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Teachers are Digitally Equipped, but for Teaching? Exploring Mathematics Teachers' Perceived Levels of Digital Competencies for Teaching with Technology

Forster D. Ntow [1], Christian Kwame Kpotosu [1,2*]

[1] University of Cape Coast, GHANA,
[2] The Pennsylvania State University, UNITED STATES
* Correspondence: christian.kpotosu001@stu.ucc.edu.gh

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ABSTRACT

Utilising technology for teaching mathematics relies on the teachers' ability to select and use suitable digital tools/resources for specific mathematics topics. Therefore, it can be anticipated that activities conducted within various instructional contexts necessitate distinct sets of competencies for teachers. This study examines senior high school mathematics teachers' perceptions of their levels of digital competencies for teaching with technology, using the Mathematical Digital Knowledge for Teaching with Technology (MDKT) framework. We used a descriptive survey design rooted in the positivist paradigm to collect quantitative data on 178 mathematics teachers' digital knowledge for teaching with technology in the Cape Coast Metropolis, Ghana. The data were collected from the mathematics teachers using a closed-ended questionnaire administered via Google Forms. The findings showed that mathematics teachers possessed high knowledge of digital content and curriculum, high knowledge of digital content and students, high specialised digital content knowledge, but moderate knowledge of digital content and teaching for teaching mathematics with technology. This calls for targeted training opportunities and professional development interventions to help teachers design and enact lessons using digital resources, thereby improving their digital knowledge for teaching mathematics with technology.

Keywords: digital competencies, digital knowledge, content, curriculum, MDKT, technology

INTRODUCTION

There is a consensus that utilising digital technologies can improve engagement and understanding of mathematical concepts and facilitate the formation of important cognitive links (Gueudet, 2015; Pepin et al., 2017). Therefore, there is a growing fascination with using technology to teach mathematics. Tabach and

Trgalová (2019) acknowledged that a significant component of a teacher's professional duties extends beyond the classroom. This encompasses various tasks such as lesson preparation, resource exploration, and communication with fellow teachers. Teachers employ diverse technological tools in their pedagogical practices, including specialised mathematical software designed to facilitate instruction in numerical concepts. However, mathematics instructors are facing new challenges in selecting, evaluating, and incorporating resources due to the abundance of technology tools available (Thomas & Edson, 2018). All of these emphasised the significance of teachers possessing the necessary competencies to efficiently utilise technology in the classroom to communicate mathematical concepts to their students.

As defined by the Organisation for Economic Co-operation and Development (OECD, 2003, p. 4), "A competency is more than just knowledge or skills. It involves the ability to meet complex demands by drawing on and mobilising psychosocial resources (including skills and attitudes) in a particular context." As per Tabach and Trgalová (2018), mathematical digital knowledge for teaching involves teachers possessing a variety of skills and competencies- from utilising digital tools to improve teaching methods to creating and presenting engaging mathematical content using digital platforms. For this research, "digital competence" is defined as mathematics teachers' familiarity with and skill in selecting and implementing appropriate technological tools to teach specific mathematical concepts. For instance, understanding the role of GeoGebra in supporting algebraic thinking and enhancing spatial reasoning requires teachers to possess high levels of digital competencies for teaching mathematics with technology. This level of digital competence helps mathematics instructors evaluate, select, and use digital materials (such as GeoGebra) based on their expertise, background, and preferences.

Understanding how incorporating digital resources into educational practices can help achieve learning objectives in a specific subject requires a combination of subject expertise and experience with technology in teaching. This has prompted scholars to explore mathematics teachers' technology knowledge (Kartal & Çınar, 2022) and digital literacy (Quaicoe & Pata, 2015; 2020). Thus, prior research frequently emphasised general digital competencies instead of those tailored to the instruction of mathematics using technology. For example, Ardiç and Isleyen (2017) observed in their workshop that teachers effectively integrated technology into their classroom practices, resulting in transformation and amplification. However, Birgin et al. (2020) found that Turkish mathematics teachers predominantly use ICT for social media and communication, indicating limited understanding and proficiency in utilising ICT for instructional purposes. Ardiç (2021) found that teachers often used smartboards exclusively during instructional sessions, showing a preference for teacher-centred classroom activities that lacked the necessary hardware and software for student engagement. These findings indicate that teachers' access to and familiarity with digital tools do not guarantee pedagogically meaningful use of technology in mathematics instruction. They suggest a persistent gap between technical proficiency and instructional application, which reinforces the need to examine their perceived levels of digital competencies for teaching mathematics rather than technology use per se.

To close this gap, Tabach and Trgalová (2018, 2019, 2020) developed a digital competencies framework, Mathematical Digital Knowledge for Teaching with Technology (MDKT), for teaching mathematics with technology to investigate teachers' competencies in utilising technology in teaching mathematics. The MDKT framework was customised to address specific technological aspects of mathematics. This framework included the specialised digital content knowledge, knowledge of digital content and students, knowledge of digital content and teaching, and knowledge of digital content and curriculum.

The teacher's specialised knowledge of digital content requires teachers to assess the quality and impact of digital materials, and to choose and adjust them to align with educational goals. In addition, understanding the effective integration of digital technology into the teaching of mathematics, while considering pedagogical aspects of instruction and learning, demonstrates teachers' competence with digital content and teaching, which may differ in a tech-driven setting due to the availability of digital resources. Teachers' understanding of digital content and curriculum, derived from their familiarity with the recommended use of digital resources, relates to their ability to seamlessly incorporate digital technology into mathematics curriculum development and instruction. Thus, mathematics teachers should have a strong understanding of how to design and develop a mathematics curriculum that effectively incorporates digital technology. This is important because understanding students' preferred modes of digital communication and utilising digital tools to customise instruction and personalise learning to meet individual student needs is essential in this digital age.

In the Ghanaian context, prior research presents a fragmented picture of teachers' technology use. While Donkor (2018) reported low levels of ICT integration among in-service mathematics teachers in the Cape Coast Metropolis, Barfi et al. (2020) found that teachers were generally comfortable using ICT resources in teaching and learning. This divergence suggests that teachers' apparent ease with digital tools may not reflect subject-specific digital knowledge for mathematics instruction, such as understanding how tools like GeoGebra support algebraic and spatial thinking. Consequently, there is limited empirical evidence on mathematics-specific frameworks such as MDKT, creating a critical gap that we sought to address. To the best of our knowledge and as at the time this study was conducted, only Trgalová and Tabach (2020) used the MDKT framework in empirical studies. They reported that most teachers in France and Israel possess an intermediate level of knowledge in creating and modifying digital resources and in lesson planning.

Additionally, the current competence frameworks focus on general digital competencies rather than the specific mathematical digital competencies needed for teaching mathematics with technology, to assess teachers' perceived levels of knowledge of digital content and students, teaching, curriculum, and specialised digital content knowledge. To this end, we argue that utilising technology for effective mathematics instruction requires teachers to possess high levels of digital competence, necessitating the adoption of Tabach and Trgalová's (2020) Mathematical Digital Knowledge for Teaching (MDKT) framework for empirical data, since prior research, specifically in the Ghanaian context, had not used it to analyse the digital competencies of mathematics teachers. Hence, the research question that guided the study is: *What are senior high school mathematics teachers' perceptions of their level of digital knowledge for teaching with technology?*

Policies and Challenges in ICT Integration in Ghana

Ghana's government has prioritised ICT in driving the country's economy over the years. These policies have enabled Ghana to make significant progress in integrating technology into its educational system through initiatives that encourage its use in classrooms. Despite these efforts, challenges persist that impede the successful integration of technology in Ghanaian classrooms. Moreover, reports and studies (Amenyedzi et al., 2011; GhanaWeb Regional News, 2015) indicate a disconnect between teachers' digital competencies and the integration of ICT in the classroom. The effectiveness of technology integration policies depends heavily on how they are implemented and monitored. Oftentimes, there is a disconnect between policy development and implementation (Gomez Jr., 2020), resulting in less-than-ideal outcomes. This also results in a disconnect between the curriculum and the technology available to teachers and students (Grimus, 2020).

Many teachers in Ghana face challenges in embracing new ideas and utilising technology, especially in areas with a digital divide (Quaicoe & Pata, 2015). Thus, these teachers often struggle to connect digital tools to the prescribed curriculum, hindering effective technology integration. Access to digital resources can be influenced by socioeconomic disparities and geographic variations, affecting teachers. In furtherance, addressing the challenge of providing equal access to technology for all teachers remains a major hurdle. Recent policies include providing one laptop per teacher, dubbed 'One-Teacher-One-Laptop,' which was launched in 2021, and large-scale distribution continued through 2024. The *One-Teacher-One-Laptop* policy (Citinewsroom, 2021) was implemented to provide teachers with laptops (loaded with subject-specific digital tools and materials), enabling them to create digital lesson plans and access educational resources to improve their teaching methods. This initiative sought to enhance the overall quality of teaching by utilising technology to support teachers' professional growth and instructional methods. Additionally, the implementation of the one-teacher-one-laptop policy was designed to ensure that every teacher had access to a laptop, enabling them to engage in personalised learning and develop their digital literacy skills. This initiative aimed to narrow the digital access gap and equip teachers with the skills needed for a contemporary, technology-driven society. Unfortunately, a significant number of teachers, from the beginning of the policy, do not possess the essential skills to utilise the laptops they have been given effectively, and questions remain about pedagogically meaningful use, especially in teaching mathematics. Since the launch of the program, teachers' access to digital devices has increased substantially (Citinewsroom, 2021; Graphic Online, 2024); however, access alone does not account for mathematics-specific digital competencies required for teaching with technology. Also, device distribution alone does not ensure pedagogically meaningful technology integration, thereby motivating our focus on teachers' perceived digital competencies for teaching with technology.

THEORETICAL FRAMEWORK

The theoretical framework we used is the Mathematical Digital Knowledge for Teaching (MDKT) framework (Tabach & Trgalová, 2020), shown in **Figure 1**. The MDKT framework offers a specialised perspective that surpasses general frameworks such as TPACK and TAM, as well as international (UNESCO, ISTE) and national (P21.org, Israel, US, Australia, France, and NCTM) ICT standards documents, by focusing on the interaction between mathematics as a field and digital tools. General frameworks focus on broad technological competencies, whereas MDKT highlights the knowledge required to effectively utilise digital tools for mathematical reasoning, problem-solving, and representation. This specificity facilitates a comprehensive understanding of how technology influences mathematical instruction and learning.

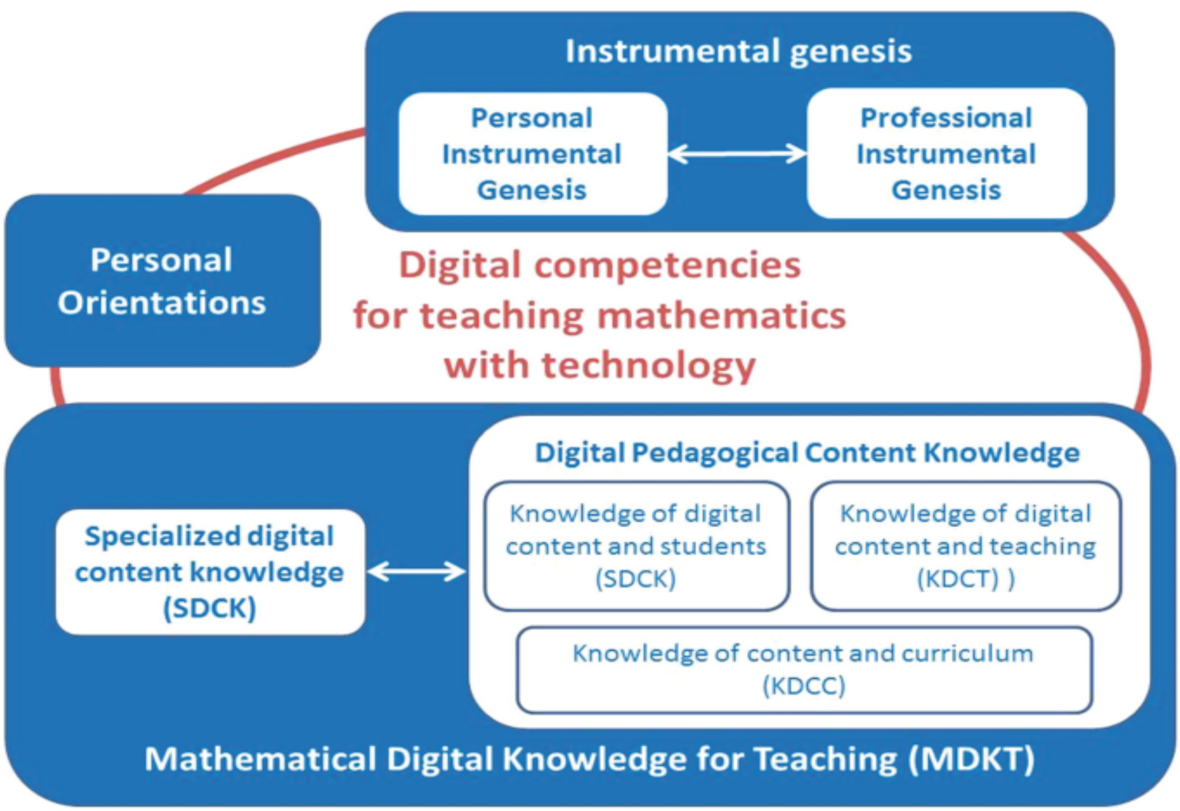

Figure 1. Mathematical Digital Knowledge for Teaching (MDKT) Framework (Adopted from Tabach & Trgalová, 2020)

The MDKT framework explores mathematics teachers' digital knowledge in teaching with technology, encompassing specialised digital content knowledge and digital pedagogical content knowledge about students, teaching, and curriculum. The framework provides an in-depth explanation of digital competencies tailored for mathematics teachers. It serves as a tool for examining the digital competencies teachers exhibit when incorporating technology into the mathematics classroom. Having these digital competencies enables teachers to effectively utilise digital tools and resources to improve student learning and equip students for the digital landscape they will face.

The MDKT framework was used as both a conceptual and analytical guide. Specifically, the four domains, specialised digital content knowledge, knowledge of digital content and students, knowledge of digital content and teaching, and knowledge of digital content and curriculum, were operationalised into questionnaire items that measured teachers' perceived levels of competence in each domain. The framework informed the design of the data collection instrument, the organisation of the results section, and the interpretation of findings by enabling domain-specific analysis of teachers' digital competencies for teaching mathematics with technology. Consequently, the use of the MDKT allowed the study to move beyond general descriptions of technology use and to identify specific areas of strength and need in teachers' digital knowledge for mathematics instruction.

METHODS

Research Design

This study adopted a descriptive research design, which focuses on systematically documenting and summarising characteristics of a population at a single point in time. This design was appropriate because it enabled the examination of mathematics teachers' perceived digital knowledge related to teaching with technology without manipulating the study context. Moreover, the descriptive approach facilitated the inclusion of participants from across the target population, thereby enabling a broad portrayal of prevailing patterns in teachers' technology-related practices and perceptions.

Participants

The target population for this study was all SHS mathematics teachers from the ten public SHSs in the Cape Coast Metropolis. There were approximately 213 mathematics teachers in the Metropolis (Ghana Education Service [GES], 2023). The census method was employed to involve the 213 mathematics teachers in the research. Collecting data from nearly all mathematics teachers was made possible by the census, considering that not all teachers may be accessible or willing to participate in the study.

Before a teacher was allowed to take part in the study, they were asked whether they had ever used any digital technologies (Microsoft PowerPoint, Microsoft Excel, MathLab, GeoGebra, etc) in collaboration with a projector to teach mathematics before. The teachers who responded affirmatively were included in the study. Of the teachers invited to participate in the study, 178 responded voluntarily, yielding an 83.6% response rate. This response rate is appropriate because the study used a census to include the entire teacher population. Hence, the sample obtained is likely to be more representative of the population, thereby increasing the generalisability of the study's findings to a broader population of teachers beyond the sample. Regarding the teachers' sex, 133 (74.7%) were male, whereas the remaining 45 (25.3%) were female. Regarding the teachers' highest academic qualification, 110 (61.8%) had a first degree, 39 (21.9%) had a master's degree, and the lowest proportion, 29 (16.3%), were diploma holders. Additionally, their professional background qualifications revealed that 149 (83.7%) have educational backgrounds, whereas 29 (16.3%) do not. Finally, 99 (55.6%) of the teachers have been teaching for less than 5 years, 53 (29.8%) for 5-10 years, and the remaining 26 (14.6%) for more than 10 years.

Table 1. KMO and Bartlett's Test for Measuring Sampling Adequacy

Tests		Values
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.950
Bartlett's Test of Sphericity	Approx. Chi-Square	3480
	df	496
	Sig.	.000

Data Collection Instrument

The instrument used for data collection was a closed-ended questionnaire. The closed-ended questionnaire consists of 30 items (see **Appendix**) developed by the researchers to elicit teachers' responses on their mathematical digital knowledge (knowledge of digital content and curriculum, knowledge of digital content and students, knowledge of digital content and teaching, and specialised digital content knowledge) for teaching with technology. The questionnaire was designed on a 5-point Likert scale (Strongly Disagree – Strongly Agree). The use of closed-ended questionnaires in this study provided an efficient and reliable means of collecting quantitative data for statistical analysis. Both content and construct validity were used to establish the questionnaire's validity. Content validity was assessed by presenting the questionnaire and the structured observation checklist to peers and three experts in mathematics education to examine the items and evaluate whether they represent a comprehensive and representative sample of the domains being measured.

To assess construct validity, the questionnaire underwent pre-testing to evaluate the items measuring mathematics teachers' digital competencies. An exploratory factor analysis (EFA) using principal component analysis (PCA) with Varimax rotation was used to establish construct validity. This was done by pre-testing the questionnaire on 150 mathematics teachers selected from senior high schools in the Komenda, Edinaman, Ebirem, and Aguafo (KEEA) Metropolis and the Abura Asebu Kwaman Kese (AAK) District. The pre-testing of the questionnaire was appropriate because Ikart (2019, p. 4) averred that "pre-testing is the only technique to evaluate in advance whether a questionnaire poses problems for the respondents."

First, Bartlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) test were conducted to assess the suitability of the data for factor analysis. The KMO index ranges from 0 to 1. The acceptability range is thought to be between 0.5 and 1. Thus, a KMO value of 0.90 is deemed marvellous, a KMO value of 0.80 is regarded as wonderful, a KMO value of 0.70 is recognised as ordinary, and a KMO value of 0.60 is labelled below par. The results from **Table 1** indicated that the KMO (0.950) and Bartlett's Test (X^2 = 3480, p ≤ 0.05, df = 496) were acceptable for the variables measuring mathematics teachers' perceived digital knowledge for teaching with technology. These results indicated that the sampling is adequate (Kaiser, 1974) for factor analysis.

Second, exploratory factor analysis was employed in this study using principal component axis to reduce the potential number of factors. This basic factor structure was extracted using the Varimax rotation approach. The factors with one or more eigenvalues were maintained, while those with less than one eigenvalue were removed. Thus, four components were extracted based on the factor loadings (≥ 0.05) shown in the **Appendix**.

Items such as "*I can use digital resources in managing the mathematics learning environment*" and "*I am comfortable with the use of digital resources for designing and implementing project-based mathematics learning activities*" have factor loadings less than 0.5; hence, they have not been included in the final instrument. The remaining items are used to name the components as:

Component 1: Knowledge of digital content and curriculum

Component 2: Knowledge of digital content and students

Component 3: Knowledge of digital content and teaching

Component 4: Specialised digital content knowledge

Once the validity of the instruments was confirmed, the Cronbach's alpha coefficient (α) was utilised to assess the questionnaire's reliability. According to Nunnally and Bernstein (1994), a reliability coefficient of 0.70 is considered the benchmark for confirming the instrument's reliability during data collection. The reliability coefficient for this study ranges from 0.937 to 0.970, as shown in **Table 2**, indicating that the instrument is reliable for data collection.

Data Collection Procedure

Prior to data collection, an application for ethical clearance was submitted to the University's Institutional Review Board (IRB), and the questionnaire was sent to the schools for data collection. Furthermore, due to the unavailability of some teachers at the school premises during the visit, the questionnaire was converted into a Google Form survey and sent to their WhatsApp platforms. The Google Form was also sent to individual teachers whose WhatsApp accounts were restricted from sharing information unrelated to school activities. The Google Form survey helped collect data quickly and facilitated easy data coding. Data collection spanned from October to December 2023 during the regular academic year. During data collection, respondents were informed that participation in the study was voluntary, and anyone who wished to withdraw was free to do so without any problems. Again, the teachers who needed further clarification on the questionnaire items were addressed promptly.

Data Processing and Analyses

The data collected were verified and revised to guarantee the accuracy of the responses. Data collected through questionnaires administered via Google Forms were prepared for analysis through systematic coding procedures to support accurate data management and interpretation. Statistical analyses were performed using SPSS (version 27.0) and Jamovi (version 2.3.21.0). The analyses relied on descriptive statistical techniques, including frequencies, percentages, means, and standard deviations, to summarise the data. Prior to addressing the research questions, initial diagnostic checks were conducted to examine distributional assumptions. Visual inspections of the histogram (**Figure 2**) and normal P-P plot (**Figure 3**) indicated that the data approximated a normal distribution and exhibited homogeneity of variance. The mean values calculated from our data were categorised and referenced with the sentiment scores adopted from Derder et al. (2023), as presented in **Table 3**. The means derived from the collected data were compared with the sentiment scores to enable the researchers to determine the level of teachers' digital competencies.

Hence, a mean value less than 2.61 is considered as "low digital competence", a mean value between 2.61 and 3.40 is considered as "average/moderate digital competence", and a mean value greater than 3.40 is considered as "high digital competence." Standard deviations were used to assess the degree of agreement and/or disagreement among respondents. When standard deviation values are closer to zero (<1), it suggests that the respondents have similar views. Conversely, standard deviation values far away from zero (≥1) reflect variations in the views of the respondents.

Table 2. Reliability of Questionnaire Constructs

Construct	No. of items	α
Knowledge of Digital Content and Curriculum	10	0.970
Knowledge of Digital Content and Students	9	0.967
Knowledge of Digital Content and Teaching	7	0.961
Specialised Digital Content Knowledge	4	0.937

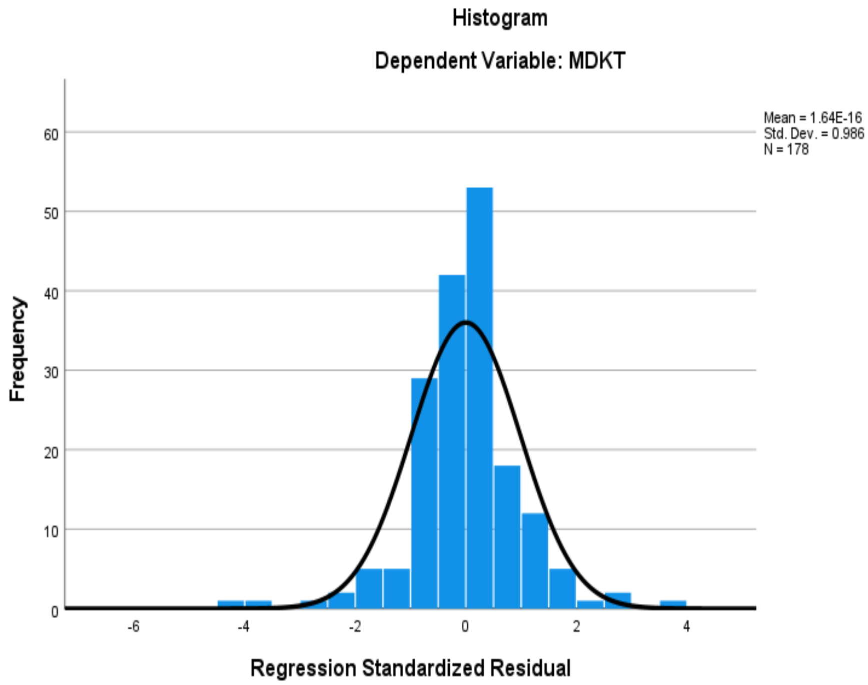

Figure 2. Histogram

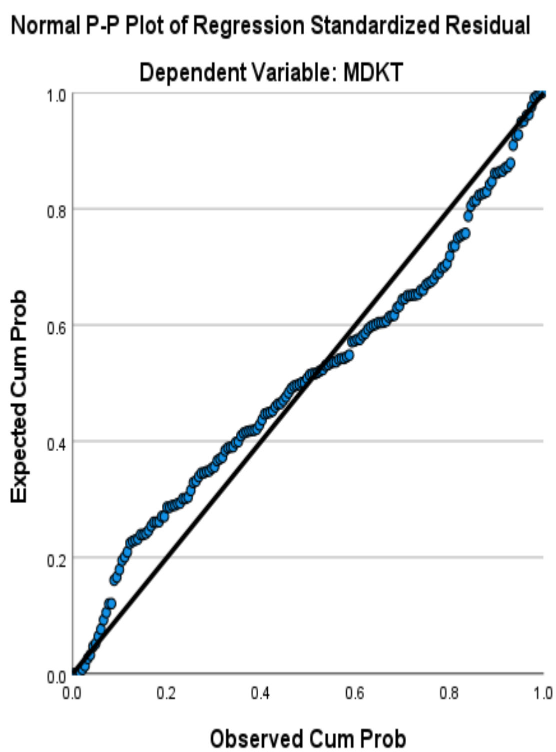

Figure 3. Normal P-P Plot

Table 3. Sentiment Score Ratings

Scale	Descriptive Rating	Item-specific Interpretation	Overall Interpretation
1.00 – 1.80	Strongly Disagree	Very low knowledge	Very low digital competence
1.81 – 2.60	Disagree	Low knowledge	Low digital competence
2.61 – 3.40	Neutral	Average/moderate knowledge	Average/moderate digital competence
3.41 – 4.20	Agree	High knowledge	High digital competence
4.21 – 5.00	Strongly Agree	Very low knowledge	Very high digital competence

Source: Adapted from Derder et al. (2023)

RESULTS

We presented the mean and standard deviation scores from the data we collected to answer the question: What are senior high school mathematics teachers' perceptions of their level of digital knowledge for teaching with technology?

Teachers' Perceived Knowledge of Digital Content and Curriculum

The first digital knowledge for teaching mathematics with technology explored is teachers' knowledge of digital content and curriculum (**Table 4**), which depicts a teacher's understanding of how to effectively integrate digital technology in the design and delivery of mathematics curriculum. Results in **Table 4** indicate that teachers appear to agree on all items used to measure their knowledge of digital content and curriculum; however, there are notable variations in their responses, as all standard deviations exceed 1. Notably, 106 (59.6%) teachers agreed or strongly agreed with item 2, while 31 (17.4%) disagreed or strongly disagreed. It is also noteworthy that 41 (23.0%) of the teachers remain undecided on this item. Hence, most (M = 3.62, SD = 1.10) teachers reported being highly comfortable incorporating multimedia content into mathematics instruction to support students' learning. Nevertheless, the fact that 40.4% of teachers are undecided or disagree or strongly disagree with this statement highlights a cause for concern. In addition, considering that several teachers were undecided, there is a need for more research and clarification on the comfortability of using digital tools in creating multimedia content to support students' learning.

Similarly, 110 (61.8%) of the 178 teachers agreed or strongly agreed with item 1, whereas 32 (18.0%) disagreed or strongly disagreed. This suggests that most (M = 3.62, SD = 1.15) teachers possess high knowledge of using digital technologies to boost student engagement and motivation in the mathematics classroom. Nevertheless, the fact that 18.0% of teachers seem to lack this knowledge highlights the knowledge gap and provides extra assistance and instruction to help teachers acquire the skills to utilise digital resources and involve and motivate students in learning mathematics.

Furthermore, a comparable 99 (55.6%) of the teachers either agreed or strongly agreed on items 9 and 10. However, 36 (20.2%) and 40 (22.5%) respectively either disagreed or strongly disagreed with items 9 and 10. Regarding these two items, 43 (24.2%) and 39 (21.9%) respondents, respectively, expressed uncertainty. It is noteworthy that, although some teachers expressed high confidence in their ability to utilise digital resources for teaching mathematics to develop 21st-century skills (M = 3.50, SD = 1.15), about 20.2% expressed low confidence in using digital resources for teaching mathematics to support 21st-century skills. This indicates that there are a substantial group of teachers who are confident in incorporating technology into their teaching, thereby promoting crucial skills for the contemporary world. In contrast, others are not confident in that regard.

Table 4. Knowledge of Digital Content and Curriculum

No	Statement	SA	A	N	D	SD	M	StD	Interpretation
		F (%)	F (%)	F (%)	F (%)	F (%)			
1	I know about how digital technologies can be used to promote student engagement and motivation in mathematics	43 (24.2)	67 (37.6)	36 (20.2)	21 (11.8)	11 (6.2)	3.62	1.15	High
2	I am comfortable with the use of digital tools for creating multimedia content that supports students' learning in mathematics	42 (23.6)	64 (36.0)	41 (23.0)	24 (13.5)	7 (3.9)	3.62	1.10	High
3	I am confident in using digital resources to enhance my professional development as a mathematics teacher	40 (22.5)	65 (36.5)	26(14.6)	24 (13.5)	23 (12.9)	3.42	1.32	High
4	I apply digital resources to enhance my mastery of mathematics	30 (16.9)	74 (41.6)	35 (19.7)	24 (13.5)	15 (8.4)	3.45	1.17	High
5	I am familiar with the digital resources available for teaching mathematics	34 (19.1)	70 (39.3)	31 (17.4)	28 (15.7)	15 (8.4)	3.45	1.21	High
6	I am knowledgeable about how digital technologies can support teaching and learning in mathematics	35 (19.7)	68 (38.2)	40 (22.5)	23 (12.9)	12 (6.7)	3.51	1.15	High
7	I am confident in my ability to implement technology-enhanced lessons that are aligned with learning objectives in mathematics	43 (24.2)	58 (32.6)	40 (22.5)	31 (17.4)	6 (3.4)	3.57	1.13	High
8	I am familiar with the different pedagogical approaches in mathematics that can be used to integrate digital technologies into the teaching of mathematics	39 (21.9)	62 (34.8)	37 (20.8)	29(16.3)	11 (6.2)	3.50	1.18	High
9	I am confident in my ability to use digital resources to teach mathematics to support the development of 21st-century skills	37 (20.8)	62 (34.8)	43 (24.2)	25(14.0)	11 (6.2)	3.50	1.15	High
10	I am knowledgeable about the different types of digital content that can be used to support students' learning in mathematics	37 (20.8)	62 (34.8)	39 (21.9)	32 (18.0)	8 (4.5)	3.49	1.14	High
	Overall Mean and Standard Deviation						3.51	1.17	High

Key: SA = Strongly Agree, A = Agree, N = Neutral, D = Disagree, and SD = Strongly Disagree, M = Mean, and StD = Standard Deviation

Likewise, a major proportion (M = 3.49, SD = 1.14) of teachers know about the different types of digital content that can support students' learning. Nevertheless, concerns and uncertainties about teachers' knowledge of digital content for supporting students' learning highlight this area and help alleviate these issues. In addition, some teachers (24.2% and 21.9%) expressed uncertainty about their confidence and knowledge. This highlights continuous support and guidance for effectively incorporating technology into mathematics instruction. Even though a comparable 40 (22.5%) of teachers are neutral towards items 6 and 7, in general, the mean score of (M = 3.51, SD = 1.17) when compared to the sentiment scores in **Table 3** revealed that the majority of mathematics teachers possessed high levels of knowledge of digital content and curriculum when teaching mathematics with technology. However, not all teachers have strong knowledge of digital content and curriculum, as several of them disagreed or strongly disagreed with the statements provided. Therefore, it is crucial to address these negative responses to promote a more inclusive and effective integration of technology to implement the mathematics curriculum.

Teachers' Perceived Knowledge of Digital Content and Students

This knowledge is characterised by mathematics teachers' understanding of their students' preferred modes of digital communication and how to use digital tools to differentiate instruction and personalise learning to meet individual students' needs. The results are presented in **Table 5**. From **Table 5**, the items used to measure mathematics teachers' knowledge of digital content and students received varying responses. Some teachers agreed or strongly agreed with the items, some were undecided, and others either disagreed or strongly disagreed.

Table 5. Knowledge of Digital Content and Students

s/n	Statement	SA	A	N	D	SD	M	StD	Interpretation
		F (%)	F (%)	F (%)	F (%)	F (%)			
1	I am confident in my ability to use digital resources to support student learning in mathematics	34 (19.1)	58 (32.6)	42 (23.6)	34 (19.1)	10 (5.6)	3.40	1.16	Moderate
2	I am familiar with the use of digital resources for creating instructional materials for mathematics teaching and learning	32 (18.0)	64 (36.0)	39 (21.9)	29 (16.3)	14 (7.9)	3.40	1.19	Moderate
3	I am comfortable with the use of digital resources for communicating with students in my mathematics classrooms	37 (20.8)	67 (37.6)	35 (19.7)	26 (14.6)	13 (7.3)	3.50	1.18	High
4	I know of the different digital resources and software available for teaching mathematics	40 (22.5)	61 (34.3)	40 (22.5)	27 (15.2)	10 (5.6)	3.53	1.16	High
5	I am confident in my ability to use digital resources to differentiate mathematics instruction for diverse learners	43 (24.2)	65 (36.5)	31 (17.4)	26 (14.6)	13 (7.3)	3.56	1.21	High
6	I am comfortable with the use of digital resources for assessment in my mathematics classrooms	35 (19.7)	70 (39.3)	36 (20.2)	24 (13.5)	13 (7.3)	3.51	1.17	High
7	I am competent in designing teaching methods in mathematics using digital resources	37 (20.8)	63 (35.4)	40 (22.5)	24 (13.5)	14 (7.9)	3.48	1.19	High
8	I am confident in using digital resources to enhance my mastery of mathematics	35 (19.7)	64 (36.0)	46 (25.8)	23 (12.9)	10 (5.6)	3.51	1.12	High
9	I am confident in my ability to use digital resources to create, edit, and share instructional materials related to mathematics	36 (20.2)	65 (36.5)	38 (21.3)	26 (14.6)	13 (7.3)	3.48	1.18	High
	Overall Mean and Standard Deviation						3.49	1.17	High

Key: SA = Strongly Agree, A = Agree, N = Neutral, D = Disagree, and SD = Strongly Disagree, M = Mean, and StD = Standard Deviation

Hence, while 108 (60.7%) teachers agreed or strongly agreed with item 5, 39 (21.9%) disagreed or strongly disagreed. It seems that some teachers have high confidence in their abilities to use digital resources to differentiate mathematics instruction for diverse learners (M = 3.56, SD = 1.21). In contrast, others lack such confidence, which may require specialised training and support to empower these teachers to confidently use digital resources to meet the unique needs of their students.

Again, 104 (58.4%) of the teachers either agreed or strongly agreed with item 3, whereas 39 (21.9%) disagreed or strongly disagreed with it. This means that some teachers expressed comfort in employing digital resources to communicate with their students (M = 3.50, SD = 1.18). In contrast, others do not seem to possess such knowledge, with a considerable number undecided about whether they are comfortable using digital resources to communicate with students.

Even though some teachers seemed to have high confidence in using digital resources to enhance their mastery of mathematics, 46 (25.8%) reported being neither confident nor not confident in their use, with a small proportion either agreeing or disagreeing. Other items (4, 7, and 9) that follow this route pose significant concerns and warrant exploration of why some teachers are uncertain about their knowledge of digital content and students.

Some teachers reported moderate knowledge of digital content and students. Notably, this was evident when 96 (54.0%) of the teachers either agreed or strongly agreed, 39 (21.9%) were undecided, and 43 (24.2%) either disagreed or strongly disagreed with item 2. Also, 92 (51.7%) either agreed or strongly agreed, 34 (19.1%) were undecided, and 45 (24.7%) either disagreed or strongly disagreed on the item. These results indicate that some teachers demonstrate some level of familiarity with creating instructional materials using digital resources (M = 3.40, SD = 1.19) and confidence in employing digital tools to facilitate students' learning of mathematics 1 (M = 3.40, SD = 1.16), whereas others do not. However, the overall mean (M = 3.49, SD = 1.17), compared with the sentiment scores in **Table 3**, suggests that, in general, mathematics teachers possess a high level of knowledge of digital content and students.

Teachers' Perceived Knowledge of Digital Content and Teaching

This knowledge type includes teachers' understanding of how to use digital tools to create and deliver engaging, interactive mathematical content, as well as to support student collaboration and communication. The results of this analysis are presented in **Table 6**. The items measuring mathematics teachers' knowledge of digital content and their teaching showed that not all teachers agreed or strongly agreed with the statements. Additionally, there are variations in teachers' responses to the items, as all standard deviations exceed 1.

Thus, item 1 received the highest response, with 100 (56.1%) of the teachers either agreeing or strongly agreeing with the statement, demonstrating that some mathematics teachers use digital resources for teaching mathematics that support their professional development (M = 3.42, SD = 1.21).

However, 29 (16.3%) were undecided, and 34 (24.7%) either disagreed or strongly disagreed on the item. Again, a total of 93 (52.2%) teachers either agreed or strongly agreed on item 4, but 85 (48.8%) were undecided, disagreed, or strongly disagreed (M = 3.41, SD = 1.14). These suggest that some teachers use digital resources to facilitate communication about their students' learning in mathematics, while others do not. Hence, as some teachers can incorporate digital tools into mathematics instruction because they perceive such integration as instrumental in facilitating communication about their students' progress, others may have challenges using digital resources for this purpose while teaching mathematics. The results above were followed by 97 (54.5%) of the teachers either agreeing or strongly agreeing on item 2, whereas 81 (45.5%) were undecided, disagreed, or strongly disagreed.

Table 6. Knowledge of Digital Content and Teaching

s/n	Statement	SA	A	N	D	SD	M	StD	Interpretation
		F (%)	F (%)	F (%)	F (%)	F (%)			
1	I use digital resources for teaching mathematics that support my professional development	33 (18.5)	67 (37.6)	34 (19.1)	29 (16.3)	15 (8.4)	3.42	1.21	High
2	I apply digital resources in designing teaching methods for mathematics	31 (17.4)	66 (37.1)	38 (21.3)	29 (16.3)	14 (7.9)	3.40	1.18	Moderate
3	I use digital resources for mathematics instructions to inspire students to learn	33 (18.5)	63 (35.4)	34 (19.1)	30 (16.9)	18 (10.1)	3.35	1.25	Moderate
4	I use digital resources to communicate about the mathematics learning of the students	31 (17.4)	62 (34.8)	45 (25.3)	29 (16.3)	11 (6.2)	3.41	1.14	High
5	I apply digital resources in communicating about my students' mathematics learning	28 (15.7)	64 (36.0)	38 (21.3)	34 (19.1)	14 (7.9)	3.33	1.18	Moderate
6	I inspire my students to learn using technologies in their mathematics lessons	35 (19.7)	56 (31.5)	44 (24.7)	31 (17.4)	12 (6.7)	3.40	1.18	Moderate
7	I choose mathematical digital technologies according to the learning objectives and context	35 (19.7)	55 (30.9)	45 (25.3)	29 (16.3)	14 (7.9)	3.38	1.20	Moderate
	Overall Mean Standard Deviation						3.38	1.19	Moderate

Key: SA = Strongly Agree, A = Agree, N = Neutral, D = Disagree, and SD = Strongly Disagree, M = Mean, and StD = Standard Deviation

The division between teachers who agree and those who are uncertain or disagree indicates a range of degrees of embrace of digital resources in the development of instructional approaches for teaching mathematics. Again, while 96 (53.9%) of the teachers either agreed or strongly agreed on item 3, 34 (19.1%) were undecided, and 48 (27.0%) either disagreed or strongly disagreed. These findings suggest that while some teachers use digital resources to some extent to inspire their students to learn (M = 3.35, SD = 1.25), others are not certain or do not use them. Hence, these teachers are perceived as possessing moderate knowledge of digital content and technology in mathematics instruction.

Similarly, the teachers can be said to possess moderate knowledge in applying digital resources in communicating about their students' mathematics learning (M = 3.33, SD = 1.18), with 92 (51.7%) either agreeing or strongly agreeing and the remaining 86 (48.3%) being neutral, disagreeing or strongly disagreeing to the statement. This indicates a wide range of digital skills among teachers, emphasising the importance of a detailed understanding of their ability to use technology for effective communication about students' mathematical learning. It is also concerning that 45 (25.3%) and 44 (24.7%) have expressed uncertainty on items 4, 7, and 6, respectively.

In general, the mean (M = 3.38, SD = 1.19) is lower than the sentiment scores in the **Table 3**, indicating that mathematics teachers possess average/moderate knowledge of digital content and teaching. Thus, in general, some teachers seem to possess moderate knowledge of how to use technology to motivate students to acquire mathematical knowledge, considering both learning objectives and the specific educational environment when choosing appropriate digital resources. These teachers are perceived as possessing moderate competencies because, although they are not technology experts, they demonstrate a willingness to incorporate new tools into their teaching. These teachers may try to create a balance by integrating technology into their mathematics instruction while also being receptive to continuous professional development to improve their digital teaching abilities.

Teachers' Perceived Specialised Digital Content Knowledge

This knowledge relates to the expectations of mathematics teachers to have a deep understanding of the content they teach, as well as a strong familiarity with various digital tools and resources for teaching it. The results are presented in **Table 7**. The specialised digital content knowledge possessed by mathematics teachers revealed that teachers have high knowledge of item 1 but possess moderate knowledge of items 2, 3, and 4.

Table 7. Specialised Digital Content Knowledge

s/n	Statement	SA	A	N	D	SD	M	StD	Interpretation
		F (%)	F (%)	F (%)	F (%)	F (%)			
1	I am confident in my ability to select appropriate digital resources to support my teaching mathematical goals	42 (23.6)	58 (32.6)	36 (20.2)	31 (17.4)	11 (6.2)	3.50	1.20	High
2	I am familiar with the different mathematical software available for collaboration and communication with other teachers	32 (18.0)	59 (33.1)	47 (26.4)	27 (15.2)	13 (7.3)	3.39	1.16	Moderate
3	I am confident in my ability to troubleshoot and resolve technical issues that arise when using digital resources for teaching mathematics	31 (17.4)	58 (32.6)	44 (24.7)	34 (19.1)	11 (6.2)	3.36	1.16	Moderate
4	I am knowledgeable about the ethical and legal issues related to the use of digital resources in teaching mathematics	38 (21.3)	49 (27.5)	47 (26.4)	32 (18.0)	12 (6.7)	3.39	1.20	Moderate
	Grand Mean and Standard Deviation						3.41	1.18	High

Key: SA = Strongly Agree, A = Agree, N = Neutral, D = Disagree, and SD = Strongly Disagree, M = Mean, and StD = Standard Deviation

Thus, regarding item 1, 100 (56.2%) teachers agreed or strongly agreed, whereas 42 (23.6%) disagreed or strongly disagreed. Additionally, a considerable number 36 (20.2%) of them are uncertain about item 1. Variation in teachers' confidence in selecting appropriate digital tools to enhance mathematical instruction highlights the diverse range of confidence levels among teachers. While some teachers feel highly confident (M = 3.50, SD = 1.20) in their ability to select digital resources for mathematical goals, others may encounter difficulties or uncertainties in navigating the complexities of these tools.

Furthermore, the fact that a significant percentage (20.2%) of teachers expressed uncertainty about their confidence in selecting appropriate digital resources calls for establishing a nurturing environment that empowers teachers to explore and test different digital tools, thereby boosting their confidence in choosing and using technology to improve student learning.

More so, on item 2, 91 (51.1%) of the teachers either agreed or strongly agreed, whereas 40 (22.5%) either disagreed or strongly disagreed. This suggests that some teachers seem not very familiar with the different digital resources available for collaborating and communicating with their colleagues (M = 3.39, SD = 1.16), whereas others may not familiarise themselves with these resources at all for the same purpose. Again, results on item 3 showed that 89 (50.0%) of the teachers either agreed or strongly agreed, while 45 (25.3%) either disagreed or strongly disagreed. These teachers seem to have moderate knowledge (M = 3.36, SD = 1.16) of their ability to troubleshoot and resolve technical issues that arise when using digital resources for teaching mathematics.

It therefore appears that many teachers are quite confident in their ability to handle any technical challenges that may arise during instructional activities involving digital tools. Nevertheless, the teachers (25.3%) who expressed disagreement or strong disagreement about their confidence in resolving technical problems may require training to address technical issues that arise when using technology to teach mathematics.

In addition, 87 (48.8%) of the teachers either agreed or strongly agreed, whereas 44 (24.7%) either disagreed or strongly disagreed on item 4. Therefore, these teachers may possess moderate knowledge about the ethical and legal issues related to the use of digital resources in teaching mathematics (M = 3.39, SD = 1.20). Although some teachers agreed with their knowledge of ethical and legal considerations, a considerable number disagreed or were unsure, suggesting possible deficiencies in their understanding.

Again, the number of teachers who expressed uncertainty [47 (26.4%), 44 (24.7%), 47 (26.4%)] on items 2, 3, and 4, respectively, showed that some teachers require practical experience, collaboration with peers, and access to valuable digital resources to gain the necessary knowledge and skills to overcome technical obstacles and encourage ethical digital practices.

DISCUSSION

This study utilised a technology framework to determine the levels of Senior High School mathematics teachers' digital competencies (specialised digital content knowledge, knowledge of digital content and students, knowledge of digital content and teaching, and knowledge of digital content and curriculum) for teaching with technology. Regarding teachers' knowledge of digital content and curriculum, the results revealed that mathematics teachers demonstrated a high level of proficiency in utilising digital tools to design multimedia materials, devise and deliver technology-infused instructional sessions, and enhance their professional development as mathematics teachers. These resonate with Kampylis et al.'s (2023) study, which shows that teachers' digital competencies involve not just the technical use of digital tools but also their integration into pedagogical and professional practices, including lesson design and instructional decision-making. This means that teachers' use of digital technologies can contribute to mathematics education and enhance the understanding of complex concepts. Additionally, these tools offer teachers and students diverse avenues to refine their mathematical skills. The findings indicate that mathematics teachers in the Cape Coast

Metropolis exhibit a high level of knowledge of digital content and curriculum. This could align with the curriculum's constant demand on mathematics teachers to use technology in their instructional practices.

Teachers' knowledge of digital content and students showed that teachers are confident in their ability to differentiate mathematics instruction for a diverse student body by utilising digital resources. This demonstrated that mathematics teachers in the Cape Coast Metropolis are aware of a variety of digital tools and software that can be used to teach mathematics to suit the needs of diverse students in their mathematics classrooms. They also expressed comfort with using digital resources for formative and summative assessments in their mathematics classrooms, emphasising that mathematics teachers are proactive in integrating technology for evaluating students' progress. This result may be attributed to improved access to personal digital devices (laptops) following the one-teacher-one-laptop initiative, which has lowered logistical barriers to the use of digital assessment tools for tracking, recording, and analysing student performance.

Furthermore, these teachers expressed confidence in their ability to use digital resources not only to enhance their mastery of mathematics but also to communicate with their students. This demonstrates teachers' adaptability to the changing needs of modern education, requiring them to use technology not only to enhance teaching but also to communicate with students. The result is consistent with research (Johanson, 2023) showing that teachers' digital interaction and communication competencies underpin effective technology-mediated pedagogical practice, enabling a richer instructional engagement and student-teacher interaction. In addition, teachers can develop mathematics teaching methods that emphasise creating engaging learning experiences tailored to the curriculum and students' specific needs.

The findings revealed that teachers are adept at using digital resources to create, edit, and share instructional materials in mathematics. This is a skill critical for providing customised content aligned with the curriculum and, as a result, fostering a deeper understanding of mathematical concepts among students. These results are supported by recent research (Leung et al., 2024) showing that digital curriculum resources extend beyond simple content repositories, enabling teachers to design tasks, integrate feedback mechanisms, and orchestrate shared digital learning spaces that align with curriculum goals and student understanding. In general, these demonstrated that mathematics teachers in the Cape Coast Metropolis possess high levels of knowledge about digital content and their students.

Concerning mathematics teachers' knowledge of digital content and teaching, the findings revealed that they understand the use of digital content and its application in the classroom, with an emphasis on using digital resources for their professional development. These results align with Saikkonen and Kaarakainen (2021) study, which found that teachers' engagement in sustained professional learning is associated with deeper integration of digital content into pedagogical practice. This highlights the intertwined nature of digital content knowledge and professional development. Moreover, teachers use digital resources for communication, sharing and monitoring students' mathematical progress. This dual approach, which emphasises both self-improvement and student assistance, highlights the extent of the digital skills possessed by mathematics teachers. This finding aligns with Trgalová and Tabach (2020), who found that teachers rely on a diverse range of alternative sources, including collaborative platforms and official repositories, to locate digital content pertinent to their instructional needs. Additionally, the findings contradict Ardiç (2021), who found that teachers frequently relied solely on smartboards during instructional sessions, preferring teacher-centred classroom practices that did not incorporate the hardware and software necessary for student engagement.

In addition, the teachers demonstrate a strong aptitude for developing instructional strategies that incorporate digital tools, fostering an environment that encourages students to engage with mathematics through technology. As outlined in the ISTE Standards-T (2008), teachers should employ their expertise in subject matter, pedagogy, and technology to facilitate experiences that promote student learning, creativity, and innovation. This strategy ensures that digital resources are purposefully integrated to achieve specific learning objectives, while taking classroom context into account. Thus, Trgalová and Tabach (2020) also found in their study that teachers deliberately select mathematical digital technologies based on specific learning objectives and contextual factors.

Moreover, we found that teachers are competent in utilising digital resources to motivate students, resulting in an educational environment in which technology is not only a tool for instruction but also a source of motivation for students to learn mathematics. This result may be explained by teachers' strategic use of interactive digital features such as visualisation, immediate feedback, and dynamic representations that align with students' ways of engaging with mathematical ideas and sustain attention. Thus, Borba et al. (2023) show that when digital tools are used to support exploration and sensemaking rather than passive consumption, they can enhance students' motivation and engagement in mathematics learning. Overall, the findings indicate that mathematics teachers have a high level of knowledge in digital content and instruction, as evidenced by their use of technology for professional development, effective communication, teaching strategies, student motivation, and the attainment of specific learning objectives.

The findings regarding teachers' specialised digital content knowledge showed that mathematics teachers were confident in their ability to identify and utilise appropriate digital resources to advance mathematics educational objectives. Indicative of their readiness to participate in a digitally connected professional community is their familiarity with a variety of mathematical software designed for collaboration and communication with other teachers. As averred by Tabach and Trgalová (2019), a teacher's professional duties extend beyond the classroom, including, but not limited to, resource exploration and communication with fellow teachers.

In addition, the teachers demonstrated an understanding of the ethical and legal considerations associated with the use of digital resources in mathematics instruction. This demonstrates that the teachers are responsible and well-informed in integrating technology into their mathematics classrooms. In addition, the teachers' confidence in troubleshooting and resolving technical issues that arise while utilising digital resources demonstrates their readiness to face potential challenges when using technology to teach. In conclusion, the research findings demonstrate that mathematics teachers understand specialised digital content, indicating their ability to use technology to enhance mathematics instruction. This aligns with Zambak and Tyminski (2017), who argue that the robust use of technology is necessary to provide evidence of teachers' specialised content knowledge when utilising technology to teach mathematics.

Drawing on individual findings on the level of digital knowledge mathematics teachers possess for teaching mathematics with technology, we found that mathematics teachers in the Cape Coast Metropolis generally possess high levels of digital competencies. Several important factors contribute to the high level of digital competencies among mathematics teachers. Firstly, the One-Teacher-One-Laptop policy in Ghana may also significantly influence the high levels of digital competency observed among mathematics teachers, as compared to past studies. The primary objective of this initiative is to provide all teachers with access to personal computing devices, enabling them to acquire the skills required for effective technology integration in teaching. Although direct empirical evidence may be limited, multiple plausible explanations and mechanisms exist through which this policy could improve digital competencies. However, these findings are not in line with past studies such as Trgalová and Tabach (2020) and Birgin et al. (2020). The results indicate a favourable attitude toward incorporating technology into teaching mathematics in the Cape Coast Metropolis.

CONCLUSION

This study is among the initial applications of the digital competencies for teaching mathematics with technology, using the Mathematical Digital Knowledge for Teaching (MDKT) framework to assess the essential digital competencies required for effective mathematics instruction with technology. To the best of our knowledge, this is the first study to use the MDKT framework in the Ghanaian context.

According to the study's findings, teachers differ in their engagement with digital content resources. We inferred from the empirical results that some teachers use these resources exclusively, possessing the skills to search for, select, and adapt the available digital content effectively. On the other hand, there are teachers who not only utilise these resources but also design and modify them. These teachers are capable of (re-) designing, amending, developing, and sharing the digital content resources at their disposal. Hence, the utilisation of mathematical digital knowledge in a teaching framework helped unravel the levels of mathematics teachers' specific digital competencies for teaching with technology, unlike past studies that used general competence frameworks.

The research indicates various methods by which mathematics teachers interact with digital content resources. As our empirical results show, some teachers reported relying exclusively on existing resources. In contrast, others demonstrate the capacity to design and adapt them, reflecting differing levels of competence in creating and adapting digital content. This finding underscores the need to address teachers' varied needs in implementing professional development programs to improve digital competencies.

Furthermore, this study advances scholars' understanding of teachers' digital competencies by demonstrating that access to and familiarity with digital tools are insufficient indicators of readiness to teach mathematics with technology. By applying the MDKT framework, we provide domain-specific evidence that teachers' competencies vary across content, pedagogy, and professional learning, refining how digital competence should be conceptualised and studied in mathematics education. The findings also extend the literature by situating these competencies within a policy context, illustrating how national initiatives may support access while leaving pedagogical use uneven. Collectively, the study strengthens the field's move toward subject-specific, analytically grounded examinations of technology use in teaching mathematics.

RECOMMENDATIONS

Given the varied levels of teachers' competence in teaching mathematics with technology, the Ghana Education Service (GES) should provide targeted training opportunities to enhance teachers' digital knowledge. Future research could investigate the effects of various professional development programmes, such as online courses, workshops, or mentorship programmes, on teachers' abilities to use technology in mathematics instruction.

Limitations

The study was conducted in the Cape Coast Metropolis of Ghana, limiting the applicability of the results to other settings. Future research should investigate the applicability of these competency levels in other regions of Ghana or in countries with comparable ICT initiatives. In addition, the study predominantly utilised self-reported data from teachers obtained via a closed-ended questionnaire. Integrating supplementary data sources, such as classroom observations, lesson plan analyses, and assessments of student outcomes, would yield a more thorough and nuanced understanding of the relationship between teachers' digital competencies and their classroom practices.

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REFERENCES

Amenyedzi, F. W., Lartey, M. N., & Dzomeku, B. M. (2011). The use of computers and internet as supplementary source of educational material: A case study of the senior high schools in the Tema metropolis in Ghana. *Contemporary Educational Technology*, *2*(2), 151-162. https://doi.org/10.30935/cedtech/6049

Ardiç, M. A. (2021). Opinions and attitudes of secondary school mathematics teachers towards technology. *Participatory Educational Research*, *8*(3), 136-155. https://doi.org/10.17275/per.21.58.8.3

Ardiç, M. A., & Isleyen, T. (2017). High school mathematics teachers' levels of achieving technology integration and in-class reflections: The case of mathematica. *Universal Journal of Educational Research*, *5*(12B), 1-17. https://doi.org/10.13189/ujer.2017.051401

Barfi, K. A., Amenu, A., & Arkoful, V. (2020). Assessing the integration of ICT resources in teaching and learning in selected senior secondary schools in Cape Coast metropolis. *Library Philosophy and Practice, Article 4111*. https://digitalcommons.unl.edu/libphilprac/4111.

Birgin, O., Uzun, K., & Mazman Akar, S. G. (2020). Investigation of Turkish mathematics teachers' proficiency perceptions in using information and communication technologies in teaching. *Education and Information Technologies*, *25*(1), 487-507. https://doi.org/10.1007/s10639-019-09977-1

Borba, M., Askar, P., Engelbrecht,J., Gadanidis, G., Llinares, S. y Sánchez-Aguilar, M. (2016). Blended learning, e-learning and mobile learning in mathematics education. *ZDM Mathematics Education, 48*(5), 589-610. https://doi.org/10.1007/s11858-016-0798-4

Citinewsroom.com.gh (September 7, 2021). *Government funds 70% of 'one teacher one laptop' initiative through GETFund*. https://citinewsroom.com/2021/09/government-funds-70-of-one-teacher-one-laptop-initiative-through-getfund/?utm_source=chatgpt.com#google_vignette

Derder, A., Sudaria, R., & Paglinawan, J. (2023). Digital infrastructure on teaching effectiveness of public-school teachers. *American Journal of Education and Practice*, *7*(6), 1-13. https://doi.org/10.47672/ajep.1719

Donkor, A. (2018). *In-service teachers' use of ICT in teaching mathematics in Ghana. A case study in the Cape Coast metropolis* [Master Thesis, University of Cape Coast].

GhanaWeb Regional News (2015, January). *GNA: Strengthen capacity of teachers in ICT*. Accra. https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Strengthen-capacity-of-teachers-in-ICT-344131.

Gomez Jr., F. C. Jr. (2020). *Technology integration self-efficacy reframed through the ISTE standards: An investigation among urban K-12 teachers* [Doctoral Dissertation, Boise State University]. https://doi.org/10.18122/td/1692/boisestate

Graphiconline.com.gh (August 13, 2024). *1 Teacher 1 Laptop distribution: Mop up in six regions underway*. https://www.graphic.com.gh/news/education/1-teacher-1-laptop-distribution-mop-up-in-six-regions-underway.html?utm_source=chatgpt.com

Ghana Education Service. (2023). Ghana Education Service. https://ges.gov.gh/

Grimus, M. (2020). Emerging technologies: Impacting learning, pedagogy and curriculum development. In: Yu, S., Ally, M., Tsinakos, A. (Eds.), *Emerging technologies and pedagogies in the curriculum. Bridging human and machine: Future education with intelligence*. Springer, Singapore. https://doi.org/10.1007/978-981-15-0618-5_8

Gueudet, G. (2015). Resources at the core of mathematics teachers' work. In: Cho, S. (Eds.), *Selected regular lectures from the 12th international congress on mathematical education*. Springer, Cham. https://doi.org/10.1007/978-3-319-17187-6_14

Ikart, E. M. (2019). Survey questionnaire survey pretesting method: An evaluation of survey questionnaire via expert reviews technique. *Asian Journal of Social Science Studies*, *4*(2), 1-17. https://doi.org/10.20849/ajsss.v4i2.565

International Society for Technology in Education [ISTE]. (2008). *ISTE standards for teachers*. http://www.iste.org/standards/standards/standards-for-teachers

Johanson, L. B. (2023). Competence in digital interaction and communication—A study of preservice teacher digital communication skills. *Journal of Digital Learning in Teacher Education, 58*(3), 270-288. https://doi.org/10.1080/08878730.2022.2122095

Kampylis, P., et al. (2023). Assessing teachers' digital competence in primary and secondary education: Applying a new instrument to integrate pedagogical and professional elements for digital education. *Education and Information Technologies, 28*, 16017–16040. https://doi.org/10.1007/s10639-023-11848-9

Kartal, B., & Çınar, C. (2022). Preservice mathematics teachers' TPACK development when they are teaching polygons with GeoGebra. *International Journal of Mathematical Education in Science and Technology*, *55*(5), 1171-1203. https://doi.org/10.1080/0020739X.2022.2052197

Leung, A., Baccaglini-Frank, A., Bokhove, C., Nagari-Haddif, G., & Yerushalmy, M. (2024). Digital curriculum resources in digital mathematics curriculum: design features and implementation. In *International Handbooks of Education* (pp. 1143–1173). Springer Nature. https://doi.org/10.1007/978-3-031-45667-1_58

Organisation for Economic Co-operation and Development (2003). *The definition and selection of key competencies*. Executive summary. https://www.oecd.org/pisa/35070367.pdf.

Pepin, B., Choppin, J., Ruthven, K., & Sinclair, N. (2017). Digital curriculum resources in mathematics education: foundations for change. *ZDM*, *49*, 645-661. https://doi.org/10.1007/s11858-017-0879-z

Quaicoe, J. S., & Pata, K. (2015). The teachers' digital literacy: determining digital divide in public basic schools in Ghana. In *Information Literacy: Moving Toward Sustainability: Third European Conference, ECIL 2015, Tallinn, Estonia, October 19-22, 2015, Revised Selected Papers 3* (pp. 154-162). Springer International Publishing.

Quaicoe, J. S., & Pata, K. (2020). Teachers' digital literacy and digital activity as digital divide components among basic schools in Ghana. *Education and Information Technologies*, *25*, 4077-4095. https://doi.org/10.1007/s10639-020-10158-8

Saikkonen, L., & Kaarakainen, M. T. (2021). Multivariate analysis of teachers' digital information skills-The importance of available resources. *Computers & Education, 168*, Article 104206. https://doi.org/10.1016/j.compedu.2021.104206

Tabach, M., & Trgalová, J. (2018). ICT standards for teachers: Toward a frame defining mathematics teachers' digital knowledge. In H.-G. Weigand, A. Clark-Wilson, A. Donevska-Todorova, E. Faggiano, N. Grønbæk, & J. Trgalová (Eds.), *Proceedings of the Fifth ERME topic conference (ETC 5) on mathematics education in the digital age (MEDA 2018)* (pp. 273–281). University of Copenhagen. https://www.math.ku.dk/english/research/conferences/2018/meda/proceedings/MEDA_2018_Proceedings.pdf

Tabach, M., Trgalová, J. (2019). The Knowledge and Skills that Mathematics Teachers Need for ICT Integration: The Issue of Standards. In: Aldon, G., Trgalová, J. (Eds.), *Technology in mathematics teaching: mathematics education in the digital era*, 13. Springer, Cham. https://doi.org/10.1007/978-3-030-19741-4_8

Tabach, M., Trgalová, J. (2020). Teaching Mathematics in the Digital Era: Standards and Beyond. In: Ben-David Kolikant, Y., Martinovic, D., Milner-Bolotin, M. (Eds.), *STEM teachers and teaching in the digital era*. Springer, Cham. https://doi.org/10.1007/978-3-030-29396-3_12

Thomas, A., & Edson, A. J. (2018). Integrating mathematics teaching with digital resources: Where to begin? *Australian Primary Mathematics Classroom, 23*(2), 14-19.

Trgalová, J., & Tabach, M. (2020). Bi-national survey on mathematics teachers' digital competences. In H.-G. Weigand, A. Clark-Wilson, A. Donevska-Todorova, E. Faggiano, N. Grønbaek, et al. (Eds.), *Proceedings of the Fifth ERME topic conference (ETC 5) on mathematics education in the digital age* (MEDA) (pp. 117–124). ERME. https://hal.science/hal-02500112

Zambak, V. S., & Tyminski, A. M. (2017). A Case study on specialised content knowledge development with dynamic geometry software: The analysis of influential factors and technology beliefs of three pre-service middle grades mathematics teachers. *Mathematics Teacher Education and Development*, *19*(1), 82-106.

Appendix. Component Factor Loadings of Questionnaire Items

	Component			
	1	2	3	4
I am confident in using digital resources to enhance my professional development as a mathematics teacher	0.588			
I successfully apply digital resources to enhance my mastery of mathematics	0.637			
I am familiar with the digital resources available for teaching mathematics	0.752			
I am knowledgeable about the different types of digital content that can be used to support students' learning in mathematics	0.666			
I am confident in my ability to use digital resources to teach mathematics to support the development of 21st-century skills	0.627			
I am knowledgeable about how digital technologies can support teaching and learning in mathematics	0.664			
I am familiar with the different pedagogical approaches in mathematics that can be used to integrate digital technologies into the teaching of mathematics	0.643			
I am confident in my ability to design and implement technology-enhanced lessons that are aligned with learning objectives in mathematics	0.624			
I am comfortable with the use of digital tools for creating and delivering multimedia content that supports students' learning in mathematics	0.521			
I know about how digital technologies can be used to promote student engagement and motivation in mathematics	0.706			
I am confident in my ability to use digital resources to support student learning in mathematics		0.717		
I am familiar with the use of digital resources for creating and managing instructional materials for mathematics teaching and learning		0.681		
I am comfortable with the use of digital resources for communicating with students in my mathematics classrooms		0.635		
I know of the different digital resources and software available for teaching mathematics		0.534		
I am confident in my ability to use digital resources to differentiate mathematics instruction for diverse learners		0.694		
I am comfortable with the use of digital resources for formative and summative assessment in my mathematics classrooms		0.674		
I am competent in designing teaching methods in mathematics using digital resources		0.556		
I am confident in using digital resources to enhance my mastery of mathematics		0.595		
I am confident in my ability to use digital resources to create, edit, and share instructional materials related to mathematics		0.598		
I choose mathematical digital technologies according to the learning objectives and context			0.555	
I inspire my students to learn using technologies in their mathematics lessons			0.624	
I use digital resources to communicate about the mathematics learning of the students			0.693	
I use digital resources for teaching mathematics that support my professional development			0.564	
I apply digital resources in designing teaching methods for mathematics			0.544	
I use digital resources for mathematics instructions to inspire students to learn			0.678	
I apply digital resources in communicating about my students' mathematics learning			0.641	

I am knowledgeable about the ethical and legal issues related to the use of digital resources in teaching mathematics	0.595
I am confident in my ability to troubleshoot and resolve technical issues that arise when using digital resources for teaching mathematics	0.713
I am familiar with the different mathematical software available for collaboration and communication with other teachers	0.652
I am confident in my ability to select and use appropriate digital resources to support my teaching mathematical goals	0.510