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Technology Integration in Secondary Mathematics: How Preservice Teachers Select and Use Digital Tools

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Abstract

This study explores how preservice secondary mathematics teachers (PSMTs) select and integrate digital tools into their technology portfolios, focusing on high school mathematics courses such as Algebra, Geometry, Calculus, and Probability and Statistics. Guided by the frameworks of Dick and Hollebrands (2011) and Pea (1985, 1987), the study categorizes digital tools as either conveyance tools or mathematical action tools, and further distinguishes their use as amplifiers or reorganizers of mathematical thinking. The findings reveal that PSMTs predominantly use mathematical action tools, such as Desmos, GeoGebra, and Geometers Sketchpad, as amplifiers to enhance efficiency in tasks like graphing and computation. However, the patterns of tool use vary across mathematical domains: in Geometry, tools are more frequently employed as reorganizers to support dynamic conceptual exploration, whereas in Calculus and Algebra, tools are largely used as amplifiers. The minimal use of conveyance tools, such as Microsoft Excel, highlights a gap in the integration of tools that support data sharing and collaboration. These patterns suggest that while PSMTs have a basic grasp of how technology can support instruction, they still need more support and practice to grow their skills and use digital tools in more meaningful and creative ways. The study concludes by advocating for enhanced training in teacher preparation programs that provides structured, hands-on experiences with a range of digital tools and emphasizes their dual potential to support and transform student learning in mathematics.

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Introduction

As technology becomes increasingly integrated into mathematics curricula worldwide, teacher education programs play a critical role in preparing pre-service mathematics teachers to use a range of digital tools. These programs expose teachers to general technology courses and mathematics methods courses focused on incorporating technology into instruction. Contemporary literature and mathematics curricula predominantly emphasize digital technologies, such as dynamic geometry software like GeoGebra and The Geometer's Sketchpad for geometry classes, graphing calculators and algebra systems like Desmos and Maple for algebra, and modeling software like TinkerPlots and CODAP for statistics and probability (e.g., CCSSI, 2010; MoNE, 2018; NCTM, 2000; Hollebrands, 2017).

The integration of technology into education has transformed how mathematics is taught and learned, introducing new possibilities for enhancing student engagement and conceptual understanding. As digital tools evolve, their role in mathematics instruction continues to expand, offering teachers innovative ways to visualize and explore complex mathematical concepts. In this context, preparing future educators to effectively integrate technology into their teaching practices is paramount.

The National Council of Teachers of Mathematics (NCTM) emphasizes that "technology is essential in teaching and learning mathematics; it influences the mathematics taught and enhances students' learning" (NCTM, 2000). Similarly, the Association of Mathematics Teacher Educators (AMTE, 2017) highlights the importance of leveraging digital tools to foster meaningful mathematical engagement. For secondary mathematics courses—such as Algebra, Geometry, Calculus, Probability and Statistics—digital tools offer opportunities to create dynamic, interactive, and learner-centered experiences.

This study explores how preservice secondary mathematics teachers (PSMTs) select and integrate digital tools into their teaching portfolios. By examining how these tools are chosen and used to support instruction, the study provides insights into the decision-making processes of preservice teachers and their approaches to integrating technology in high school mathematics courses. Specifically, the study examines PSMTs' use of digital tools through two established theoretical frameworks: (1) Dick and Hollebrands' (2011) distinction between conveyance tools and mathematical action tools, and (2) Pea's (1985, 1987) classification of mathematical action tools as amplifiers or reorganizers of mathematical thinking.

Through this analysis, the study reveals that while PSMTs predominantly select digital tools as amplifiers to enhance efficiency and accuracy, there is significant potential for fostering their ability to use these tools as reorganizers that transform and deepen mathematical understanding. By focusing on the practical and theoretical implications of these findings, this study underscores the need for targeted training in teacher preparation programs to equip future educators with the skills and knowledge required for meaningful technology integration.

Purpose of the Study

This study holds significant implications for teacher preparation programs and the broader field of mathematics education. It identifies trends in the selection and use of digital tools among preservice teachers, highlighting strengths and areas for growth. The findings underscore the importance of moving beyond technology use as an efficiency enhancer (amplifiers) toward its application as a transformative force for deeper understanding (reorganizers). By equipping preservice teachers with the skills to effectively integrate digital tools into instruction, teacher preparation programs can contribute to more innovative and effective mathematics teaching practices.

Through this analysis, the study aims to bridge the gap between theoretical knowledge and practical application in technology integration, advocating for enhanced training and support to help preservice teachers maximize the potential of digital tools in mathematics instruction.

Research Questions

This study addresses the following research questions:
What kinds of digital technologies do preservice teachers select for exploring mathematical concepts in high school mathematics courses (Algebra, Geometry, Calculus, Probability, and Statistics)?

How do preservice teachers classify and rationalize their use of these tools based on their perceived utility (as conveyance tools, mathematical action tools, amplifiers, or reorganizers)?

Literature Review and Theoretical Framework

Literature Review

The integration of technology into mathematics education has been a growing focus in recent decades, driven by its potential to enhance learning outcomes and transform traditional pedagogical practices. Several studies emphasize the critical role of technology in pre-service mathematics teacher education (Goldenberg, 2000; Niess, 2005; Tondeur et al., 2012; Bray & Tangney, 2017; Mishra & Koehler, 2005). For example, Goldenberg (2000) underscores the thoughtful integration of technology in mathematics classrooms, highlighting how it can enhance mathematical thinking and communication skills. However, Goldenberg also cautions against the misconception that technology can replace effective teaching practices, advocating instead for its reflective and purposeful use in supporting instruction. Similarly, Niess (2005) argues that effective integration of technology into science and mathematics education requires teachers to develop a specialized skill set that goes beyond mere technical knowledge. In a broader review, Tondeur et al. (2012) synthesize qualitative evidence from various studies, examining how pre-service teachers are prepared to integrate technology into their future classrooms. They identify common challenges, effective strategies, and themes in technology integration across the literature. The effective integration of digital technologies in mathematics education requires careful consideration of teachers' knowledge, curriculum goals, and student needs. Mishra and Koehler (2005) emphasize that technology use in classrooms should be informed by teachers' pedagogical content knowledge, the curriculum, and student characteristics.

The National Council of Teachers of Mathematics (NCTM) highlights the importance of digital technologies in enriching instruction, facilitating conceptual understanding, and engaging students in dynamic mathematical practices (NCTM, 2000). Digital tools such as GeoGebra, Desmos, and CODAP have enabled educators to visualize abstract concepts, promote interactivity, and provide opportunities for students to explore mathematical relationships in innovative ways.

Teacher preparation programs play a pivotal role in equipping preservice teachers with the skills and knowledge needed to effectively integrate technology into the classroom. Studies have shown that preservice teachers often struggle to move beyond superficial uses of technology, such as for visualization or efficiency, and toward more transformative applications that deepen conceptual understanding (Ertmer & Ottenbreit-Leftwich, 2010). Developing the ability to select and implement appropriate digital tools is therefore a critical component of teacher education.

Existing research has also highlighted frameworks for understanding how technology is utilized in mathematics education. Dick and Hollebrands (2011) distinguish between conveyance tools—used for transmitting and presenting mathematical knowledge—and mathematical action tools, which engage users in performing mathematical operations or exploring concepts interactively. Similarly, Pea (1985, 1987) categorizes digital tools based on their cognitive impact, classifying them as amplifiers (enhancing efficiency and accuracy) or reorganizers (transforming thinking and fostering deeper understanding). These frameworks provide valuable lenses for analyzing how preservice teachers conceptualize and integrate digital tools into their instructional practices.

Digital Learning Environments and Tools

Digital learning environments and tools are transforming mathematics education by fostering interactive learning, conceptual understanding, and student engagement (Heid, 2018). Platforms such as Desmos, CODAP, GeoGebra, Kahoot!, Scratch, and Geometer's Sketchpad offer innovative ways to make mathematics instruction dynamic and engaging. These tools provide both educators and students with opportunities to explore mathematical concepts through visualization, collaboration, and real-time feedback, contributing to more engaging and effective teaching practices.

Desmos, a dynamic online graphing calculator, is widely recognized for its ability to facilitate real-time visualization of mathematical functions and concepts (Chechan et al., 2023; Gulli, 2021; Peni and Dewi, 2023). Its interactive features allow users to explore functions, equations, and inequalities while fostering collaborative problem-solving. Research highlights Desmos' significant impact on student comprehension and engagement. For example, Chechan et al. (2023) reported that Swedish high school students using Desmos showed improved understanding of functions and enhanced post-test scores compared to those taught with traditional methods. Similarly, Gulli (2021) demonstrated how Desmos supports experimentation with geometry and algebra, empowering students to engage with mathematical modeling. Peni and Dewi (2023) further emphasized Desmos' role in increasing student engagement and enhancing problem-solving skills, making it a valuable tool for modern mathematics education.

CODAP (Common Online Data Analysis Platform) is another powerful tool, enabling collaborative data exploration and analysis (Mojica et al., 2019; Budde et al., 2020; Frischemeier et al., 2021). Designed to engage students with real-world data, CODAP promotes statistical literacy and inquiry-based learning. Mojica et al. (2019) highlighted CODAP's effectiveness in teaching seventh-grade students to analyze roller coaster data, which improved their statistical reasoning. Budde et al. (2020) also demonstrated CODAP's potential in developing students' statistical inquiry skills, while Frischemeier et al. (2021) illustrated how CODAP facilitates multivariate data analysis and enhances understanding of descriptive statistics. Together, these studies show CODAP's utility in fostering meaningful engagement with data in educational settings.

GeoGebra is a dynamic mathematics software platform that integrates geometry, algebra, and other mathematical domains, making it a versatile tool for dynamic constructions and visualizations (Shadaan and Leong, 2013; Jelatu and Ardana, 2018; Kim and Md-Ali, 2017). Studies have consistently demonstrated GeoGebra's effectiveness in improving student achievement and understanding. Shadaan and Leong (2013) found that GeoGebra enhances students' comprehension of geometric concepts, fostering critical and innovative thinking. Jelatu and Ardana (2018) reported that the GeoGebra-aided REACT strategy improved

students' geometry understanding and conceptual skills. Kim and Md-Ali (2017) emphasized that GeoGebra supports problem-solving and spatial visualization, making it an essential tool for educators aiming to promote active and meaningful mathematics learning. Kahoot!, a game-based learning platform, has gained popularity for its ability to engage students through interactive quizzes and gamified learning experiences. By providing instant feedback and fostering competition, Kahoot! enhances motivation and participation in mathematics education (Curto Prieto et al., 2019; Zarzycka, 2014). Research has shown that Kahoot! strengthens student engagement and peer relationships, making learning more enjoyable and effective. Scratch, a block-based programming platform, introduces computational thinking and coding through creative projects that integrate mathematics. Its utility in geometry education was explored by Iskrenovic-Momcilovic (2020), who found that Scratch made learning geometry more engaging and effective. By promoting cross-disciplinary learning and fostering creativity, Scratch supports students in developing problem-solving skills and algorithmic thinking.
These tools are also selected and used from the participants of this study, and they tried to integrate the tools in to their digital portfolio entries. As seen in the literature these tools and considered effective tools for mathematics education.

Theoretical Frameworks

This study employs two complementary theoretical frameworks to examine the use of digital tools in mathematics education: *Conveyance and Mathematical Action Tools and Amplifiers and Reorganizers of Mathematical Thinking*

Various classification frameworks have been proposed to categorize digital tools based on their functions and impact on mathematical concepts. Both teachers and students have access to an array of technological resources, including interactive boards, projectors, computers, tablets, specialized software like Desmos, GeoGebra and CODAP, and presentation tools such as PowerPoint. However, there is a distinction in how teachers and students employ these technologies, reflecting variations in their utilization and interaction with the available tools. Dick and Hollebrands (2011) compiled the technologies used in mathematics instruction through two primary approaches: (i) instruments designed for conveying/presenting mathematical knowledge (conveyance tools/technologies), and (ii) tools aimed at actively engaging in mathematical tasks (mathematical action tools). The key distinction lies in the intended purpose for which these technologies are chosen. This classification underscores the dual role of digital tools in conveying mathematical concepts and facilitating mathematical actions, providing a nuanced perspective on their instructional potential.

Pea (1985, 1987) classifies cognitive tools based on their function in supporting learning: Amplifiers and Reorganizers.

Amplifiers enhance the efficiency and accuracy of tasks that could otherwise be performed manually. For example, using a graphing calculator to quickly plot a function saves time but does not necessarily alter the way students understand the underlying concept. Reorganizers enable learners to approach concepts in novel ways, fostering deeper understanding and transforming cognitive processes. For example, GeoGebra allows users to dynamically manipulate geometric constructions, facilitating a more profound exploration of relationships and properties.

Combining this framework with Dick and Hollebrands' classification enables a nuanced analysis of the ways preservice teachers integrate technology into their teaching. By examining whether digital tools are used as amplifiers, reorganizers, or both, this study sheds light on how technology can either support or limit mathematical reasoning and understanding.

Application of Frameworks in This Study

The frameworks of Dick and Hollebrands (2011) and Pea (1985, 1987) guided the analysis of preservice teachers' digital portfolio entries, focusing on their choices and rationales for integrating digital tools in high school mathematics courses. This dual lens allows for a comprehensive evaluation of how preservice teachers utilize technology to engage with mathematical concepts and supports an understanding of their decision-making processes.

By situating the findings within these frameworks, this study contributes to the broader discourse on preparing future mathematics educators to effectively integrate technology into their teaching practices. It highlights the potential for teacher preparation programs to bridge the gap between technology use as an amplifier and its use as a reorganizer, fostering more transformative approaches to mathematics instruction.

Methodology

Participants and Context

The study was conducted with 14 preservice secondary mathematics teachers (PSMTs) enrolled in a secondary mathematics teaching methods course during the Fall 2020 semester at a mid US university. As part of the course requirements, these PSMTs were tasked with preparing digital portfolios to document their exploration and integration of digital tools for teaching high school mathematics concepts. The participants, all preservice teachers preparing to teach grades 9–12, demonstrated varying levels of familiarity and expertise with digital tools, reflecting diverse backgrounds in prior technology usage.

Data Collection

Digital portfolio data was obtained from technology portfolios within the mathematics methods course. These portfolios, encompassing all studies undertaken for specific purposes during the academic tenure of participants (preservice teachers in this study) or designated time frames (Kemp & Toperoff, 1998), serve as evaluative tools reflecting the academic development of students. Having found widespread application in secondary school courses and teacher training programs, portfolios have extended their utility to diverse domains, including mathematics education (Assaidi & Hibi, 2020). The portfolio assignment created by the instructor is structured by the technology principles outlined by NCTM (2000), emphasizing the integral role of technology in the teaching, and learning of mathematics. This involves the impact of technology on the content taught and its contribution to enhancing students' learning experiences.

In the portfolio assignment, pre-service teachers (PSTs) provided their understanding of technology applications, evidence of their knowledge of the uses of technology, and their practical use in the learning and teaching of mathematics. The portfolio entries drew from their coursework in mathematics, mathematics methods, and field experiences. They adapted previous work to align with the portfolio's requirements and ventured into unfamiliar areas to generate new content. Each entry encompassed a discussion of at least three tools, such as spreadsheets, dynamic geometry tools, dynamic graphing tools, computer algebra systems, dynamic statistical packages, graphing calculators, and data-collection devices.

The final portfolio comprised various entries, with each entry allocated one or more pages. Typically, a page was dedicated to the specific item being addressed, such as an exploration, lesson, or resource. Another page or more was devoted to reflection or discussion, wherein the individuals explained how the item demonstrated their achievement of the goals set for that category. For instance, if an entry focused on an exploration using an applet, one page contained a screenshot of the applet, while another page presented the text describing the exploration, learning objectives, and an analysis of how the tool contributed to reaching those objectives.

The primary data for this study consisted of portfolio entries submitted by PSMTs. Each portfolio included ten entries distributed across four main themes:

Exploring Mathematical Concepts with Technology: Four entries focused on different subject areas—Geometry, Algebra, Calculus, and Probability & Statistics.

Knowledge of Resources for Teaching Mathematics with Technology: Two entries evaluating the technologies preservice teachers were familiar with and a critical analysis of one digital tool.

Integrating Technology in Classroom Learning: Two lesson plans incorporating technology for specific educational objectives.

Reflecting on Teaching and Learning Mathematics with Technology: Two entries reflecting on the use of digital tools in lesson plans and their evaluation.

For this study, the analysis was limited to the four entries under the Exploring Mathematical Concepts with Technology theme. For this theme, PSTs included entries that show their experience exploring mathematical concepts with technology or supporting students' exploration of mathematical concepts with technology. They had two options for this category, actual explorations that they conducted or explorations that students conducted and they had the chance to observe. For either option, they should include an explicit statement of the exploration task or better yet, the task itself something that could be given to others (students) to have them work on the exploration. For the first option, they should find a task that they can explore using technology. they should include (1) description of the exploration task, (2) the learning goal of the exploration, (3) a description of the tool used in the exploration (applet, software, graphing calculator), (4) how the tool supported your mathematical learning describing the understandings gained while exploring with the tool, and (5) compare and contrast with a similar task that could be done without the use of technology addressing what is gained with the use of technology and what is lost. For the second option, the entry should be about supporting a student's exploration. They should (1) describe the exploration task (preferably include the statement of the task) and how the instructor introduced the student to the use of the tool, (2) describe the learning goal of the exploration, (3) describe the tool, (4) describe how the tool supported students' mathematical learning including your observations of what the students did while exploring with the tool, and (5) compare and contrast with a similar task that could be done without the use of technology addressing what is gained with the use of technology and what is lost. For this category they should include at least three entries out of four content areas: 1) Explore geometric ideas and their applications, 2) Explore algebraic ideas and solve problems, 3) Explore fundamental concepts of calculus, and 4) Explore fundamental concepts of probability and statistics. Each PSMT was allowed to choose any mathematical concept and order for their submissions, providing freedom to explore and integrate tools based on their preferences and teaching styles.

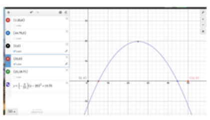
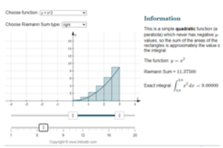
Data Analysis

The data collected was analyzed using two main theoretical approaches. The first approach used was Dick and Hollebrands' (2011) framework to investigate how PSMTs choose digital technologies for teaching mathematics. This framework categorizes digital tools as either conveyance tools or mathematical action tools. If a digital tool is used to present mathematical knowledge, such as a projector, it is considered a conveyance tool. If the tool is used to actively do mathematics, it is considered a mathematical action tool. The digital technologies chosen by PSMTs for exploring mathematical concepts were analyzed according to whether they were used as a conveyance or mathematical action tools. This approach helped identify PSTMs' knowledge and awareness in selecting digital tools.

It was used Pea's (1985; 1987) framework for analyzing how PSMTs use digital tools to identify the ways in which they use them. The framework categorizes digital tools as either amplifiers or reorganizers. If a tool is a mathematical action tool, it was looked deeper into how PSMTs use it to explore mathematical concepts. If the tool simply makes operations faster and easier without requiring a deeper understanding of the concept, it is considered an amplifier. If it requires a deeper understanding and reorganizes the way PSMTs approach the concept, it is considered a reorganizer. If PSMTs used the tool for both making it easier and faster and getting a deeper understanding of the content taught, then I coded as both amplifier and reorganizer. It was also analyzed all the entries submitted by PSMTs according to these frameworks. Table 1 provides examples of how these tools were classified based on Dick and Hollebrands' (2011) and Pea's (1985; 1987) theoretical frameworks.

As seen in Table 1, PSMT2002 chose Microsoft Excel for the Surface area in Calculus as a conveyance tool. It was coded it as a conveyance tool because the teacher used the tool only easier and quicker to graph for all possible dimensions and help learn the technology used for students. The teacher did not mention any benefits of the tool for mathematical meaning. It was coded PSMT2010, PSMT2004 and PSMT2001 selections as mathematical action tools but categorized differently because of their usage. PSMT2010 used Desmos as an amplifier because he/she mentioned that tool requires less time, graph drawn correctly. PSMT2004 used Desmos as an organizer because it helps deeper understanding, help develop analysis and logical thinking skills.

Table 1. Analysis examples for PSMTs' entries by means of Dick and Hollebrands' (2011) and Pea's (1985; 1987) frameworks

Participant	**PSMT2002**	**PSMT2010**	**PSMT2004**	**PSMT2001**
Entries	Entry 3 Calculus Surface area Coke Can Optimization	Entry 2 Finding a Real-Life Parabola	Entry 1 Scatter Plots Linear & nonlinear associations	Entry 4 Integral Riemann Sums
PSMTs' Activities				

Digital Technology	Microsoft Excel	Desmos Graphing Calculator	Desmos	Interactive Mathematics
Selection Classification of the Digital Technologies (Hollebrands and Dick's (2011) framework)	Conveyance	Mathematical Action Tool	Mathematical Action Tool	Mathematical Action Tool
Use of Digital Technologies (Pea's (1985; 1987) framework)	NA	Amplifier	Reorganizer	Amplifier & Reorganizer
Explanation	Easier and quicker to graph for all possible dimensions and help learn technology use	Less time, graph drawn correctly	Show how graphs are represented, encourages understanding, help develop analysis and logical thinking skills.	faster, more flexible, and interactive. Help for deeper understanding.

Validity and Reliability

To ensure consistency in coding, all entries were carefully reviewed and categorized by the author. The classification process followed clear criteria derived from the theoretical frameworks, ensuring that each tool's purpose and application were accurately identified. Future studies could enhance reliability by involving multiple researchers to cross-check coding decisions.

Ethical Considerations

The study adhered to ethical guidelines for research involving human participants. Data were anonymized to protect the identities of PSMTs, and participation in the study was voluntary. The analysis focused solely on coursework submissions, which were part of standard course requirements.

Findings and Discussions

The findings of this study reveal critical insights into how preservice secondary mathematics teachers (PSMTs) select and use digital tools for teaching high school mathematics concepts. Analysis of the portfolio entries demonstrated distinct patterns in tool selection across Algebra, Geometry, Calculus, and Probability & Statistics. Table 2 illustrates the range of digital tools chosen by PSMTs for each mathematical domain, shows preferences for widely used platforms like GeoGebra and Desmos, alongside other tools such as CODAP and Geometer's Sketchpad. The data indicate that PSMTs predominantly opted for mathematical action tools rather than conveyance tools, with a strong emphasis on tools serving as amplifiers to enhance efficiency and visualization. However, some entries also showcased the potential of these tools to act as reorganizers, fostering deeper conceptual understanding and engagement with mathematical ideas.

Table 2. Selection of the digital technologies for each entry of the theme of Exploring Mathematics Concepts

	Entry 1		Entry 2		Entry 3		Entry 4	
Participant	Course	Digital tool	Course	Digital tool	Course	Digital tool	Course	Digital tool
PSMT2001	Statistics & Probability	Google Sheets	Algebra	Desmos	Geometry	GeoGebra	Calculus	Interactive math
PSMT2002	Statistics & Probability	CODAP	Algebra	Geometers Sketchpad	Calculus	Microsoft Excel	Geometry	GeoGebra
PSMT2003	Statistics & Probability	Coin Toss Simulation	Calculus	Mathematica	Algebra	Java Bars	Geometry	GeoGebra
PSMT2004	Algebra	Desmos	Statistics& Probability	Desmos	Geometry	GeoGebra	Calculus	GeoGebra
PSMT2005	Statistics & Probability	CODAP	Geometry	Hyper Rouge Game	Algebra	Geometers Sketchpad	Calculus	Desmos
PSMT2006	Algebra	Geometers Sketchpad	Geometry	GeoGebra	Statistics & Probability	CODAP	NA	NA
PSMT2007	Geometry	GeoGebra	Statistics & Probability	CODAP	Calculus	Desmos	Algebra	Desmos
PSMT2008	Algebra	Desmos	Statistics & Probability	CPM Probability	Calculus	Wolfram Alpha	Geometry	Geometry Calculator
PSMT2009	Algebra	GeoGebra	Geometry	Desmos	Calculus	Interactive Calculus Tool	Statistics& Probability	Adjustable Spinner
PSMT2010	Calculus	Microsoft Excel	Algebra	Desmos	Statistics & Probability	CODAP	Geometry	GeoGebra
PSMT2011	Calculus	Desmos	Algebra	Geometers Sketchpad	Statistics& Probability	Microsoft Excel	Geometry	GeoGebra
PSMT2012	Algebra	GeoGebra	Geometry	Geometers Sketchpad	Statistics & Probability	Math Warehouse	Calculus	Shodor
PSMT2013	Algebra	GeoGebra	Statistics & Probability	Rossman/ Chance Collection	Geometry	GeoGebra	Calculus	GeoGebra
PSMT2014	Calculus	GeoGebra	Algebra	Geometers Sketchpad	Geometry	Desmos	Statistics& Probability	Microsoft Excel

As seen in Table 2, four PSMTs chose Statistics and Probability, six PSMTs chose Algebra, three PSMTs chose Calculus and one PSMT chose Geometry in Entry 1. Four PSMTs chose Statistics and Probability, five PSMTs chose Algebra, one PSMT chose Calculus and four PSMTs chose Geometry in Entry 2. Four PSMTs chose Statistics and Probability, two PSMTs chose Algebra, four PSMTs chose Calculus and 4 PSMTs chose Geometry in Entry 3. Two PSMTs chose Statistics and Probability, one PSMT chose Algebra, five PSMTs chose Calculus and five PSMTs chose Geometry in Entry 4.

PSMTs choose different digital tool for their entries. 15 PSMTs chose GeoGebra (Dynamic geometry environment and computer algebra system), 11 PSMTs chose Desmos (Online interactive dynamic geometry environment and computer algebra system), 6 PSMTs chose Geometer's Sketchpad (Interactive geometry software program) , 5 PSMTs chose CODAP (Common Online Data Analysis Platform), 4 PSMTs chose Microsoft Excel (Spreadsheet software).

The second research question examined how PSMTs select and use digital technologies when exploring mathematical concepts. The participants were free to choose a mathematical concept for each topic and determine the order of their assignment submissions. Is was analyzed the digital technology chosen by the participants using the framework of conveyance and mathematical action tools developed by Hollebrands and Dick in 2011. Is was also analyzed how these technologies were integrated into teaching specific mathematical concepts using Pea's classification (1985; 1987) in conjunction with Hollebrands and Dick's framework. Table 3 illustrates the quantitative findings for the distribution of digital technologies PSMTs choose for each entry of the theme of exploring mathematics concepts. Table 4 also demostrates the quantitative findings for the classification of each entry and PSMTs entries.

Table 3. Distribution of digital technologies PSMTs choose for each entry of the theme of Exploring Mathematics Concepts

Entries for Exploring Mathematics Concepts / Selection and Use of Digital Technologies		**Algebra (n=14) F (%)**	**Geometry (n=14) F (%)**	**Calculus (n=13) F (%)**	**Probability & Statistics (n=14) F (%)**
Conveyance Tools		-	-	1 (7.69)	-
Mathematical Action Tools	*Amplifier*	9 (64.29)	5 (35.71)	10 (76.92)	9 (64.29)
	Reorganizer	4 (28.57)	7 (50)	-	3 (21.43)
	Amplifier & Reorganizer	1 (7.14)	2 (14.29)	2 (15.38)	2 (14.29)

According to Table 3, almost all digital technologies used for exploring mathematical concepts in different entries were mathematical action tools. Only one participant (i.e., PSMT2002) indicated one conveyance tool in the Calculus entry. However, PSTM2002 still had another digital tool (i.e., CODAP, GeoGebra, and Geometer's Sketchpad) to be used to teach mathematical concepts in Geometry, which are used as mathematical action tools. In each course, PSMTs mostly chose to use mathematical action tools as amplifiers. In Algebra, Calculus, and Probability& Statistics, more than 64% of students chose to use amplifiers. In Geometry, 50% of students chose to use reorganizers. None of the students chose to only reorganizer in the calculus course and most of the tools were selected as amplifiers. Table 4 categorizes the entry order and each student's selection of the tools. In all of the entries, PSMTs chose mathematical action tools as amplifiers. In entry 1, 5 PSMTs chose the digital tools both amplifiers and reorganizers. As seen in the table below, all of the PSMTs chose the mathematical actions as reorganizers at least in one entry except PSMT2010. PSMT2010 chose to use all entries as amplifiers. Half of the PSMTs chose only one entry as both amplifiers and reorganizers.

Table 4. Classification for each entry and PSMTs entries

	Conveyance Tools	Mathematical Action Tools		
		Amplifier	Reorganizer	Amplifier & Reorganizer
Entry 1	NA	8	1	5
Entry 2	NA	10	3	1
Entry 3	1	7	6	NA
Entry 4	NA	8	4	1
PSMT2001	NA	2	1	1
PSMT2002	1	1	1	1
PSMT2003	NA	2	1	1
PSMT2004	NA	3	1	NA
PSMT2005	NA	2	1	1
PSMT2006	NA	2	1	NA
PSMT2007	NA	2	1	1
PSMT2008	NA	3	1	NA
PSMT2009	NA	1	2	1
PSMT2010	NA	4	NA	NA
PSMT2011	NA	3	1	NA
PSMT2012	NA	3	1	NA
PSMT2013	NA	3	1	NA
PSMT2014	NA	2	1	1

In general, almost all of the PSTMs chose to digital tools as mathematical action tool in each entry except one entry. When we consider Pea's (1985; 1987) frameworks, 60% of the digital tools were selected to use as amplifiers, more than 25% of the digital tools were selected to use as reorganizers, 13% of the digital tools were selected as both reorganizers and amplifiers. The entry orders matter for using digitals tools as reorganizers. In entry 1, only one PSMT chose to use as reorganizer, and it increased with the following entries. This could be because they learn more about using digital tools during the course and decided to use more deeper understanding of mathematical content taught.

Discussion

The findings of this study reveal important patterns in how preservice secondary mathematics teachers (PSMTs) select and use digital tools in their teaching portfolios. The predominance of mathematical action tools, such as GeoGebra and Desmos, reflects a strong inclination toward leveraging technology for dynamic visualization and interactive learning. These tools' adaptability across various mathematical domains, including Algebra, Geometry, and Calculus, highlights their role in fostering exploratory and student-centered approaches to mathematics education.

One notable trend is the emphasis on tools as amplifiers, primarily used to enhance efficiency and streamline tasks such as graphing or computation. While this demonstrates PSMTs' understanding of technology's potential to simplify processes, it also points to a missed opportunity to fully use these tools as reorganizers that can transform students' conceptual understanding. For instance, tools like GeoGebra have the capacity to enable deeper engagement with mathematical relationships through dynamic manipulation, yet this potential was not consistently realized in all entries.

The limited use of conveyance tools, such as Microsoft Excel, raises questions about how PSMTs perceive these tools' relevance to mathematics instruction. While conveyance tools can facilitate information sharing and collaborative learning, their underutilization suggests a need for teacher preparation programs to emphasize their integration in conjunction with mathematical action tools. By doing so, preservice teachers can create more balanced instructional strategies that incorporate both interactive exploration and effective communication.

The variations in tool selection across different mathematical domains also shed light on PSMTs' confidence and familiarity with specific technologies. The frequent use of dynamic geometry software for Geometry, compared to a narrower range of tools for Statistics and Probability, highlights the importance of targeted exposure to diverse digital tools during teacher training. Equipping preservice teachers with the knowledge and skills to use specialized tools, such as CODAP or probability simulators, can broaden their ability to design innovative learning experiences across all mathematical disciplines.

Overall, these findings highlight the critical role of teacher preparation programs in developing preservice teachers' technological pedagogical content knowledge (TPACK). Providing structured opportunities to experiment with a variety of digital tools and frameworks, such as conveyance versus mathematical action tools and amplifiers versus reorganizers, can help PSMTs make more intentional and effective decisions about technology integration in their future classrooms.

Conclusion

This study provides valuable insights into the decision-making processes of preservice secondary mathematics teachers regarding the selection and integration of digital tools in high school mathematics instruction. By analyzing their teaching portfolios through established frameworks, the findings highlight both strengths and areas for growth in their approach to technology integration.

The results emphasize the prevalence of mathematical action tools as the primary choice for exploring mathematical concepts, particularly in their roles as amplifiers. While this demonstrates an understanding of how technology can enhance efficiency, it also reveals opportunities to further develop PSMTs' ability to use tools as reorganizers, fostering deeper conceptual engagement. Additionally, the underutilization of conveyance tools and the limited variety of tools used for certain mathematical domains, such as Statistics and Probability, suggest that more comprehensive training is needed to expand preservice teachers' technological repertoire.

As mathematics education continues to evolve, the integration of technology remains essential in fostering meaningful learning experiences. This study advocates for teacher preparation programs to provide more targeted and hands-on experiences with diverse digital tools, equipping preservice teachers with the confidence and skills to effectively integrate technology in their instruction. By empowering future educators to use technology as both amplifiers and reorganizers, we can enhance the quality and accessibility of mathematics education for all learners.

Limitations

While this study provides valuable insights into preservice secondary mathematics teachers' (PSMTs) selection and integration of digital tools, it is important to acknowledge its limitations. First, the sample size was limited to 14 participants from a single cohort in a teacher preparation program. This may restrict the generalizability of the findings to other contexts or programs. Expanding the sample to include multiple cohorts or institutions would allow for a more comprehensive understanding of PSMTs' decision-making processes.

Second, the study focused on the digital portfolio entries created as part of a course requirement, which may reflect theoretical understanding more than practical implementation. Observing PSMTs in authentic teaching settings or collecting additional data from live teaching sessions could yield richer insights into their instructional strategies and the challenges they face.

Third, while this study analyzed a specific subset of the technology portfolio (entries exploring mathematical concepts), it did not examine the entirety of the portfolio. A broader analysis of all portfolio components could provide a more holistic view of how PSMTs conceptualize and implement technology integration across various aspects of their teaching.

Lastly, the coding and analysis of data were conducted by a single researcher. Although established theoretical frameworks guided the analysis, incorporating additional coders and employing inter-rater reliability checks would enhance the rigor and reliability of the findings.

Future Studies

This study represents the foundation for a larger, ongoing research project as part of a dissertation study. Future work will analyze the full technology portfolios of PSMTs across multiple cohorts, enabling a longitudinal comparison of how preservice teachers develop their Technological Pedagogical Content Knowledge (TPACK) over time. By examining entries from different years, this larger study aims to identify trends, shifts, and growth in technology integration practices.

Additionally, the expanded study will explore how the course structure and content support the development of TPACK. Specific focus will be placed on understanding how various assignments, such as lesson planning and critical evaluation of tools, contribute to preservice teachers' ability to integrate technology effectively in the classroom. This research could also investigate how different pedagogical approaches or interventions influence PSMTs' ability to use digital tools as both amplifiers and reorganizers.

Moreover, future studies could adopt a mixed-methods approach, combining portfolio analysis with classroom observations, interviews, and surveys to capture a more nuanced picture of PSMTs' technology integration practices. Comparing data across diverse educational contexts, such as varying levels of technological access or differing institutional priorities, could provide insights into external factors shaping technology use.

Finally, the inclusion of student perspectives in future research would enrich our understanding of the impact of digital tools on learning outcomes. Investigating how students engage with and respond to the tools selected by their teachers could inform recommendations for teacher preparation programs and guide the development of more effective instructional practices.

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