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Exploring factors influencing 21st century mathematics in Thai secondary schools: A study in Lopburi Province

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ABSTRACT

The objective of this study was to ascertain the elements that influence the effectiveness of mathematics instruction in the 21st century for secondary school students within the jurisdiction of the secondary educational service area office Lopburi (SEAOL). The research utilized survey methodology. The study population consisted of 400 secondary school students from SEAOL during the first semester of 2022. The participants were selected using a stratified random selection technique. The research tool utilized in this study was a questionnaire, which demonstrated a high level of reliability with a coefficient of .934. The research employed principal component analysis as the statistical analysis approach. The findings of the study indicate that there are various factors that influence the effectiveness of mathematics instruction in the 21st century for secondary school students in SEAOL. These factors include the level of technology support from schools, use of technology, ability to use basic technology, ability to use specialized technology, knowledge of content, math is crucial, and variety of teaching methods. Additionally, the study reveals that gender, program, and education level have a significant impact on knowledge and opinions regarding mathematics instruction, with statistical significance observed at a significance level of .05.

Keywords: factor analysis, instructional, mathematics, Lopburi, secondary school

INTRODUCTION

In the contemporary era, commonly referred to as the 21st century, the prevalence of information technology has ushered in a period characterized by the incessant growth of knowledge. We are neither interested in children who possess exceptional surfing abilities nor children who demonstrate optimal academic performance only. We look for individuals who are enthusiastic in acquiring knowledge and have a strong desire to engage in continuous learning. Therefore, they can acquire knowledge through effective learning abilities. Additionally, it is desirable for children to develop proficient living skills to enhance their overall quality of life. These matters have commonalities in their importance and significance. In a study conducted by Panich (2015), When considering the learners of the 21st century, it is evident that they differ significantly from their predecessors. Specifically, the current generation of learners possesses a vast amount of knowledge and has convenient access to information. Hence, learners encounter significant challenges in maintaining their focus on classroom instructions. Due to the existence of other pressing concerns, the prioritization of these topics takes precedence. Strategies for cultivating learning in the 21st century is important for possessing the ability to effectively stimulate the cognitive faculties of the learner to cultivate a deep affection for the pursuit of knowledge and intellectual growth and encourage pleasure from the process of acquiring knowledge.

One approach to enhancing the educational experience is to cultivate an environment that fosters enjoyment and intrinsic motivation, thereby promoting sustained engagement in the learning process. Teachers are required to adhere to the pedagogical idea known as “teach less, learn more.” This approach emphasizes the need for teachers to organize student activities in a manner that involves questioning and assessing students’ understanding. By doing so, students can effectively acquire and comprehend the subject matter being taught. What are the responsibilities and duties of teachers? Alternatively, one may choose to refrain from taking any action in this scenario. Teachers have a significantly heightened role in the educational process. This statement calls for instructors to use their utmost effort to address the obstacles they encounter to competently facilitate student learning while ensuring the acquisition of essential skills. Teachers will assume a significantly heightened level of significance. The instructor is required to modify the function of a “coach,” whereby the teacher must provide the essential abilities to facilitate student learning. To foster the application, integration, and extension of acquired information, it is crucial to motivate pupils. In contemporary times, a crucial aspect of acquiring proficiency revolves around the need to reform the educational framework for

both instruction and knowledge acquisition. The objective will be shifted from "educating" to "imparting skills," with a change in focus from instructors to be primarily on pupils.

At a meeting of US educators from diverse areas, the "partnership for 21st century skills" was founded. This initiative created a conceptual framework for teaching and learning, emphasizing the development of knowledge in four key areas (Partnership for 21st Century Skills, 2007; Secondary Education Service Area, 2016):

(1) Core subjects, including language, arts, mathematics, science, geography, history, and citizenship, and the real-life application.

(2) Learning and innovation include project-based learning.

(3) Information and technology, including

   a. information literacy, where students learn to efficiently access resources and evaluate the credibility of search databases,

   b. media literacy, where they learn to use media production tools and choose media for specific purposes, and

   c. technology literacy, where they use technology to search for information.

(4) Life and career: Adapting to change and creating innovative products to make a living; strategies for career advancement in a changing world: flexibility, adaptability, initiative, creativity, self-direction, socio-cultural awareness, productivity, portfolio, leadership, and responsibility.

These abilities will help kids flourish in a changing world. Instructors should help students "construct their own knowledge" by searching for reliable sources, promoting discussion, exploring answers that support academic theories and principles, and contributing knowledge and innovation that benefits society. "Partnership for 21st century skills" is a paradigm shift. Educational institutions worldwide are producing curriculum and textbooks that integrate knowledge and content and combine teaching and technology to improve teaching and learning (Cox, 2008). Koehler and Mishra (2009) suggest "technological pedagogical content knowledge (TPACK)" to help instructors construct 21st century instructional activities. TPACK comprises the skills instructors need to stay current in education industry:

(1) Technological knowledge (TK).

(2) Pedagogical knowledge (PK).

(3) Content knowledge (CK).

(4) Teaching without this understanding is difficult. Integrating two areas: Technological pedagogical knowledge (TPK) and technological content knowledge (TCK) and pedagogical content knowledge (PCK), and

(5) Knowledge integration throughout all three domains, including employing technology to teach and empower students to "create new knowledge".

TPACK helps teachers meet current education standards and provide students with relevant experiences.

Mathematics is a crucial domain of knowledge and ability that has significant importance in 21st century education. Beyond its capacity to develop calculation proficiencies, mathematics encompasses a range of embedded abilities. According to Saethow (2019), indispensable talents like reasoning, problem solving, planning, systematic thinking, prudence, patience, and observation play a substantial role in both personal life and future professional endeavors. However, it is worth noting that a significant number of students possess limited mathematical aptitude and commonly express the sentiment that "mathematics is a challenging subject to comprehend." This perception stems from the inherent theoretical structure of mathematics, which encompasses a multitude of abstract notions.

Consequently, pupils experience feelings of discouragement, a lack of motivation, heightened levels of stress, and the development of negative attitudes. In addition to experiencing a lack of accomplishment in acquiring mathematical knowledge, the issues may also arise due to a multitude of circumstances (Megan, 2004), including but not limited to the instructional techniques employed by teachers and the quality of teaching materials utilized. In cases, where the cause is undetermined or urgent assistance for the pupils is feasible, appropriate actions should be taken. This may lead to long-term difficulties for students in the field of mathematics. Based on the considerations, The researcher was motivated to investigate the preparedness of secondary school students and examine the elements influencing the instruction and acquisition of mathematics among secondary school students in the 21st century. The purpose of this endeavor is to establish a database that can be utilized for the advancement of mathematics education and pedagogy in the contemporary world.

To enhance the efficiency of the education system, it is imperative to focus on the reinforcement of secondary schools within the purview of the SEAOL. This research paper serves as a case study within a larger dissertation, whereby the researcher utilizes the findings to construct a mathematics curriculum that incorporates the Python programming language. The focus of this academic inquiry is on the pedagogy of mathematics instruction in the contemporary era, specifically with regards to the formulation of a study hypothesis that explores the potential influence of various factors such as gender, learning strategies, and educational attainment levels on student performance and achievement. There are several factors that have an impact on students in different ways in the teaching and learning of mathematics in the 21st century.

MATERIALS & METHODS

Research Objectives

The objective of this study is to examine the many elements that influence the instruction and comprehension of mathematics among secondary school pupils in the 21st century. Educational institutions falling within the purview of secondary educational service area office Lopburi (SEAOL).

Research Hypothesis

The present inquiry concerns the examination of gender disparities, study goals, and educational attainment among diverse student populations. Together with various variables influencing the instruction and acquisition of mathematics among individual students over the 21st century.

Scope of Research

Population & sample

The present study employs a survey research methodology. The researcher procures data through the administration of a questionnaire that investigates the many aspects that influence the instruction and acquisition of mathematics in the 21st century among students. The sample population for this study consisted of 17,916 students enrolled in secondary schools. The entity refers to SEAOL. The participants in this study consisted of secondary school students. In the first semester of the academic year 2022, a sample of 400 individuals was acquired from the population within the jurisdiction of SEAOL. The sampling method employed was multi-stage random sampling, which involved calculating the sample size using Yamane (1970) formula in the scenario, where the sampling error is precisely .05.

Research conceptual framework

The utilization of research tools and the analysis of data play a crucial role in the development and identification of high-quality research tools. The researcher began the study by establishing the conceptual framework, which involved amalgamating the notions of elements that influence the instruction and acquisition of mathematical knowledge inside ecclesiastical institutions. Churches (2016), Kharbach (2015), Koehler and Mishra (2009), March (2012), Partnership for 21st Century Skills (2007), and Saethow (2019) conducted research. In their respective studies, Chariyamakarn and Sukpan (2018) and Sripongpird (2018) employed a conceptual framework to examine the various aspects that influence the process of mathematics instruction and acquisition among secondary school students in the 21st century. The educational institutions falling under the jurisdiction of the SEAOL are categorized into four distinct domains, namely:

(1) awareness of technology (AC),

(2) technological knowledge (TK),

(3) content knowledge (CK), and

(4) teaching and learning activities (IA).

Methodology of Research

The research instrument utilized in this study was a questionnaire designed to assess the many elements influencing the teaching and learning of mathematics among secondary school pupils in the 21st century. The questionnaire consisted of 37 items, each of which was evaluated using a five-point rating scale. The responses provided by the participants in this study ranged from strong agreement to strong disagreement, with some expressing uncertainty and others indicating agreement. The scoring criterion consisted of five values, specifically one, two, three, four, and five. The criteria for interpreting the results were derived from the work of Mirasingh (2009) and were afterwards amended in the following manner: The arithmetic mean (M) of the elements influencing the teaching and learning of mathematics may be categorized into five intervals: 1.00-1.49, 1.50-2.49, 2.50-3.49, 3.50-4.49, and 4.50-5.00. These intervals correspond to low, comparatively low, moderate, high, and high degrees of impact, respectively. The questionnaire's appropriateness was assessed by three experts, and the overall confidence value (α-coefficient) of the questionnaire was established using Cronbach's alpha coefficient approach. In a study conducted by Saiyot (2000), it was examined. The coefficient alpha value for the questionnaire was determined to be .934. Additionally, the confidence levels for various aspects of the questionnaire were examined. It was seen that the perception about the use of technology, technological knowledge, content knowledge, and teaching and learning activities had confidence values of .873, .863, .778, and .852, respectively. Subsequently, the participants were instructed to perform an electronic survey using Google Forms between the time frame of 30 May to 30 June 2022. Upon receiving of the questionnaire, the principal investigator of the data was subjected to analysis to determine two key aspects:

(1) the fundamental statistical measures, namely the M and standard deviation (SD), and

(2) the variables that influence the present state of mathematics instruction and learning among secondary school pupils.

This study utilized principal component analysis (PCA), a statistical technique employed for dimensionality reduction. The primary objective of PCA is to transform a dataset containing numerous variables into a smaller set that retains most of the original information. This method facilitates more efficient and rapid data analysis while preserving the essential patterns and relationships within the data. By applying PCA, this research aimed to examine schools affiliated with SEAOL. Additionally, the study aimed to test the hypothesis about the influence of gender, programmed, and educational levels on various pupils. Various

variables influenced the instruction and acquisition of mathematics among individual students over the 21st century, using a *t*-test according to a study conducted by Wanichbuncha (2015).

RESEARCH RESULTS

Demographic Characteristics of Sample

A study on the factors influencing the teaching and learning of mathematics among secondary school students in the 21st century under SEAOL: The researcher will present the research results in the specified order. In the first sample's basic information, when analyzing the students who participated in the questionnaire, it appears that there was a total of 400 students from seven different schools. The percentage representation of students from each school is, as follows: Chai Badan Witthaya School: 24.30%; Pibul Wittayalai School: 24.30%; Phatthana Nikhom School: 14.40%; Princess Chulabhorn Science High School Lopburi: 11.50%; Phra Narai School: 9.50%; Ban Mee Wittaya School: 9.50%; and Khok Samrong Wittaya School: 6.50%. Students who participated in the questionnaire were categorized by gender. The findings revealed that 62.70% of the respondents were female, which was only 37.30% higher than the male respondents. Additionally, the number of students within the age range of 16-18 years was also considered. Most respondents 53.50% answered the questionnaire; the second-highest percentage 46.50% came from the 11-15 age range. When analyzing the number of students who responded to the questionnaire based on their study plans, it was noticeable that some students belonged to the science-mathematics study plan. Additionally, there were students from other study plans. The science-mathematics study plan accounted for 88.70% of the respondents, while the remaining 11.30% belonged to other study plans. Considering questionnaire answered by the respondents classified based on their education level, 51.70% represented those studying in high school, which is higher than those from junior high school, which accounted for 48.30%. However, some students prefer studying in a classroom setting. Out of the students who prefer online learning, specifically through the Zoom program, 70.50% fall into this category. On the other hand, only 29.50% of students prefer other methods of learning. It is worth noting that many students rely on smartphones as their primary technological device. A portable computer, Desktop computer, tablet, or iPad can be used as an advanced calculator. These devices represent 94.80% of the market, with the remaining percentages being 39.80, 29.80, 34.30, and 10.80, respectively. Furthermore, in terms of Internet access, it was discovered that schools, homes, and other locations like Internet cafes were the primary places, where students had the highest level of access to the Internet. When examining the duration of internet usage for different activities, it was discovered that 65.80% of students spent nine-12 hours per day engaging in various online activities. Additionally, 28.00% of students spent a shorter duration, while 29.30% spent a longer duration on average. The percentages for the time intervals are, as follows: 29.0% for more than 12 hours, 28.00% for less than four hours, 25.70% for four to 12 hours, and 17.30% for exactly four hours. In this analysis, we will examine the various factors that impact the teaching and learning of mathematics among secondary school students in the 21st century in schools that fall under SEAOL. The researcher examined four factors: There are four main categories of variables in this study: perceptions about technology use, technology knowledge, content knowledge, and teaching and learning activities. The following are the results of the research.

Mean and Standard Deviation of Student Questionnaire Scores

In **Table 1**, an examination was conducted on the questionnaire pertaining to the elements influencing the instruction of mathematics in the 21st century among secondary school students.

Table 1. Mean & standard deviation of results from a questionnaire on 21st century secondary school mathematics teaching & learning elements

Variable/question	M	SD	Level
Awareness of technology (AC)			
AC_211: Do your school or organization have enough computers for use?	4.20	0.83	Quite a lot
AC_212: Does your school or organization support cloud storage, such as Google Drive or Microsoft OneDrive?	3.97	0.97	Quite a lot
AC_213: Does your school or organization support teaching software, such as Microsoft Office or Zoom Meeting?	4.10	0.89	Quite a lot
AC_214: Does your school has projectors?	4.35	0.82	Quite a lot
AC_215: Does your school or organization have a printer?	3.85	1.03	Quite a lot
AC_216: Does your school or organization have high-speed internet access or Wi-Fi?	4.22	0.85	Quite a lot
AC_217: Does your school or organization prioritize programming in a particular language like Python, C, C++, or Java?	3.39	0.98	Moderate
AC_218: Do you want to use technology to teach because it helps students understand the lesson more concretely?	4.19	0.88	Quite a lot
AC_219: Do you want to use technology for teaching because it serves as an intermediary for communication both inside and outside the school or organization?	4.31	0.82	Quite a lot
AC_2110: Do you want to use technology for teaching because it makes it easier for students to research and find information?	4.49	0.75	Quite a lot
AC_2111: Do you want to use technology in teaching because it helps create learning innovation and improves teaching and learning?	4.33	0.75	Quite a lot
AC_2112: Can knowledge of technology contribute to the efficiency of teaching and learning?	4.30	0.81	Quite a lot
AC usage perceptions	4.14	0.87	Quite a lot
Technological knowledge (TK)			
TK_221: Can you use a word processor such as Microsoft Word or Google Docs?	3.85	0.95	Quite a lot
TK_222: Can you use an electronic spreadsheet such as Microsoft Excel or Google Sheets?	3.49	1.01	Moderate
TK_223: Can you use a presentation program such as PowerPoint or Google Slides?	3.83	0.97	Quite a lot

Table 1 (Continued). Mean & standard deviation of results from a questionnaire on 21st century secondary school mathematics teaching & learning elements

Variable/question	M	SD	Level
TK_224: Can you use dynamic geometry software such as GSP or GeoGebra?	3.02	1.18	Moderate
TK_225: Can you program in a specific language, such as C, C++, Python, or Java?	2.85	1.14	Moderate
TK_226: Can you communicate via the internet using tools like email, Line, or Messenger?	4.51	0.81	A lot
TK_227: You have the option to store a wide range of data, including flash cards, CDs, DVDs, Google Drive, or Dropbox.	3.65	1.00	Quite a lot
TK_228: Do you keep up with modern technology and constantly study its use?	4.00	0.92	Quite a lot
TK_229: Can you use specialized software as a medium for teaching mathematics, such as Scratch?	3.19	1.07	Quite a lot
TK_2210: Do you believe that technological knowledge affects the teaching and learning of mathematics today?	4.01	0.94	Quite a lot
TK usage perceptions	3.64	0.99	Quite a lot
Content knowledge (CK)			
CK_231: Can you identify or explain the meaning of the subject matter being taught?	3.51	0.82	Quite a lot
CK_232: Can you explain the origin of the teachings?	3.38	0.86	Moderate
CK_233: Can you apply your knowledge correctly?	3.60	0.87	Quite a lot
CK_234: Are you always seeking more knowledge from up-to-date sources?	3.58	0.95	Quite a lot
CK_235: 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?	3.71	0.99	Quite a lot
CK_236: What do you think is the current content of mathematics instruction? Does it respond to learners' needs?	3.38	0.94	Moderate
CK_237: Do you believe that having complex math problems will affect effectiveness of teaching & learning mathematics?	3.67	0.99	Quite a lot
CK usage perceptions	3.55	0.92	Quite a lot
Teaching and learning activities (IA)			
IA_241: Do you enjoy the narrative teaching method?	3.56	1.01	Moderate
IA_242: Are you satisfied when organizing teaching & learning activities that focus on students practicing on their own?	3.91	0.88	Quite a lot
IA_243: Are you satisfied when organizing teaching and learning activities that emphasize the exchange of knowledge between learners and learners or learners and teachers?	3.97	0.91	Quite a lot
IA_244: Are you satisfied when organizing teaching and learning activities where learners can create their own predictive messages?	3.79	0.88	Quite a lot
IA_245: Do you believe that learners will feel more interested in the lesson when combining teaching styles with the use of technology?	4.05	0.88	Quite a lot
IA_246: Is technology important for stimulating and creating ideas to help learners better understand the subject matter of mathematics?	3.99	0.85	Quite a lot
IA_247: Do you consider the selection of teaching techniques or methods suitable for presenting mathematics subject matter to make it easier for learners to grasp the concept of a lesson?	4.03	0.88	Quite a lot
IA_248: 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?	3.98	0.84	Quite a lot
IA usage perceptions	3.91	0.89	Quite a lot
Sum	**3.81**	**0.92**	**Quite a lot**

The analysis focused on the scores assigned to the variables that pertain to the teaching of mathematics in the era. The data analysis revealed that the M of the variables was 3.81, with a SD of 0.92. These findings suggest a significant impact of these factors on the teaching and learning of mathematics. When examining the factors that influence the instruction and acquisition of mathematics for individual students, it was discovered that the perception of technology, technological expertise, content knowledge, and teaching and learning activities play significant roles. The M for the above set of numbers are 4.14, 3.64, 3.55, and 3.91, while the corresponding SD values are 0.87, 0.99, 0.92, and 0.89, respectively. There are several levels as well.

An Analysis of Factors Influencing Learning of 21st Century Mathematics Among Secondary School Students in SEAOL

According to the findings presented in **Table 2**, an examination of the Kaiser-Meyer-Olkin (KMO) index reveals that the variables pertaining to the teaching and learning of mathematics in the 21st century among students exhibit KMO values of .902, .852, .829, and .881 in relation to aspects of perception about the use of technology, technology knowledge, content knowledge, and teaching and learning activities, respectively.

Table 2. Impacting mathematics teaching & learning

Variable	Factor		Communalities
	1. Technology support from schools (Access_FAC1)	2. Use of technology (Access_FAC2)	
Awareness of technology (AC)			
AC_215	.695		.499
AC_212	.694		.524
AC_217	.680		.494
AC_211	.640		.455
AC_213	.625		.487
AC_214	.624		.516
AC_216	.615		.383
AC_2111		.858	.774
AC_2110		.836	.736

Table 2 (Continued). Impacting mathematics teaching & learning

Variable	Factor		Communalities
	1. Technology support from schools (Access_FAC1)	2. Use of technology (Access_FAC2)	
AC_219		.817	.716
AC_218		.755	.642
AC_2112		.738	.592
Eigenvalue	3.582	3.235	
% of variance	29.847	26.961	
Cronbach's alpha=.873, Total=56.808%, KMO=.902, Bartlett's test of sphericity approximate Chi-square=2,030.227**, df=66, & Significances=.000			
	3. Ability to use basic technology (TK_FAC1)	4. Ability to use specialized technology (TK_FAC2)	
Technological knowledge (TK)			
TK_226	.773		.624
TK_221	.744		.662
TK_223	.693		.608
TK_2210	.689		.475
TK_228	.643		.480
TK_227	.635		.561
TK_225		.823	.678
TK_224		.809	.664
TK_229		.628	.433
TK_222		.605	.606
Eigenvalue	3.211	2.581	
% of variance	32.111	25.806	
Cronbach's alpha=.863, Total=57.917%, KMO=.852, Bartlett's test of sphericity approximate Chi-square=1,491.199**, df=45, & Significances=.000			
	5. Knowledge of content (CK_FAC1)	6. Math is crucial (CK_FAC2)	
Content knowledge (CK)			
CK_233	.838		.702
CK_232	.835		.722
CK_231	.786		.648
CK_236	.722		.639
CK_234	.692		.505
CK_237	.460		.221
CK_235		.939	.901
Eigenvalue	3.259	1.090	
% of variance	49.503	15.572	
Cronbach's alpha=.778, Total=61.981%, KMO=.820, Bartlett's test of sphericity approximate Chi-square=934.969**, df=21, & Significances=.000			
	7. Variety of teaching methods (IA_FAC1)		
Teaching & learning activities (IA)			
IA_246	.815		.664
IA_247	.806		.650
IA_245	.802		.643
IA_248	.802		.643
IA_243	.753		.568
IA_244	.710		.504
IA_242	.613		.376
IA_241	.329		.209
Eigenvalue	4.155		
% of variance	51.937		
Cronbach's alpha=.852, Total=51.937%, KMO=.881, Bartlett's test of sphericity approximate Chi-square=1,360.904**, df=28, & Significances=.000			

These KMO values align with the results obtained from Bartlett's test of sphericity, which yielded χ^2 values of 2030.227, 1491.199, 934.969, and 1360.904 for the aspects, respectively.

The study determined that there is a statistically significant relationship between the variables influencing the instruction and acquisition of mathematical knowledge among students in the 21st century across all four dimensions. The data exhibits statistical equality at a significance level of .01. The variables in factor analysis exhibited a range of values, spanning from .209 to .901. Furthermore, the PCA approach identified key elements in each aspect with eigenvalues larger than 1.00. Therefore, the variables within each aspect were found to meet this criterion. There were four primary components, with relative percentages of variation for all variables being 56.808%, 57.917%, 61.981%, and 51.937%. Furthermore, this study examines the many elements that influence the instruction and acquisition of mathematical skills among secondary school pupils in the 21st century. In the study, participants were classified based on their gender, educational program, and educational attainment. The analysis revealed that male students exhibited certain characteristics. The study programs in science and mathematics encompass both high school students and college students. The components with the highest M were six, five, and two, which were equivalent to .07 (SD=.95), .04 (SD=.99), and .15 (SD=.93), respectively. Several pupils exhibited variables with statistical significance levels of .05 for factors five and seven, whereas other factors did not demonstrate significant differences.

Table 3. Hypothesis test results on comparison between gender, curriculum, & educational level of students with factors influencing student's mathematics learning & teaching

Factor	Gender			Curriculum			Educational level		
	t	df	p	t	df	p	t	df	p
Access_FAC1	-.83	398	.408	1.03	398	.306	-1.71	357.91	.089
Access_FAC2	-.446	398	.656	.59	398	.556	-3.06*	398	.002
TK_FAC1	.93	398	.355	1.52	398	.130	-3.16*	398	.002
TK_FAC2	.81	398	.420	.80	398	.424	.98	398	.329
CK_FAC1	-.14	398	.889	2.25*	398	.025	-.97	398	.334
CK_FAC2	1.00	398	.316	.62	398	.535	-1.99*	398	.047
IA_FAC1	-.58	398	.562	1.98*	398	.049	-2.70*	398	.007

Note. *p<.05

Hypothesis Testing in Research

From **Table 3**, when considering students' gender, revealed that factors technology support from schools, use of technology, ability to use basic technology, ability to use specialized technology, knowledge of content, math is crucial, and variety of teaching methods did not differ significantly at the .05 level of significance. Furthermore, when examining students' curriculum, it was found that factors technology support from schools, use of technology, ability to use basic technology, ability to use specialized technology, and math is crucial did not differ significantly, while factors knowledge of content and variety of teaching methods did differ significantly at the .05 level of significance.

However, when considering students' educational level, it was found that factors technology support from schools, ability to use specialized technology and knowledge of content did not differ significantly, while factors use of technology, ability to use basic technology, math is crucial, and variety of teaching methods did differ significantly at the .05 level of significance.

DISCUSSION & RECOMMENDATIONS

The overall M obtained from the student questionnaire, as well as the M for each facet of the variables influencing the teaching and learning of mathematics in the 21st century, were found to be significantly high. However, several variables have the lowest M at the moderate level, namely the variable labeled "TK_225". Undoubtedly, the advent of the COVID-19 pandemic has undeniably had a significant influence on the process of learning, mostly because of the widespread adoption of online learning methodologies. Particularly pragmatic disciplines, such as computational science, necessitate adherence to the instructor's prescribed programming protocols. Consequently, there is a lack of comprehension among students regarding programming. Nevertheless, possessing an understanding of the syntax and structure of a certain programming language may not suffice to effectively develop a program. It is imperative that pupils possess a comprehensive understanding of mathematics as well. Through examination of the IPST textbook, a curriculum designed for secondary school students, it is evident that the computational science course provides an opportunity for students to develop programming skills by using their mathematical knowledge.

The objective is to provide students with programming abilities that are grounded in mathematical principles. According to Martinez (2022) study, the integration of programming, namely the Python language, with the acquisition of mathematical knowledge has been investigated. The instrument in question will serve as a valuable resource, facilitating the development of mathematical comprehension among pupils. However, it can also serve as a catalyst for the development of enhanced mathematical thinking abilities among children. Based on the data shown in **Table 1**, it can be observed that the percentage of students possessing electronic equipment for educational purposes and having a home internet connection was below 50.00%. However, the absence of these technical resources or the fact that there are individuals who lack the ability to connect to the Internet within their residence do not hinder effective learning as the availability of technology and internet connectivity within educational institutions mitigates potential obstacles for students. The researcher has anticipated that the utilization of the Python programming language in the development of mathematics teaching and learning activities might potentially boost the learning efficiency of secondary school pupils.

The cohort of high school student's educational institutions falling within the purview of the SEAOL study revealed the viewpoint surrounding the utilization of technology. There are two primary variables that provide support for the integration of technology into educational institutions. The demand factor for instructional technology is a significant consideration in educational settings. The possible cause of this phenomenon may be attributed mostly to educational institutions. The primary area of interest pertains to the utilization of technology among students in secondary education. The alignment of data storage support in cloud systems with the research findings of Sripongpird (2018) suggests that the supply of equipment, support, and learning-related documents are the significant elements influencing efficiency. The acquisition of knowledge among students. Furthermore, programing is ranked third concerning its significance. Pantarakphong (2019) believes that if students can perceive the correlation between programming and mathematics, it is likely to lead to an enjoyable learning experience that fosters systematic thinking and enhances their appreciation for the significance of mathematics and answer the demand for educational technologies among secondary school pupils for the purpose of enhancing pupils' access to supplementary mathematical information in addition to its utilization for intra- and inter-school communication.

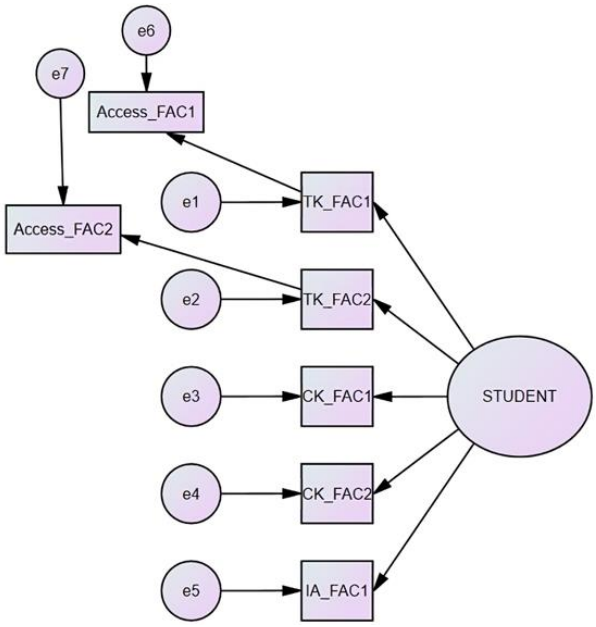

Figure 1. Structured equation modeling analysis of factors impacting secondary school students' learning of 21st century mathematics (Tiengyoo, 2023)

As for the realm of technological knowledge, there were two primary factors identified in this study. The first factor was proficiency in utilizing fundamental technological tools. It was observed that students placed the highest level of significance on communication technology facilitated by the Internet. This preference could have been attributed to the widespread use of email, Line, or Messenger as the primary means of submitting assignments. These platforms are considered the most convenient and expedient communication channels in the present-day context. According to research by Kaewwit and Prakobtham (2007), the Internet is comparable to a vast library of knowledge. However, the authors argue that for the Internet to effectively aid students, it is imperative that teachers provide proper guidance and training on its appropriate usage. Furthermore, in relation to the knowledge component pertaining to the use of certain technologies, it was shown that proficiency in programming across several programming languages exhibited the most significance within this element. This is consistent with Cetin (2009) observation. According to a study conducted in 2009, programming plays a significant role in not only improving students' understanding of mathematical concepts but also fostering their interest in learning mathematics. Additionally, the findings of Vidakovic et al (2018) indicate that programming serves as a valuable tool for expediting students' comprehension of mathematics when providing pupils with opportunities to investigate and analyze mathematical concepts until they can formulate their own predictions. In the acquisition of knowledge pertaining to a certain subject matter, the one aspect that holds primary significance is the administration of teaching and learning, which may be due to the fact that the utilization of technology in education is well regarded by students as it facilitates the visualization of knowledge through the integration of many teaching methodologies, complemented by the incorporation of technological tools (Mazen, 2021). **Figure 1** shows structured equation modeling analysis of factors impacting secondary school students; learning of 21st century mathematics.

Furthermore, the test findings are derived from the underlying concept that there exists a correlation between many factors, such as gender, learning goals, and educational levels of pupils. Various variables influenced the teaching and learning of mathematics in the 21st century, with each element exerting its own distinct impact. When examining the gender and study goals of various students, it was seen that there were two components, namely factor 5 and factor 7, which manifested at varying levels. The concept of statistical significance is a fundamental aspect of quantitative research and data analysis. It refers to the level of confidence one might have in the results obtained from a statistical test. In the above scenario, it was observed that factor 5 exhibited no significant variation while the remaining components remained constant, perhaps attributable to male and female pupils exhibit readiness for maturity and experience. The provision of technology or the acquisition of mathematical knowledge at the secondary level, as well as the level of satisfaction with teaching and learning styles, contextual factors, and the presence of peers of comparable age, do not pose a barrier to the elements. This aligns with the principles of learning theory in the field of mathematics. According to Dienes (1971), it was argued that gender was not a significant factor influencing pupils' mathematical learning. Nevertheless, the presence of preparedness in all facets, along with ample learning experience, are regarded as influential variables in the acquisition of mathematical knowledge. Many pupils receive assistance through the utilization of technology. Individuals possess the capacity to proficiently utilize fundamental and specialized technological tools, together with harboring an extensive range of viewpoints pertaining to mathematical concepts that surpass the immediate requirements for practical application in the foreseeable future. However, the level of proficiency in mathematics varies across individuals.

According to the findings of a study conducted by Saethow (2019), it was seen that students who pursued the science-math study plan had superior mathematical ability in comparison to their counterparts who pursued alternative study plans. The discrepancy in academic performance between students who followed the science-math study plan and those who pursued alternative study plans may be attributed to many factors. Students enrolled in alternative study programs had unfavorable views and expressed apprehension over their early proficiency in mathematics. Irrespective of whether educators modify their

instructional methods and approaches to make them more engaging, the study by Thanaratanasrisakul (2015) suggests that while including Mathematics into the curriculum may enhance the interest of students pursuing alternative study plans, it may not provide the same level of enthusiasm, as shown among students enrolled in science-mathematics study plans who had pre-existing aptitude and a favorable attitude towards the subject. However, after considering the varying educational levels of pupils, there were four components (two, three, five, and seven) that exhibited statistically significant differences. While all other components remained constant, the value at zero increased to five perhaps attributable to the utilization of technology for educational purposes, which is constrained when there is a disparity in educational attainment levels and proficiency in using fundamental technology. The inclusion of comments about the mathematical content is crucial for a successful implementation. This study examines the level of satisfaction with the disparity in teaching and learning styles. Piaget's theory of cognitive development says that people's intelligence grows in a way that prevents them from skipping or passing over developmental stages (Prawat & Floden, 1994).

For future research, structured equation modeling is a useful tool for readers interested in learning more regarding the elements influencing mathematics education in the 21st century.

Author contributions: KT: analyze previous work done on 21st century skills & TPACK framework, develop a guiding theoretical framework, collect data from students; **SS:** develop the study's subject of inquiry & design & use methods from statistical analysis to analyze data being analyzed; & **ST:** review existing literature on factor analysis. All authors have agreed with the results and conclusions.

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REFERENCES

Cetin, I. (2009). *Students' understanding of limit concept: An APOS perspective* [Doctoral dissertation, Middle East Turkey University]. https://www.researchgate.net/publication/289375642_STUDENTS'UNDERSTANDING_OF_LIMIT_CONCEPT_AN_APOS_PERSPECTIVE

Chariyamakarn, R., & Sukpan, C. (2018). Factors influencing mathematics learning achievement of Princess of Naradhiwas students: Multilevel analysis. *Princess of Naradhiwas University Journal of Humanities and Social Sciences*, *5*(2), 26-40. https://so05.tci-thaijo.org/index.php/pnuhuso/article/view/133576

Churches, A. (2016). *21st century pedagogy*. https://www.teachthought.com

Cox, S. M. (2008). *A conceptual analysis of technological pedagogical content knowledge*. https://scholarsarchive.byu.edu/etd/1482

Dienes, Z. P. (1971). *Building up mathematics*. Hutchinson Educational LTD.

Kaewwit, R., & Prokobtham, B. (2001). *Factors influencing Internet use behaviour of tertiary students in Bangkok and its vicinity Bangkok University.* Bangkok University Press. http://dspace.bu.ac.th/jspui/handle/123456789/3355

Kharbach, M. (2015). *The 20 digital skills every 21st century teacher should have*. http://www.educatorstechnology.com/2012/06/33-digital-skills-every-21st-century.html

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary Issues in Technology and Teacher Education*, *9*(6), 60-70. https://scirp.org/reference/referencespapers?referenceid=1565932

March, T. (2012). *21st century teaching skills*. http://tommarch.com

Martinez, A. (2022). *Emergent modeling: Using python in an instructional task sequence on logic and set theory*. https://www.researchgate.net

Mazen, H. (2021). *Cognitive constructivist*. http://www.hosamma2en.blogspot.com

Megan, M. L. (2004). *Examining school climate: Defining factors and educational influences*. https://citeseerx.ist.psu.edu

Mirasingh, V. (2009). *Some factor affecting information technology utilization to enhance learning in the classroom of the fourth interval students in schools under the basic education commission, Bangkok educational service area office II* [Unpublished master's thesis]. Srinakharinwirot University.

Panich, W. (2015). Ways of creating learning for students in the 21st century. *Journal of Learning Innovation, 1*(2), 1-4.

Pantarakpong, P. (2019). *Basic mathematics for computer programming*. Thammasat University Press.

Partnership for 21st-century skills. (2007). *Framework for 21st-century learning*. https://www.teacherrambo.com/file.php/1/21st_century_skills.pdf

Prawat, R. S., & Floden, R. E. (1994). Philosophical perspective on constructivist view of learning. *Educational Psychologist, 29*(1), 37-48. https://doi.org/10.1207/s15326985ep2901_4

Saethow, P. (2019). The factors affecting students learning mathematics in Dusit Thani College, Pattaya. *Dusit Thani College Journal*, *13*(2), 294-306. https://so01.tci-thaijo.org/index.php/journaldtc/article/view/241073

Saiyot, A. (2000). *Techniques for measuring learning outcomes*. Chula Press.

Secondary Education Service Area. (2016). *Framework for 21st-century learning*. http://sesa.obec.go.th

Sripongpird, M. (2018*). Selected factors affecting the 21st century learning management efficiency of primary school teachers in Pathum Thani Province* [Master's thesis, Rajamangaka University of Tehnology]. http://www.repository.rmutt.ac.th/dspace/bitstream/123456789/3558/1/RMUTT-161622.pdf

Thanaratanasrisakul, M. (2015). *Analysis of factors affecting achievement in mathematics for students in grade 6 at Rajini Burana School*. Kasetsart University Press.

Tiengyoo, K. (2023). *The development of instructional activates to enhance mathematical understanding levels of Set based on APOS theory by using python for mathayomsuksa students* [Unpublished doctoral dissertation, Srinakharinwirot University]. http://ir-ithesis.swu.ac.th/dspace/handle/123456789/2221

Vidakovic, D., Dubinsky, E., & Weller, K. (2018). *Creativity and technology in mathematics education APOS theory: Use of computer programs to foster mental constructions and student's creativity*. Springer. https://doi.org/10.1007/978-3-319-72381-5_18

Wanichbuncha, K. (2015). *Advanced statistical analysis by SPSS*. Chula Press.

Yamane, T. (1970). *Statistics–An introductory analysis*. John Weather Hill, Inc.