentage of excellent responses signals an opportunity for comprehensive training initiatives to elevate teachers' proficiency in mathematical modeling.

These findings hold particular relevance for mathematics education in Asia, where diverse pedagogical traditions and cultural nuances shape teaching practices. The observed gender differences and varied conceptualizations of mathematical modeling underscore the need for region-specific interventions. Tailoring professional development programs to address misconceptions and enhance teachers' conceptualization of modeling can contribute significantly to elevating mathematical education standards in Asia.

4. Conclusion

This comprehensive study on the Mathematical Modeling Knowledge Scale (MMKS) sheds light on the nuanced landscape of teachers' understanding of mathematical modeling in the Asian educational context. The robust reliability of the MMKS, indicated by a high alpha value ($\alpha = .80$), attests to its utility in effectively assessing teachers' knowledge in this domain. The observed gender-based differences underscore the need for tailored professional development, as female teachers exhibited a more nuanced comprehension of mathematical modeling. The qualitative analysis revealed a spectrum of responses, exposing prevalent misconceptions and highlighting the necessity for targeted interventions to enhance conceptual clarity. The study's significance lies in its contribution to the ongoing discourse on the importance of empirical tools for evaluating teachers' comprehension of mathematical concepts. Furthermore, the research design, encompassing a cross-sectional survey with a diverse sample of K–12 mathematics teachers, provides valuable insights into the current state of mathematical education in Asia. The study's findings carry implications for the development of region-specific interventions to address misconceptions and elevate teaching standards, emphasizing the crucial role of instructors' strong understanding in shaping the educational landscape. The detailed research design, rigorous data collection, and robust analyses contribute to the credibility of the study's conclusions, emphasizing the need for continuous research and development of quantitative tools to enhance the teaching of mathematical modeling.

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