Research Article

Second-Order Confirmatory Factor Analysis of 21st Century Mathematics Teaching Predicament among Secondary Mathematics Teachers in Secondary Educational Service Area Office Lopburi

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ABSTRACT

This study aimed to anlyze the second-order confirmatory factor analysis (CFA) of the 21st century mathematics teaching predicament (MTP) among secondary mathematics teachers in Secondary Educational Service Area Office Lopburi (SEAOL). The study uses a quantitative research approach and the Technological Pedagogical Content Knowledge (TPACK) framework to examine teaching, learning and knowledge theory. In the first semester of 2022, sixty secondary school mathematics instructors were chosen by multi-stage random selection from the SEAOL. A 0.94-confidence questionnaire was used to study mathematics teaching predicament. The data were analyzed using second-order confirmatory factor analysis (CFA) with the AMOS program. The results of the study showed that the 21st century MTP model had a good fit with the data (χ^2 = 11.852, *df* = 10, χ^2/df = 1.185, *p*-value = 0.295, *GFI* = 0.952, *TLI* = 0.963, *CFI* = 0.982, *NFI* = 0.906 and *RMSEA* = 0.056) with technological capability, knowledge of content, variety of teaching methods, requirements for using technology, school technology support, the narrative teaching method, and the use of technological tools to influence mathematics teaching predicament, with influence values of 0.85, 0.73, 0.67, 0.63, 0.31, 0.08, and 0.00, respectively. The research showed how each element affected these secondary school math instructors. The least influential factor was the use of technology. The results showed that, to improve education, educators should develop and apply new technology in the classroom.

Keywords Structural equation model, Instructional, Mathematics, Lopburi, Thailand

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Introduction

The emergence of the conceptual framework for teaching and learning represents a significant paradigm shift. Consequently, the global education industry is designing curricula and developing textbooks that integrate content, teaching methods, and technology. These elements are believed to be essential for the advancement of teaching and learning [1]. According to Koehler and Mishra [2], the effectiveness of education in achieving the objectives of the new teaching and learning framework depends on teachers' willingness to design modern teaching and learning activities, so the concept of "Technological Pedagogical Content Knowledge (TPACK)" has been proposed. TPACK includes the prerequisites for teachers in developing modern methods. These elements include: (1) Technological Knowledge (TK), (2) Pedagogical Knowledge (PK), (3) Content Knowledge (CK), (4) Knowledge Integrating two of these three areas this integration would result in either (4.1) Technological Content Knowledge (TCK), or (4.2) Pedagogical Content Knowledge (PCK), and (5) Knowledge integrating all three areas would be called TPACK.

Additionally, we synthesized six research studies examining the factors that influence the teaching of mathematics, including Chariyamakarn and Sukpan [3]; Hanhaw [4]; Saethow [5]; Sirithon et al [6]; Sripongpird [7]; and Soythong [8]. These studies identified the factors affecting mathematics teaching, including, in order of importance, knowledge of content, knowledge of teaching and learning activities, attitude towards mathematics, and knowledge of technology. These findings align with concepts of modern education. This study employed factor analysis to examine the teaching of mathematics in schools under the SEAOL, identifying seven important factors: 1) technology support, 2) requirements for use of technology in teaching, 3) proficiency in the use of basic technology, 4) proficiency in the use of specialized technology, 5) knowledge of content, 6) variety of teaching methods, and 7) narrative teaching methods [9].

This article examines these seven factors. We employed the Analysis of Moment Structures software (AMOS) package for confirmatory component analysis and consistency checking allowing us to verify the relationships among the factors and their impact on mathematics teaching predicament.

Literature Review

The 21st century teaching and learning framework

The 21st century teaching initiative began with a gathering of educators in the United States from various fields, at which was established the "Partnership for 21st Century Skills". This initiative created a conceptual framework for teaching and learning, emphasizing the development of knowledge in four key areas [10, 11] which include:

(1) *Knowledge of Core Subjects*, including language, the arts, mathematics, science, geography, history, and citizenship, and the real-life application of knowledge to the social, global, financial, economic, health, and environmental domains. Consequently, teaching and learning activities that foster the integration of knowledge across various subjects are vital.

(2) *Learning and Innovation*, including project-based learning (PBL), by which students explore interests, formulate hypotheses, plan project designs based on principles or theories, and collaborate and discuss to reach conclusions. Innovative designs demonstrate critical thinking, problem-solving, effective communication, teamwork, and creativity.

(3) *Information and Technology*, including (3.1) Information Literacy, by which students learn to access resources efficiently and evaluate the credibility of search databases; (3.2) Media Literacy, by which students learn to use media production tools and choose media suited to specific purposes; and (3.3) Technology Literacy, by which students use technology to search for information.

(4) *Life and Career*, which includes adapting to change and creating innovative products in order to earn a living; strategies for career advancement in a changing world, which include flexibility, adaptability, initiative, creativity, self-direction, socio-cultural awareness, productivity, establishing a portfolio, leadership, and responsibility.

These skills will help students to succeed in a changing world. Classroom activities should empower students to "construct their own knowledge" under the guidance of instructors, who can help students search for information from reliable sources, promote discussion, explore answers that support academic theories and principles, and create knowledge and innovation beneficial to society.

The "Partnership for 21st Century Skills" model represents a significant paradigm shift. Educational institutions worldwide are designing curricula and textbooks that emphasize the integration of knowledge and content, and the fusion of teaching and technology, seen as crucial for the advancement of teaching and learning [1]. Koehler and Mishra [2] emphasize that teachers must design modern educational activities to achieve the goals of the 21st century teaching and learning framework and propose "Technological Pedagogical Content Knowledge (TPACK)". TPACK includes the elements teachers should develop to keep up with advances in education, including:

(1) Technological Knowledge (TK), including the ability to use technology, understand its functionality, and select suitable tools, with knowledge of computer operating systems, hardware, and popular software.

(2) Pedagogical Knowledge (PK) refers to teachers' proficiency in aligning with educational objectives, classroom management, designing and implementing teaching plans, assessing student progress, and using diverse teaching techniques to engage students.

(3) Content Knowledge (CK) entails a deep understanding of academic content, concepts, theories, and scope. Without this knowledge, teaching would be challenging.

(4) Integration of two of these areas: (4.1) Technological Pedagogical Knowledge (TPK) refers to adapting technology to the classroom; (4.2) Technological Content Knowledge (TCK) adapts technology for subject-specific content and complex topics, such as graphing functions or finding their values; and (4.3) Pedagogical Content Knowledge (PCK), which entails using pedagogical expertise to teach.

(5) Integration of knowledge across all three areas, including technology in teaching, and using technology to empower students to "create new knowledge". By TPACK, teachers satisfy the demands of modern education, and create meaningful experiences for students.

In Thailand, Sripongpird [7] studied effective teaching in Pathum Thani. She identified technology, content, teaching activities, responsibility, and classroom lectures as the important factors. Saethow [5] asserted that attitude, gender, age, and education level also play a role. Similarly, Sirithon et al [6] identified content, classroom activities, attitudes, classroom atmosphere, and assessment as important factors. These findings align with the principles of teaching and learning articulated in the "Partnership for 21st Century Skills" model and the TPACK theory.

The researcher identified seven key factors in the teaching of mathematics in schools under the Lopburi Secondary Education Area Office: (1) Technology support from schools, (2) Use of technology, (3) Ability to use basic technology, (4) Ability to use specialized technology, (5) Knowledge of content, (6) Variety of teaching methods, and (7) Use of narrative teaching methods. These seven factors shape effective mathematics education, as presented in Table 1 [9].

Table 1 Factors affecting current mathematics teaching and learning in schools

Effective Mathematics education requires	Variable, (Load score)	Factor
Awareness of technology (AC)	AC_211, (0.736) Do your school or organization have enough computers for use?	(1) Technology support from schools
	AC_212, (0.646) Does your school or organization support cloud storage, such as Google Drive or Microsoft OneDrive?	
	AC_213, (0.800) Does your school or organization support teaching software, such as Microsoft Office or Zoom Meeting?	
	AC_214, (0.670) Does your school or organization have a projector?	
	AC_215, (0.679) Does your school or organization have a printer?	
	AC_216, (0.660) Does your school or organization have high-speed internet access or Wi-Fi?	
	AC_217, (0.704) Does your school or organization prioritize programming in a particular language, such as Python, C, C++, or Java?	

Effective Mathematics education requires	Variable, (Load score)	Factor
	AC_2112, (0.662) Can knowledge of technology contribute to the efficiency of teaching and learning?	
	AC_218, (0.858) Do you want to use technology to teach because it helps students understand more concretely?	(2) Use of technology
	AC_219, (0.869) Do you want to use technology for teaching because it serves as an intermediary for communication both inside and outside the school or organization?	
	AC_2110, (0.851) Do you want to use technology for teaching because it makes it easier for students to research and find information?	
	AC_2111, (0.819) Do you want to use technology in teaching because it helps create learning innovation and improves teaching and learning?	
Technological Knowledge (TK)	TK_221, (0.851) Can you use a word processor such as Microsoft Word or Google Docs?	(3) Ability to use basic technology
	TK_222, (0.811) Can you use an electronic spreadsheet such as Microsoft Excel or Google Sheets?	
	TK_223, (0.743) Can you use a presentation program such as PowerPoint or Google Slides?	
	TK_226, (0.856) Can you communicate via the internet using tools like email, Line, or Messenger?	
	TK_227, (0.609) Can you communicate via the internet using tools like email, Line, or Messenger?	
	TK_2210, (0.651) Do you believe that technological knowledge affects the teaching and learning of mathematics today?	

Effective Mathematics education requires	Variable, (Load score)	Factor
	TK_224, (0.660) Can you use dynamic geometry software such as GSP or GeoGebra?	(4) Ability to use specialized technology
	TK_225, (0.824) Can you program in a specific language, such as C, C++, Python, or Java?	
	TK_228, (0.631) Do you keep up with modern technology and constantly study its use?	
	TK_229, (0.788) Can you use specialized software as a medium for teaching mathematics, such as Scratch?	
Content knowledge (CK)	CK_231, (0.607) Can you identify or explain the meaning of the subject matter being taught?	(5) Knowledge of content
	CK_232, (0.837) Can he explain the origin of the teachings?	
	CK_233, (0.874) Can you apply your knowledge correctly?	
	CK_234, (0.747) Are you always seeking more knowledge from up-to-date sources?	
Content knowledge (CK)	CK_235, (0.597) What do you think is the content of mathematics in secondary school that is currently being taught? Is there more than necessary for the future use of learners?	(5) Knowledge of content
	CK_236, (0.775) What do you think is the current content of mathematics instruction? Does it respond to learners' needs?	
	CK_237, (0.787) Do you believe that having complex math problems will affect the effectiveness of teaching and learning mathematics?	

Effective Mathematics education requires	Variable, (Load score)	Factor
Teaching and learning activities (IA)	IA_242, (0.712) Are you satisfied when organizing teaching and learning activities that focus on students practicing on their own?	(6) Variety of teaching methods
	IA_243, (0.652) Are you satisfied when organizing teaching and learning activities that emphasize the exchange of knowledge between learners and learners or learners and teachers?	
	IA_244, (0.638) Are you satisfied when organizing teaching and learning activities where learners can create their own predictive messages?	
	IA_245, (0.851) Do you believe that learners will feel more interested in the lesson when combining teaching styles with the use of technology?	
	IA_246, (0.774) Is technology important for stimulating and creating ideas to help learners better understand the subject matter of mathematics?	
	IA_247, (0.784) Do you consider the selection of teaching techniques or methods suitable for presenting mathematics subject matter to make it easier for learners to grasp each lesson?	
Teaching and learning activities (IA)	IA_248, (0.826) Can using technology to create teaching materials that are appropriate to the context of mathematics content help learners build their own knowledge of those contents?	(6) Variety of teaching methods
	IA_241, (0.917) Does he enjoy the narrative teaching method?	(7) Use of narrative teaching methods

Additionally, Tiengyoo et al. [9] conducted a study comparing the factors influencing mathematics teaching and learning in the 21st century among mathematics teachers with different characteristics, such as gender, age, and level of education. When considering the gender and level of education of teachers, no statistically significant differences were found in all seven factors at a significance level of .01. This suggests that both male and female teachers with a bachelor's degree or higher degree possess similar technological support, secondary mathematical knowledge, instructional organization skills, and comparable student and school contexts. This finding aligns with semantic theory, which suggests that students' mathematics learning performance is influenced by their subject knowledge and the learning environment tailored to their context and the teaching methods employed by their teachers [12]. Gender and level of education, therefore, do not play a significant role in determining teaching effectiveness; rather, the experience of each teacher becomes a crucial factor [13, 14]. Regarding the age range of different teachers, a notable difference was observed in the fourth factor: the ability to use specialized technology, which showed a statistically significant difference at a significance level of .01. This disparity may be attributed to teachers between the ages of 26-40 and over 40 receiving better technological support, having a solid understanding of secondary-level math concepts, and delivering similar instruction. However, they exhibit varying degrees of proficiency in using specific technologies, as each age group may possess different levels of readiness and responsiveness to technology. This finding aligns with Thorndike's theory of association, which proposes that the ability to learn new things depends on both physical and mental readiness [15].

Term Definition

(1) Effective mathematics education requires: (1) Awareness of technology, that is, of the benefits of incorporating technology in mathematics education; (2) Technological knowledge, including proficiency in word processors, electronic spreadsheets, presentations, geodynamics, programming languages, internet usage, data storage, and leveraging modern technological resources; (3) Content knowledge, including mastery of subject matter, the foundations of mathematical content, and the ability to explain concepts; (4) Teaching and learning activities include teaching styles, methodologies, and approaches to instruction. These factors have been studied by Koehler and Mishra [2]; Saethow [5]; Sirithon et al [6]; and Sripongpird [7]. A questionnaire was used to assess the impact of these factors on the teaching of mathematics.

(2) There are several key factors in the effective teaching of mathematics: (1) Support for the use of technology from schools (access_Fac1); (2) The need for technology in teaching (access_Fac2); (3) Proficiency in using basic technology (TK_Fac1); (4) Proficiency in using specialized technology (TK_Fac2); (5) Content knowledge (CK_Fac1); (6) Variety of teaching methods (IA_Fac1); and (7) Narrative teaching methods (IA_Fac2). These factors were identified and studied by Tiengyoo et al [9].

(3) Schools under the Lopburi Secondary Education Area Office refers to a school within the jurisdiction of the SEAOL. These schools are medium-sized or larger, with 500 students or more [11].

(4) A teacher, in the context referred to here, is an individual who mathematics teaches in a secondary school under the purview of the SEAOL.

Research Methodology

This research adopts a quantitative approach, and employs literature reviews and relevant theoretical frameworks to make the findings more comprehensive. Descriptive statistical analysis and Factor Analysis [9] are used, along with SEM. The results are discussed, summarized, and supplemented, with recommendations for additional research. The AMOS software program was used to analyze SEM.

Research Objectives

To analyze the second-order confirmatory factor structure of the 21st century mathematics teaching predicament (MTP) model among secondary mathematics teachers in the SEAOL

Research Conceptual Framework

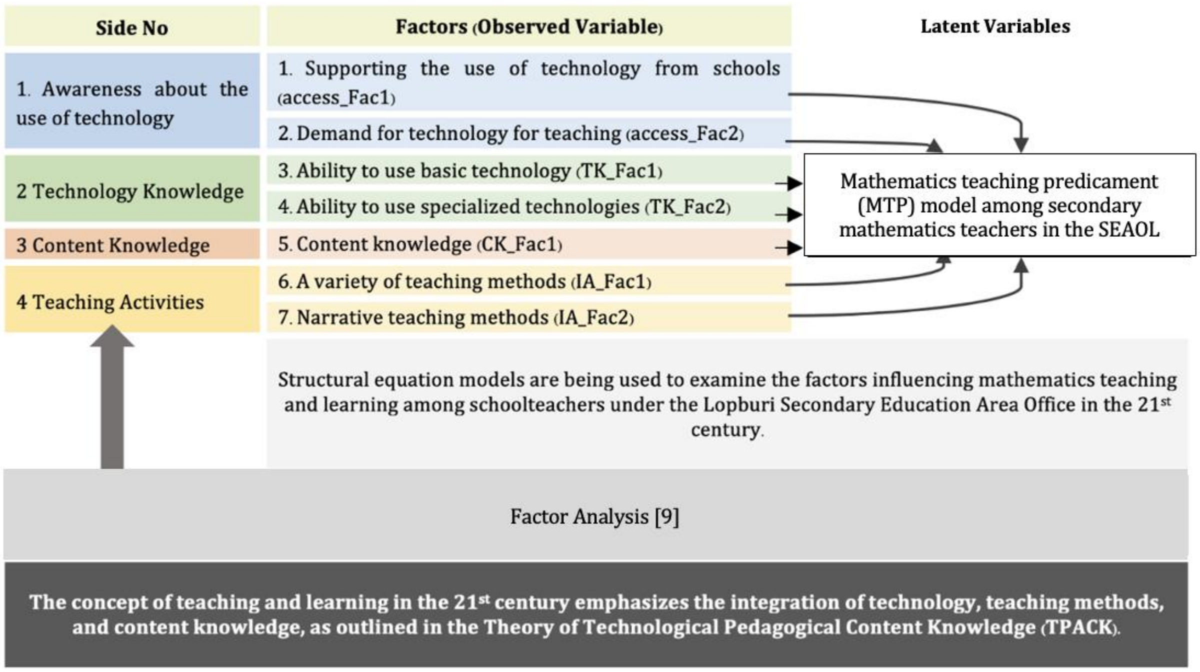

Figure 1 Research concept.

Conflict of Interest statement

This study was reviewed and approved by the institutional ethics committee of Srinakharinwirot University (SWUEC-G-220/2565). The authors declare that there is no conflict of interest.

Population and sample

The research population for this study consisted of 129 secondary mathematics teachers from 13 medium-sized schools under the SEAOL. The sample included 60 secondary mathematics teachers from seven schools in the first semester of the Academic Year 2022. Participants were selected through multi-stage sampling. The sample size was determined using the Yamane formula [16] with a sampling error of 0.1. The analysis was conducted using SEM as a statistical tool, based on the study conducted by Marsh et al and Piriyakal [17, 18]. It was determined that a sample size of n = 50 was sufficient when there were 4 or more indicators per factor, ensuring appropriateness and adequacy.

Data Collection Tools

We administered a questionnaire to secondary mathematics teachers, focusing on the factors influencing the teaching of mathematics. The questionnaire consisted of 37 questions using a 5-level rating scale. The reliability of the questionnaire was assessed using the α-coefficient of Cronbach, which yielded a confidence value of 0.940 [9].

Statistics used in data analysis

For testing the fundamental assumptions of the SEM analysis, various statistics were employed. These statistics included measures of skewness and kurtosis, as well as tests for multicollinearity using Tolerance and Variance Inflation Factor (VIF). The research incorporated various statistical techniques, including confirmatory factor analysis and SEM. Model fit was assessed using several indicators: a *p*-value of $\chi^2 > 0.05$, $CMIN/DF \leq 2.00$, $GFI \geq 0.90$, $TLI \geq 0.90$, $CFI \geq 0.90$, $NFI \geq 0.90$, and $RMSEA \leq 0.08$. Additionally, Construct Reliability (PC) and Average Variance Extracted (PV) were considered. PC was required to exceed 0.60, while PV needed to be higher than 0.50 for acceptability [19].

Collection of Information

To collect the necessary information, we obtained permission from the seven schools in the sample to administer the questionnaires. The questionnaires were distributed online through Google Forms from May 30 to June 30, 2022. We ensured that the questionnaire was completed by the participating teachers and verified the accuracy of the collected data. The data were then coded and processed using appropriate computer programs, allowing us to analyze, synthesize, and summarize the results.

Research Result

(1) The results of the distribution analysis, including skewness and kurtosis, indicate that the skewness values ranged from -1.002 to 0.125, dominance values ranged from -1.006 to 1.902, and both skewness and kurtosis values were within the acceptable range of -3 to 3 and -10 to 10, respectively. Therefore, the variables exhibit a normal distribution, as presented in Table 2.

(2) The tolerance values ranging from 0.404 to 0.866 and the VIF values ranging from 1.155 to 2.478 meet the criteria of having a tolerance greater than 0.1 and a VIF value less than 10. These findings indicate that all the observational variables exhibit a low level of correlation with each other. In conclusion, the observational variables are independent of one another, and there is no occurrence of excessive correlation among the variables (multicollinearity).

Table 2 The Observation variables were assessed for skewness, dominance, tolerance, and VIF

Observational variables	Skewness	Kurtosis	Tolerance	VIF
access_Fac1	-0.357	-0.771	0.665	1.504
access_Fac2	-0.746	-0.022	0.576	1.735
TK_Fac1	-0.891	0.009	0.404	2.478
TK_Fac2	0.125	-1.006	0.687	1.455
CK_Fac1	-0.188	-0.658	0.435	2.296
IA_Fac1	-0.541	0.386	0.508	1.967
IA_Fac2	-1.002	1.902	0.866	1.155

(3) The analysis conducted on the SEM of factors influencing the teaching of mathematics in secondary schools under the SEAOL revealed positive results. The analysis included examining the standard element weights and the observation variables. The conformity analysis of the SEM, using indices such as *p*-value, χ^2, *CMIN/DF*, *GFI*, *TLI*, *CFI*, *NFI,* and *RMSEA*, indicated that all criteria were met. Therefore, it can be concluded that the SEM accurately capture the factors influencing the teaching of mathematics in these secondary schools. The results, as summarized in Table 3, demonstrate a harmonious alignment between the empirical data and the affirmative composition of the models.

Table 3 The model fit statistics indicate the degree of conformity of the SEM

Index	Acceptable value of consistency (criteria)	Statistics obtained
χ^2	*p*-value > .05	0.295
CMIN/DF	$\leq$ 2.00	1.185
GFI	$\geq$ 0.90	0.952
TLI	$\geq$ 0.90	0.866
CFI	$\geq$ 0.90	0.982
NFI	$\geq$ 0.90	0.906
RMSEA	$\leq$ 0.08	0.056

Based on the findings presented in Table 4, the analysis of the affirmative elements of the model revealed the following results: The fidelity variable (PC) obtained a value of 0.83, indicating that the Teacher variable represents 83% of the factors influencing the teaching of mathematics. The average variance extracted (PV) was calculated to be 0.500013, which surpasses the threshold of 0.50. This signifies that the Teacher variable represents 50% of the factors influencing the teaching of mathematics in secondary schools. Overall, the precision statistics (PC) and average variance extracted (PV) affirm the significance of the Teacher variable.

Table 4 The standardized weights of the observed variables in the SEM are Indicators of the factors influencing the teaching of mathematics in the 21st century among secondary mathematics teachers in schools under the SEAOL

Element/Variable	Standardized factor loading	*S.E.*	R^2	*PC*	*PV*
Teacher				0.83	0.50
access_Fac1	0.312	6.944	0.944		
access_Fac2	0.626	13.457	0.391		
TK_Fac1	0.847	17.886	0.718		
TK_Fac2	-0.003	1.744	.000		
CK_Fac1	0.718	15.372	.515		
IA_Fac1	0.668	14.346	.446		
IA_Fac2	0.082	***	0.007		

*** Mandatory parameters (Constrain)

Results and Discussion

It is evident that mathematics teachers in schools under the SEAOL, which includes medium-sized and higher-level schools, possess several key abilities and knowledge. They demonstrate proficiency in utilizing basic technology, possess a deep understanding of subject matter, employ diverse teaching methods, and recognize the importance of technology in teaching and the support of the schools. These competencies can in part be attributed to the impact of the COVID-19 pandemic, which emerged towards the end of 2019 and has significantly disrupted education worldwide. The resulting closure of educational institutions globally has had far-reaching consequences and necessitated widespread changes. Despite the crisis, it is imperative to ensure the continuity and quality of education for students who are unable to physically attend school. In response to these challenges, innovative ideas in teaching and learning have emerged, allowing students to learn regardless of their location through distance learning facilitated by online platforms. This shift has also presented an opportunity to address various teaching and learning problems. Education personnel, including teachers and staff, have had to adapt their perspectives on teaching and learning. They have learned techniques to stimulate students' curiosity and effectively apply materials and technologies relevant to 21st century education. Teachers are expected to be lifelong learners, constantly seeking new knowledge, and adapting to evolving paradigms. This includes embracing a combination of online teaching and regular classroom instruction. The ability to navigate this blended approach is crucial in the current educational landscape. In summary, the research highlights the adaptability and resilience of mathematics teachers in schools under the SEAOL. They have demonstrated proficiency in utilizing technology, employing diverse teaching methods, and actively seeking new knowledge to adapt to the changing educational landscape, particularly considering the COVID-19 pandemic [20].

In teaching mathematics, the narrative method holds significant importance. This aligns with the assertion of Khaemmanee [21] that the unique aspect of the narrative teaching method lies in its ability to convey a substantial amount of material in a short time. Additionally, it emphasizes the need for teachers to possess expertise in specialized technologies. With a limited number of mathematics teachers available in the classroom, it becomes imperative for educators to equip themselves with high-impact teaching practices. One such practice is Project-Based Learning, which fosters student engagement by employing projects as learning tools. Through this approach, students are encouraged to question, conduct research, and independently find solutions to problems. Project-Based Learning plays a pivotal role in cultivating 21^{st} century skills among students, which are essential competencies that Thailand must prioritize to gain a competitive advantage in its human resources. These skills are crucial in propelling Thailand towards sustainable growth and progress.

Moreover, within the field of education, it is vital to incorporate technology and to embrace blended learning. Teachers and administrators must reevaluate their roles, and the organization of learning environments. This new dimension blends elements of public health and education management, allowing for the development of innovative concepts such as design thinking and the cultivation of life skills that enable individuals to effectively navigate future crises. This holistic approach to education is essential for fostering well-rounded individuals with the necessary knowledge, skills, and mindset to thrive in the 21^{st} century.

New Knowledge from Research

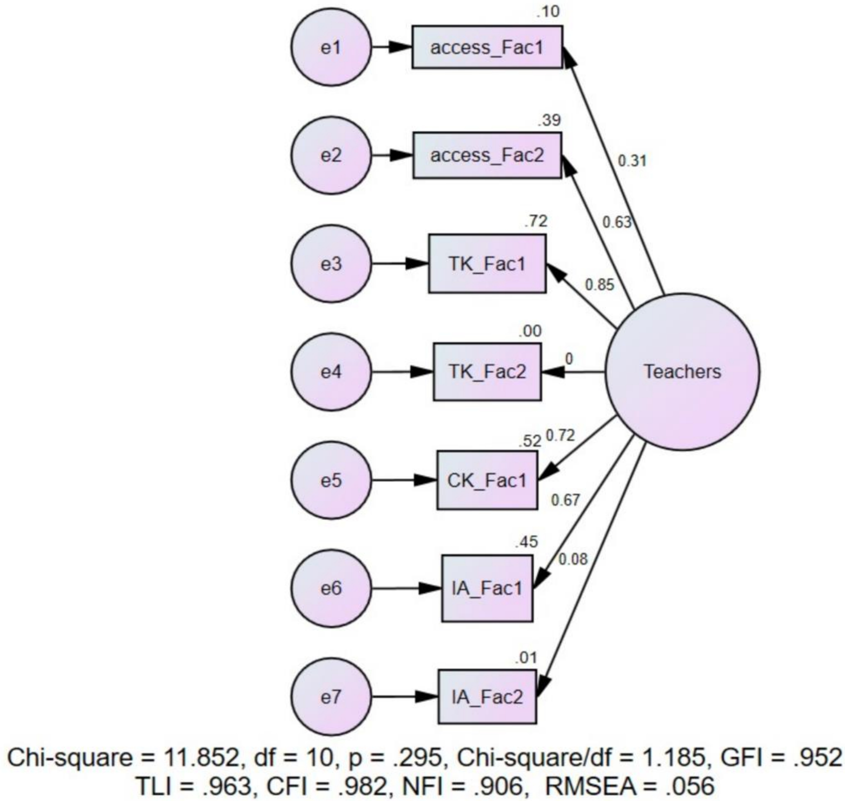

Figure 2 The Application of a SEM to Investigate the Factors Influencing Mathematics Teaching and Learning in the 21st Century among Secondary Mathematics Teachers in Schools under the SEAOL.

Figure 2 presents the influence of various elements on the teaching of mathematics in the 21st century among secondary mathematics teachers in schools under the SEAOL. The elements, in descending order of influence, include the ability to use basic technology, knowledge of content, diverse teaching methods, the need for technology for teaching, support for the use of technology from schools, narrative teaching methods, and the ability to use specialized technology, with corresponding influence rankings of 0.85, 0.72, 0.67, 0.63, 0.31, 0.08, and 0.00, respectively.

Conclusion and Recommendation

Summarize

Based on the findings, the researcher was able to provide a comprehensive overview of the structural equation model that explores the factors influencing the teaching and learning of mathematics in the 21st century among schoolteachers under the SEAOL. The model encompasses seven key factors, namely (1) technology capability; (2) content knowledge; (3) diverse teaching methods; (4) technology demand for teaching; (5) school technology support; (6) narrative teaching methods; and (7) technology competency. These factors, their impact ranked in descending order, have been identified as influential in shaping mathematics teaching.

Suggestion

Based on the results of the research, the researcher made the following suggestions:

Recommendations for using the research findings: The insights gained from this study highlight the varying levels of influence that each factor has on mathematics education. Notably, the research indicates that the utilization of specialized technology by teachers currently has a minimal impact. It is recommended, therefore, that teachers and stakeholders research and develop effective uses of specialized technology in teaching, to leverage technology effectively, and improve mathematics education.

Suggestions for the next research

(1) For future research, samples might be collected from different regions or across the nation, comparing the role of each factor on mathematics education in different regions. This research would help the development of teachers across Thailand, tailored to their strengths and weaknesses, contributing to a region-specific enhancement of mathematics education.

(2) To gain a deeper understanding of the relationship among factors influencing mathematics education, we recommend a comprehensive analysis of structural equation models (SEMs) for each region of Thailand. By examining the SEMs specific to each region, valuable insights can be obtained regarding the impact of these factors on mathematics education. A region-specific analysis would provide a more nuanced perspective, allowing for tailored strategies and interventions to enhance mathematics education based on the unique characteristics of each region.

(3) To assess teachers' ability to integrate knowledge and technology, teaching methods, and content (TPACK) in teaching mathematics, SEMs should be analyzed. This study examines the relationship between TPACK and the teaching practices of mathematics teachers. By employing SEMs, researchers can gain insights into the interconnections and influences of these variables, and shed light on the effective integration of technology, pedagogy, and content in mathematics education. This analysis will provide information to enhance teacher preparation programs and instructional practices to promote effective TPACK integration and improve mathematics teaching.

(4) Teachers and stakeholders should actively research and innovate in the use of technology in education, for example, incorporating graphing calculators in teaching mathematics. By exploring and experimenting with technology, effective instructional methods can be developed, and the student experience enhanced. Through such initiatives, educators can leverage technology to create engaging and interactive learning environments, improving the quality of mathematics education and fostering the academic growth of students.

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