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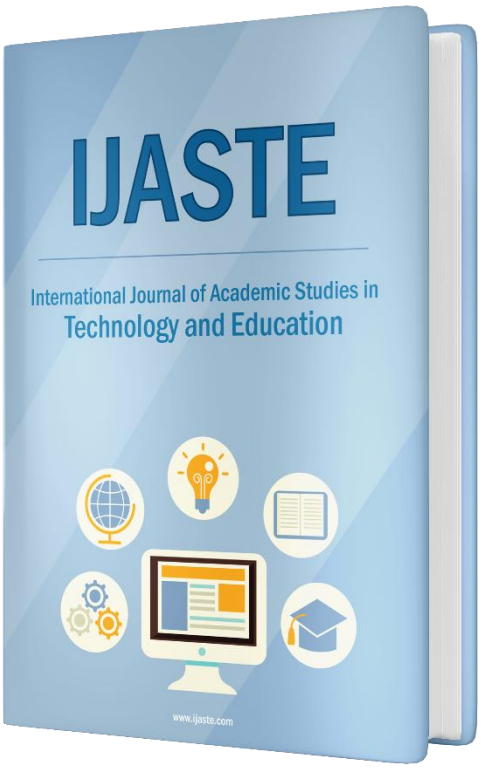

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Contact Info

International Journal of Academic Studies in Technology and Education (IJASTE)

Email: ijasteoffice@gmail.com

Web: http://www.ijaste.com

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

Selim Yavuz

Indiana University, United States / *Ministry of National Education*, Türkiye

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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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Corresponding Author: Selim Yavuz, syavuz@iu.edu

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

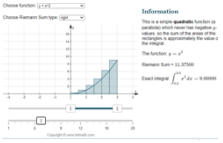
The data collected was analyzed using two main theoretical approaches. The first approach used was Dick and Hollebrands' (2011) framework to investigate how PSMTs choose digital technologies for teaching mathematics. This framework categorizes digital tools as either conveyance tools or mathematical 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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Authors Information

Selim Yavuz
https://orcid.org/0009-0005-6816-2422
Indiana University,
United States
Ministry of National Education,
Türkiye

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Unveiling Religious Identity in Virtual Classrooms: Insights and Impacts

Jennifer B. Fabula
De La Salle-College of Saint Benilde, Philippines

Karl O. Salvador
De La Salle-College of Saint Benilde, Philippines

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Abstract

The shift to online learning in universities, particularly following the pandemic, has prompted educators to adapt traditionally face-to-face courses such as religious education to virtual formats. This mixed-method study employed surveys with 308 college students at a Catholic institution and in-depth interviews with 27 participants to examine how online delivery shapes students' religious identity. Thematic analysis of interview data revealed four key themes: embracing adaptability and introspection, fostering connections beyond physical boundaries, broadening spiritual perspectives, and grappling with technological challenges. The findings illuminate the interplay between digital learning experiences and religious identity development, offering actionable insights for educators aiming to enhance virtual religious education. Recommendations include conducting longitudinal studies to monitor student religious identity shifts within online environments and evaluate digital religious education's enduring effects on faith and community engagement.

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Corresponding Author: Jennifer B. Fabula, jennifer.fabula@benilde.edu.ph

Introduction

The swift growth of online learning platforms has significantly changed the landscape of higher education, extending beyond traditional classrooms to deliver global educational opportunities (Brasca et al., 2022). Hastened by the transition to online learning in response to the COVID-19 pandemic, this shift has sparked meaningful discussions about how virtual environments impact different aspects of students' lives, including personal and spiritual growth. Experts project that online education will continue expanding by 2025 (McCue, 2018; Brasca et al., 2022), and some argue that virtual classes may ultimately replace face-to-face teaching (Waghid & Waghid, 2017). Such a transition calls for reevaluating educational approaches within technological environments, as several scholars underscore the need for adaptable pedagogy (Cambridge, 2010; Govindarajan & Srivastava, 2020).

While online learning has transformed teaching methods and widened access, its impact on students' religious beliefs, a fundamental component of personal identity, remains underexplored (Gao et al., 2024). This gap is especially notable in religious education, which traditionally relies on in-person interactions to foster deep and shared learning experiences. Zain (2021) and Halevy and Gross (2023) highlight the importance of investigating how online learning environments affect these personal and communal dimensions of student growth. In religious education, where students typically engage in group discussions, hands-on activities, and rituals that strengthen their faith, the transition to online learning introduces unique challenges and opportunities (Baburajan et al., 2022; Veronica et al., 2022; Syafii & Retnawati, 2022). This study examines whether these longstanding practices retain their impact when religious teachings are delivered virtually.

At De La Salle-College of Saint Benilde, the Theology department recently shifted all its courses from face-to-face to fully online instruction. This move has prompted educators to reconsider how theological concepts are conveyed and how students connect with spiritual teachings. Faculty members in the department have embraced these changes through various virtual teaching methods, including BigSky (the institution's Learning Management System) and video conferencing platforms such as Zoom and Google Meet, to replicate the interactive and communal experience central to theological education.

In light of these developments, this study addresses three critical questions by drawing on survey data and in-depth interviews: (1) How do students perceive their religious identity in an online religious class? (2) What is the overall level of religious identity among students? (3) Do male and female students and Catholic and non-Catholic students differ in how they perceive their religious identity? To probe these issues further, two hypotheses were tested at a 0.05 significance level:

- **Ho_1**: No significant difference exists in how males and females perceive their religious identity.
- **Ho_2**: No significant difference exists in how Catholics and non-Catholics perceive their religious identity.

Given the increased reliance on digital learning in educational institutions, this research is timely. Online platforms offer fresh insights into how virtual settings might shape the formation of religious identities (Algrim, 2020; Bingaman, 2020). Strengthening the spiritual dimension of religious teaching in the digital sphere sheds light on emerging pedagogical strategies and could influence future policies and practices in religious education.

As technology permeates education, it influences how religious teachings are delivered and learners interact with their faith and community. By situating this research at the intersection of spirituality and technological innovation, we aim to identify effective ways to leverage digital tools for deeper religious understanding and stronger interpersonal connections, thereby bridging the gap between traditional religious pedagogy and contemporary technologies. Ultimately, this study urges educators and institutions to reconsider how they foster spiritual development in a rapidly changing educational environment. The research highlights the value of creating inclusive, spiritually meaningful experiences that transcend physical boundaries by examining the interplay between online learning and religious beliefs. In a society shaped by continuous technological advancement, nurturing spiritual growth at individual and communal levels remains vital to all educational contexts.

Literature Review

Developing Religious Identity

Religious identity refers to how individuals relate to religion and spirituality. Earlier studies framed religious identity primarily as a product of societal and cultural norms shaped by factors like family, community, and traditions (Queen, 1996). More recent studies emphasize its diverse and evolving nature, highlighting how personal experiences, cultural settings, and spiritual practices play vital roles (de Bruin-Wassinkmaat et al., 2021). Particularly for young people, religion can offer a sense of meaning, belonging, and connection with peers, relatives, and a higher power, thus acting as a guiding framework for self-discovery (King, 2019).

Scholars disagree on how best to define and develop religious identity. Some focus on traditional religious observances, whereas others prioritize individual faith and personal convictions. The debate extends to the interplay between "nature" and "nurture." While some argue that religious identity is shaped through upbringing and community, others suggest a genetic component (Kitayama & Salvador, 2017). Regardless of

theoretical stance, most researchers concur that religious identity is not static but evolves through inherited traits and intentionally cultivated beliefs.

De Bruin-Wassinkmaat et al. (2021) underscore this complexity, showing how cultural contexts, personal experiences, and societal changes can reshape an individual's spiritual path. For instance, Mulder's (2018) research highlights how interacting with various subcultures, such as metal music communities, can foster empathy, challenge biases, and deepen self-reflection, ultimately enriching a person's religious identity. In our contemporary world, traditional religious practices increasingly coexist with modern approaches to faith. Open conversations with people from various backgrounds can lead to a more inclusive view of religious identity. Campbell (2020) notes that digital platforms can facilitate meaningful interfaith conversations, while Cheong et al. (2012) emphasize how these virtual interactions support community-building and inclusivity. Recent developments in immersive technologies, such as virtual reality, further expand possibilities. Liu, Li, and Gao (2023) illustrate how VR-based experiences can help users explore global religious symbols and rituals more effectively, enhancing comprehension and promoting respect for diversity.

In short, religious identity formation is a dynamic process shaped by long-established traditions and innovative technologies. Family upbringing, cultural norms, personal encounters, and societal shifts contribute to this evolution. At the same time, digital tools, from online forums to VR environments, offer opportunities for broadening spiritual perspectives and nurturing an inclusive religious identity (Campbell, 2020; Cheong et al., 2012; Liu et al., 2023). Ultimately, this synergy between tradition and innovation empowers individuals to navigate contemporary challenges while maintaining a deeply rooted sense of faith and belonging.

Exploring Online Religious Education

Against this backdrop, virtual learning has emerged as a pivotal development in modern education. While online modalities bring clear advantages, including accessibility and flexibility, some scholars point out potential drawbacks, such as the risk of distraction and difficulty replicating the communal atmosphere often integral to religious formation (Mottaqhi, 2021). Balancing these realities requires careful curricular planning to support both the personal and social dimensions of students' growth.

Multiple studies explore these complexities. Mikeska and Howell (2021) highlight the benefits of virtual environments for simulated teaching but also caution about gaps in authenticity and how a virtual platform might differ from real-world instruction. They call for a deeper focus on key authenticity aspects, including teacher embodiment and instructional effectiveness. Similarly, Al Qahtani (2019) reports that students and teachers prefer virtual English classes for convenience and communication benefits. Similarly, Shahid et al.

(2023) show how students who find helpful technology user-friendly and socially endorsed are more inclined to adopt digital learning tools positively.

These findings extend to religious education, where fostering spiritual connection often depends on collective rituals and physical gatherings. Online classes can simulate these experiences, offering forums, videoconferences, and interactive assignments, but achieving the "communal feel" in traditional settings remains challenging. Nonetheless, the potential for broader reach, cross-cultural dialogue, and immersive digital experiences highlights a clear avenue for growth in religious instruction. Such expansion depends on educators' ability to maintain the authenticity of religious traditions while adapting pedagogical methods to digital contexts.

Successful online religious education demands thoughtful design that merges conventional practices with innovative delivery modes. Programs must encourage participation, continuity of faith traditions, and meaningful engagement with religious teachings, all while leveraging digital platforms to broaden students' exposure and foster inclusivity. In today's rapidly evolving digital environment, it is increasingly important for educational institutions to examine what shapes students' willingness to embrace and actively participate in online religious education.

Methodology

Research Design

This study employed a mixed-methods convergent parallel design to examine how religious identity is expressed in online educational settings. In this approach, quantitative and qualitative data were collected simultaneously and then analyzed separately to allow for robust comparison and integration of results. By converging these two datasets, the study aimed to provide a more comprehensive understanding of how virtual platforms influence students' religious identity and engagement in digital learning environments.

Participants in the Study

Participants were drawn from the School of Multidisciplinary Studies at De La Salle College of Saint Benilde, where theology courses have transitioned to online delivery. Of approximately 400 eligible students, 308 responded to the survey, representing diverse backgrounds regarding gender and religious affiliation. Sampling was conducted voluntarily via course announcements, ensuring that all students enrolled in the relevant courses had an equal opportunity to participate.

To gain deeper qualitative insights, 21 volunteers were selected for semi-structured interviews. These interviewees were purposefully chosen to capture variation in gender (e.g., male, female) and religious affiliation (e.g., Catholic, non-Catholic), facilitating a richer exploration of personal experiences and ensuring diverse perspectives on religious identity.

Research Instruments

The online questionnaire comprised 25 Likert-scale items, with response options ranging from "very high" to "very low." These questions were designed to measure students' self-reported religious beliefs, their perceptions of online theology classes, and various aspects of interaction and engagement in virtual learning. To ensure clarity and relevance, the instrument was piloted with a small group of students with similar backgrounds to the intended population (Turner, 2010). Feedback from this pilot led to minor wording adjustments before the final version was administered.

The semi-structured interview guide focused on capturing personal stories and lived experiences concerning religious identity online. It included questions that probed how students perceive changes in their faith, sense of community, and overall spiritual engagement within virtual learning environments. After a practice run with a small sample (Bayat et al., 2019), the interview guide was refined to ensure that each question's phrasing was clear and appropriate for the participants' experiences.

To confirm the study's rigor, the Chair of Theology and an experienced statistician reviewed all survey items for content validity and alignment with the research objectives. The survey demonstrated strong internal consistency, reflected in a Cronbach's Alpha value of 0.973. This high coefficient indicates that the questionnaire reliably measured the various dimensions of students' religious experiences (see Table 1 for interpretations of Cronbach's Alpha).

Table 1. Cronbach's Alpha Interpretation

Cronbach's Alpha (α)	**Internal Consistency/ Reliability**
$\alpha > 0.9$	Excellent
$0.8 \leq \alpha < 0.9$	Good
$0.7 \leq \alpha < 0.8$	Acceptable
$0.6 \leq \alpha < 0.7$	Questionable
$0.5 \leq \alpha < 0.6$	Poor
$\alpha < 0.5$	Unacceptable

Data Gathering Procedure

Data collection began with formal approval from the Dean of the School of Multidisciplinary Studies, ensuring adherence to institutional research guidelines. The researchers then contacted the students' professors to request permission to administer the survey. In line with ethical standards, each survey accompanied a comprehensive consent form detailing the study's purpose, confidentiality measures, and an emphasis on voluntary participation. To maximize access, the survey was distributed via BigSky**,** the college's Learning Management System, and was made available to all students enrolled in specific theology courses.

Data Analysis

Two-sample t-tests with equal variances were conducted for the quantitative component to assess the strength of participants' religious identity in online classes. The analysis entailed two separate comparisons: one between males (n=25) and females (n=25) and another between Catholics (n=26) and non-Catholics (n=26). Before analysis, assumptions such as normality and homogeneity of variance were checked.

For the qualitative component, interviews were transcribed verbatim and then carefully reviewed for accuracy and completeness. The researcher manually coded these transcripts, identifying themes and recurring patterns related to online religious identity. Lastly, these qualitative findings were interpreted in the context of the study's overarching research questions. In keeping with a convergent parallel design, the quantitative and qualitative results will be compared to provide a comprehensive understanding of how virtual learning platforms influence students' religious identity.

Results and Discussions

RQ1: How do students perceive their religious identity in a virtual religious class?

Discussions with students and group interviews revealed four main themes that illuminate how participants perceive their religious identity in online theology courses**:** (1) Embracing Adaptability and Introspection, (2) Fostering Connections Beyond Physical Boundaries, (3) Broadening Spiritual Perspectives, and (4) Grappling with Technological Challenges.

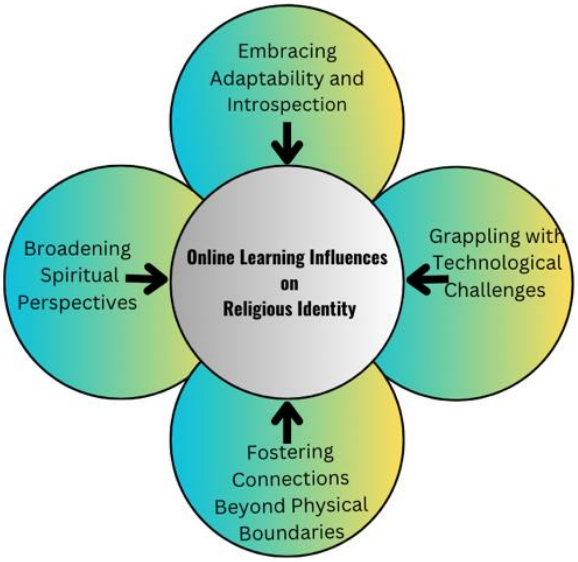

Figure 1. Schematic diagram outlining the key themes in virtual religious education

Theme 1: Embracing Adaptability and Introspection

Online learning has reshaped how students engage with religious education, turning personal spaces into havens for study and reflection. Because students can attend classes from any location, many reported feeling more relaxed and empowered to delve deeper into course content. One student observed, *"Being at home allowed me to ponder my thoughts and emotions privately, which I could not do in a traditional classroom,"* highlighting how a virtual environment can serve as a modern retreat for introspection. Another noted, *"I feel more connected to my spiritual side when I am in my environment, away from usual classroom distractions."* These observations align with Bates's (2015) findings that online platforms can enhance students' engagement with course content. Similarly, Hamilton and Friesen (2013) emphasize that digital learning environments can boost participation and self-reflection.

Theme 2: Fostering Connections Beyond Physical Boundaries

Although students are physically dispersed, virtual classrooms have successfully cultivated a sense of shared community. Interactive tools like forums, group chats, and live discussions help bridge geographic gaps and foster academic and spiritual connections. One student remarked, *"The community vibe in the class is as strong as face-to-face sessions."* Another added, *"We open up more personally because it feels safe and inclusive, which deepens the spiritual bond."* These sentiments echo Lowenthal and Moore's (2020) work, which underscores the role of digital tools in enhancing the communal aspect of online learning. Martin, Sun, and Westine (2020) further suggest that virtual religious education can transcend physical boundaries to create a dynamic, engaging learning community.

Theme 3: Broadening Spiritual Perspectives

Online theology classes expose students to diverse religious viewpoints they might not encounter in traditional settings. Classmates worldwide contribute unique perspectives on cultural practices and faith traditions, enriching spiritual understanding. One participant explained, *"Hearing insights from peers across the globe brings religious teachings to life in ways textbooks cannot replicate."* Selwyn (2014) similarly found that exposure to various religious and cultural perspectives boosts students' spiritual growth. Weller (2018) notes that the diversity in virtual classrooms fosters tolerance and encourages deeper interfaith discussions.

Theme 4: Grappling with Technological Challenges

Despite these advantages, online religious education also poses challenges. Students sometimes experience unreliable internet connections or technical glitches that disrupt class flow and reduce active participation. However, such hurdles spur creative solutions, including asynchronous activities accommodating varied schedules and time zones. One student commented, *"Although technical glitches can be frustrating, they teach us patience and adaptability, which are important spiritual lessons."* Research by Barbour and LaBonte (2019) indicates that technical interruptions can affect student engagement, but Barbour and Reeves (2009) argue that overcoming these setbacks can foster resilience. Martin, Polly, and Ritzhaupt (2020) likewise emphasize that well-designed educational technologies can minimize barriers and maintain an inclusive environment.

In summary, students generally felt that the virtual format deepened their connection to faith by providing flexibility and opportunities for introspection not always found in face-to-face settings. Despite being physically separated, a strong sense of community emerged, aided by interactive tools that transcend geographic limitations. Furthermore, exposure to diverse viewpoints broadens students' religious perspectives, while dealing with technological challenges often cultivates resilience. These four themes illustrate how online religious education can strengthen students' spiritual lives in ways that traditional classrooms may not fully replicate.

RQ2: What is the student's overall level of religious identity?

Quantitative data showed a notable difference in perceived religious identity based on gender and religious affiliation**.** Female students reported a higher average religious identity score (4.0392) than males (3.9084). Similarly, Catholic students had a higher average score (4.106923) than non-Catholic students (3.575769). These findings suggest that demographic factors, particularly gender and religious upbringing, can influence

how strongly students connect with their faith in an online learning setting. This outcome reinforces the importance of recognizing individual differences when designing and delivering virtual religious education.

RQ3: Is there a significant difference in the perceived level of religious identity between?

Male and Female Students

Ho_1: There is no significant difference in the perceived level of identity between males and females.

Table 2 shows the results of a two-sample t-test with equal variances, indicating a significant difference ($p < 0.05$) in religious identity scores between male and female students. Female participants reported higher levels of religious identity, aligning with Charzyńska and Heszen Celińska's (2020) observation that women often exhibit more pronounced religious commitments than men.

Table 2. t-Test: Two-Sample Assuming Equal Variances

	Mean: Male	**Mean: Female**
Mean	**3.9084**	**4.0392**
Variance	0.010855667	0.014957667
Observations	25	25
Pooled Variance	0.012906667	
Hypothesized Mean Difference	0	
df	48	
t Stat	-4.070574461	
P(T<=t) one-tail	8.71246E-05	
t Critical one-tail	1.677224196	
P(T<=t) two-tail	**0.000174249**	**p-Value = 0.0**
t Critical two-tail	2.010634758	

Catholic and Non-Catholic Students

Ho_2: There is no significant difference in the perceived level of identity between Catholics and Non-Catholics.

Similarly, Table 3 presents the results for Catholic vs. non-Catholic students, revealing a significant difference ($p < 0.05$) in religious identity scores. Catholic students generally reported higher levels of religious identity, suggesting that a student's religious upbringing can shape how they experience spirituality in virtual classrooms.

Table 3. t-Test: Two-Sample Assuming Equal Variances

	Catholic	Non-Catholic
Mean	4.106923	3.575769
Variance	0.010238	0.046377
Observations	26	26
Pooled Variance	0.028308	
Hypothesized Mean Difference	0	
Df	50	
t Stat	11.38254	
P(T<=t) one-tail	8.63E-16	
t Critical one-tail	1.675905	
P(T<=t) two-tail	1.73E-15	p-Value = 0.0
t Critical two-tail	2.008559	

These findings underscore how personal identity factors such as gender and religious background can affect students' engagement and spiritual growth. Carrington and Scott (2022) similarly argue that various demographic variables shape the online learning experience. Kahn et al. (2017) highlight the significance of self-reflection in virtual learning, suggesting that spiritual beliefs can play a pivotal role in how students perceive and navigate their education. Lapsley and Kelley's work further indicates that Catholic identity influences the guiding principles of Catholic education, emphasizing the need to integrate religious values into teaching methods for holistic student development. Collectively, these results illustrate the importance of recognizing and accommodating individual and cultural identities within online learning environments. Educators and administrators must tailor instructional approaches that respect diverse religious and cultural backgrounds, enhancing student engagement and fostering an inclusive academic setting.

Recommendations

In light of these findings, future research should explore tailored strategies and teaching methods in online religious education that account for both men's and women's spiritual needs, particularly those that might deepen male students' sense of connection while reinforcing the engagement of female learners. Given that Catholic students report a more robust religious identity than non-Catholics, further investigation into the societal and cultural factors driving this disparity could illuminate how upbringing and community norms shape students' spirituality. Longitudinal studies could also help determine whether improvements in religious identity persist over time, shedding light on how ongoing virtual engagement contributes to spiritual growth and commitment. Finally, examining the effectiveness of interfaith dialogues and inclusive pedagogical

approaches in digital settings is vital for broadening students' religious perspectives and cultivating a more welcoming, enriching environment for all learners, regardless of their faith backgrounds.

Conclusion

This study highlights the multifaceted impact of virtual learning on students' spiritual development. Through the combined examination of statistical results and in-depth qualitative data, the study uncovered four central themes: (1) Embracing Adaptability and Introspection, (2) Fostering Connections Beyond Physical Boundaries, (3) Broadening Spiritual Perspectives, and (4) Grappling with Technological Challenges. These themes illustrate how flexible, interactive, and reflective online learning environments can act as modern sanctuaries, where students deepen their faith through self-reflection, share and appreciate diverse religious viewpoints, and forge meaningful virtual communities that transcend physical distance.

At the same time, demographic trends point to distinct differences in religious identity, with female and Catholic students reporting higher levels of perceived faith than their male and non-Catholic counterparts. These findings reinforce the need for inclusive and adaptable teaching strategies acknowledging individual backgrounds and spiritual traditions. Navigating technological challenges, from connectivity issues to platform learning curves, often fosters resilience and a more profound commitment to one's faith, further underscoring the transformative potential of online religious education.

This research suggests that well-structured virtual classrooms can uphold academic standards and nurture profound spiritual growth, particularly when teachers and administrators tailor methods to meet diverse needs. As digital platforms evolve, so do opportunities to create welcoming, reflective, and community-centered learning experiences for students across varying religious affiliations. By thoughtfully considering demographic factors and leveraging technology, educators can pave the way for more robust faith-based engagement, setting the stage for a spiritually enriching future in online religious studies.

Implications for Educators

The outcomes of this research hold notable relevance for religious education and the broader arena of virtual learning. In highlighting four key themes: Embracing Adaptability and Introspection, Fostering Connections Beyond Physical Boundaries, Broadening Spiritual Perspectives, and Grappling with Technological Challenges, the results demonstrate how online platforms can reshape traditional teaching approaches by emphasizing flexibility, reflective practice, and inclusive community-building. Educators are encouraged to

leverage these features to create digital spaces where students can safely and deeply explore their faith, strengthening individual self-understanding and a collective sense of belonging.

Moreover, the data on gender and religious affiliation reveals that female and Catholic students generally report higher levels of religious identity, suggesting the need for gender-responsive and culturally attuned pedagogical strategies. Educators can foster more equitable environments for students from various faith traditions and backgrounds by adapting course content and activities to diverse learning needs. Tools such as synchronous discussions, breakout rooms, and moderated forums can bridge geographical gaps, encourage interfaith dialogue, and broaden learners' spiritual perspectives.

At the same time, recurring technological hurdles underscore the importance of institutional support and flexible course design. Ensuring reliable access, offering asynchronous options, and providing digital training can help minimize disruptions and maintain robust engagement. Incorporating solutions that address connectivity constraints or scheduling conflicts enhances participation and cultivates resilience and adaptability, qualities that align closely with many religious teachings.

Ultimately, these insights point to a future where virtual religious education can uphold high academic standards while deepening students' spiritual growth. Educators, administrators, and policymakers should consider these implications to nurture more inclusive, reflective, and dynamic digital learning environments. Such environments respect and celebrate the diverse religious identities of all students.

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Authors Information

Jennifer B. Fabula
https://orcid.org/0000-0001-8951-9914
De La Salle-College of Saint Benilde
2544 Taft Avenue, Manila
Philippines

Karl O. Salvador
https://orcid.org/0009-0008-2973-6122
De La Salle-College of Saint Benilde
2544 Taft Avenue, Manila
Philippines

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Participatory Experiences as Digital Literacy Intervention: Using Cultural Heritage Collections to Build

Jessica BrodeFrank

University of Illinois Chicago, United States

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Abstract

Diverse communities have been forming and interacting online for over three decades, and cultural heritage organizations have the opportunity to enhance user experiences by experimenting with new strategies for user engagement that build community and attract new audiences. Cultural Organizations are spaces for discovery, innovation, interrogation, encouraging agency and exploration of not just objects but also the very missions of the organization. By adopting a mission around using collections items, crowdsourcing projects, and programming to expose digital literacy concepts like bias, algorithms, and more, institutions have a new ability to become essential to life-long learning geared towards this second quarter of the 21st century. The Consolidated Appropriations Act of 2022 directed the Institute of Museum and Library Services to explore ways to improve information literacy within communities. As acting director of IMLS at the time, Cyndee Laundrum stated, "we want to empower these trusted library and museum professionals who play a critical role in helping improve digital, financial, and health literacy to serve the needs of diverse communities." This paper will look at lifelong learning, and participatory culture, in museums, archives, and libraries, providing examples of projects that have expanded access to collections, increased web accessibility through alt-text generation, and tackled digital literacy through hands-on use of AI models.

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Corresponding Author: Jessica BrodeFrank, jbrodefr@uic.edu

Introduction

By the mid-2010s, social tagging projects were seen by many as a "buzzword out of vogue," (Hyperallergic, 2017) and many projects that were still active struggled to attract participants. The initial context for crowdsourcing in museums, of tagging as a means to increase retrieval, as advocated by Vander Wal and others, had lost steam with museum professionals. The resources (monetarily, technologically, and staff time wise) that it took to run these projects had many people in the field in the 2010s shifting away from running these projects in favor of experimenting with machine learning and AI models they believed held the promise of tagging visual elements like color and subjects. As Colin Allen noted in 2013, "people continue to supply a depth of understanding that we don't see machines achieving any time soon" (Allen, 2013). It is this depth and diversity that are best addressed by the strengths of socially constructed, or crowdsourced, metadata. The more metadata systems reflect the diversity, variations, and coinages in the nomenclature of their objects, the better they support discoverability and relevancy of the objects.

Redefining Participation in Cultural Heritage Organizations

Over the last 15 years, notable practitioners and scholars have supported the use of crowdsourcing in museums, and for metadata creation, as a way to expand access points for searchability and discoverability, but also to diversify these access points for better representation and varied contexts. In the late 2010s and early 2020s, this evolved again to begin thinking of crowdsourcing's value as its experience as well. This shift in building and planning crowdsourcing projects around engagement and experience falls in line with the questions on motivation for participants raised previously, but also in the longer standing discussion of museums as spaces for learning and action.

The largest museum associations throughout the world began shifting priorities for museums in the twenty-first century to better align with museums as spaces for engagement. Museum policy advocates from the Museum Association (MA) and the International Council of Museums (ICOM) prompted museums to step up their focus on audience engagement in the last decade, recognizing museums needed to be more than a collection to be viewed. This push for engagement in museum spaces was in many ways fueled by the Web 2.0 shift of consumers to producers, with the public no longer visiting museum spaces as passive observers, vessels to be filled, but instead looking to engage directly with collections in experiences that are "digital, participatory and informed" (Barnes & McPherson, 2019). Within this recognized need for museums to shift, to become more engaging and co-productive, crowdsourcing of metadata can be seen anew as an extension of the museum's mission for interactive learning.

Cameron and Kenderdine, and Fahy all discussed the need for active visitors and hands-on interactivity as a part of the museum experience. In 2001, Fahy noted the importance for incorporating hands-on participant driven experiences in museums was in part due to these experiences increasing retention for learning objectives, stating, "whilst we only remember ten percent of what we read, we remember ninety percent of what we say and do" (Fahy, 2001). Ross Gibson and Zahava Doering conducted research in the early 2000s to 2010s looking into the experiences that visitors found satisfying in museums. Gibson saw the museum's strongest mission-centric activity, and in fact power, to be that of alteration where an opportunity to experience what it is to be other alters the person's perspective of this otherness. And Doering et al. found that the most satisfying experiences for guests often revolved around "gaining new information or knowledge" and "seeing the real thing (as in an object)" (Pekarik, Doering, & Karns, 2010). Crowdsourcing projects allow the public the opportunity to see real objects in the collections, often those that are not currently on physical display, and to help add new information to these objects' metadata while themselves experiencing the new experience of participating in the cataloging process.

Michael Haley Goldman and Eric Schmalz suggested in 2020 that more institutions should prioritize the benefits that the crowdsourcing process itself has for volunteers as part of the fundamental purpose of these projects' creation. By placing more of an emphasis on the crowdsourcing process itself as opposed to focusing primarily or exclusively on the end results such as data collection, access, or transformation, there could be a stronger defense of the resources and staff time these projects cost museum staff to run, as mentioned by Severson.

There was early support for the process of metadata tagging in particular, but crowdsourcing in museums at large, being a key component and motivation for running such projects, as opposed to only focusing on the output goals. As early as 2009, the steve.museum team published reports looking to answer questions on participants' motivations and incentivizations. The report highlighted that the majority of the public who were considered frequent contributors noted that they participated most for "fun" and were in fact not interested in increasing findability of collections or connecting with others (Leason, 2009). This was seen by the team to indicate that tagging was an engaging activity in itself, and users enjoyed the experience, lending early support for designing crowdsourcing projects with the expressed goal of creating an engaging experience.

Senseney, Koehl, and Nay's study in 2019 found that primary motivators included filling skills gaps or skill development, as well as developing an expertise or community around a given topic – two motivations based on the experience of the project more than the outputs created (Senseney, Koehl, & Nay, 2019). In the 2021 work "The Collective Wisdom Handbook: Perspectives on Crowdsourcing in Cultural Heritage" by Ridge, Blickhan, and Ferriter, participants in GLAM crowdsourcing consistently listed that contributing to a bigger

cause was a primary motivation for their work. However Ridge, Blickhan, and Ferriter found that motivations could include extrinsic motivations such as a grade, a score, or a record; intrinsic motivations such as fun, socializing, community, or interest in the subject; and altruistic motivations such as the above stated contributing to a bigger cause (Ridge, Blickhan, Ferriter, 2021).

Similarly, Perry Collins, a senior program officer at the National Endowment of Humanities Office of Digital Humanities, stated in 2015 that institutions should always consider public engagement with a collection as its own end goal to any crowdsourcing effort. In line with Goldman, Schmalz, Doering, and Gibson, Collins emphasized the process itself, stating, "The goal is not only to create hundreds of thousands of tags. A major goal is also to engage people in the digital humanities and in library collections. While the quality of what they do matters a lot, I think the process of what they do matters a lot, too" (Enis, 2015).

It is the values and missions of cultural heritage institutions that position them in the opportune place to invite public participation according to former Library of Congress researcher Trevor Owens. Owens supported the shift in mentality away from considering crowdsourcing to outsource labor to a crowd, and instead as a way to invite participation of that crowd into the creation and development of the public good where the process is as important as the tags created (Owens, 2013). Perhaps at the forefront of this shift has also been the British Library's Mia Ridge.

As early as 2013, Ridge was advocating cultural heritage institutions to take up crowdsourcing. Though Ridge advocated for the usefulness of crowdsourcing in helping take time- and resource-intensive tasks and distributing that work amongst a crowd to improve content about collections, she was also one of the first people to articulate the importance of recognizing crowdsourcing as its own valuable form of public engagement with cultural heritage. As she encouraged institutions to engage in crowdsourcing, she continually highlighted the act of crowdsourcing as a form of engagement and the value that process had for the public in and of itself. These interactive forms of creation and engagement have created a new way of thinking of crowdsourcing, but also a new form of attraction and interest for a wider array of public visitors, helping to expand the value and relevance of the projects themselves (Ridge, 2013).

By refocusing on crowdsourcing not just as a process by which to increase access points, or even to reach a more diverse range of voices to increase representational context of collections, but indeed as an engaging form of participation that in itself benefits participants, it is possible to see even more support for incorporating these types of projects into the museum cataloging process. This shift in prioritizing the process as well as the outputs allows a refocusing on the value of the process of crowdsourcing and a better understanding of its need for resources and support institutionally while also framing the importance the process itself should take in project

designs in order to motivate public participation. With the importance of the process and the act of participation made clear, it is now possible to focus on the modern considerations for motivations and learning objectives these projects can expand to.

Redefining Museums

The International Council of Museums (ICOM) had proposed a new definition of a museum in 2019. The proposed definition was a departure from "dominant paradigms for what is, and should be, at the center of the work that museums do in society" (Moore, Paquet, Wittman, 2022) – with a focus on diversity, equity, and inclusion, it was considered too political by many voting members of ICOM and was actually struck down. However, in the wake of the 2020 dual upheaval of the COVID-19 pandemic and social justice movements, a new definition was again proposed at ICOM in 2022, and this time it was ratified. The new definition of a museum now reads:

> A museum is a not-for-profit, permanent institution in the service of society that researches, collects, conserves, interprets and exhibits tangible and intangible heritage. Open to the public, accessible and inclusive, museums foster diversity and sustainability. They operate and communicate ethically, professionally and with the participation of communities, offering varied experiences for education, enjoyment, reflection and knowledge sharing. (Liu, 2022).

This new definition stresses a new aim for museums to facilitate diversity and sustainability, with the museum's mission and reason for being shifting from the previous definition's use of the word "study" to the new definition stating museums exist to be places for "reflection and knowledge sharing." This subtle shift signals that the cultural heritage sector is moving away from a neutral position of privileged authority and towards a more level network of collaboration, and considering the ICOM definition of museums is often a determinant in definition that national governments use to define museums and their activities, this shift is critical in how organizations may be funded or taxed.

As Moore, Paquet, and Wittman argue, this is a global shifting of cultural heritage institutions that acknowledges the non-neutral nature of the activities professionals in museums, archives, and libraries conduct, demanding these professionals do more critical reflection on these activities' context and processes.

In August 2022, the American Alliance of Museums published their newest "Excellence in DEAI Report" (AAM, 2022), specifically responding to the "social, political, and cultural polarization, and clear structural racism and other forms of oppression in the United States and around the world," by centering diversity, equity,

accessibility, and inclusion in the understanding and practice of museums. One of the key implications of this report was the express call for institutions to shift away from white-dominated characteristics of work, specifically those of perfection, risk aversion, and conflict avoidance. Many of the resounding criticisms to crowdsourcing projects, revolved around risk aversion, conflict avoidance, and a call for perfectionism. As the AAM report itself calls for, it is more important to foster an environment of iterating and trying new things, with a focus on transparency. This is perfectly encapsulated in the following quote from the report:

> "Making mistakes, being accountable about those mistakes, iterating, and trying again will support museums and museum leaders in building the capacity and skills to sustain DEAI in the long term. DEAI in museums is not about getting everything perfect; it is about lifelong learning and continuous improvement" (AAM, 2022).

There is a flexibility afforded to institutions who focus on these newer definitions of diversity, equity, accessibility, and inclusion, and ability to work with the public, to not fear mistakes but instead embrace opportunities to try to be better. With this ability to constantly adapt by including and incorporating feedback and experiences of their own community, peers, and the field at large, institutions can be more agile and responsive, which remains key in the current environment plagued by pandemic, climate crisis, and social justice movements. By being transparent and vulnerable with the public, with a focus on co-creation, institutions can more effectively create opportunities for diverse groups of people to have a voice, enabling the institutions to be more proactive and effective in responding to the changing times we occupy.

Crowdsourcing as Exposure, Exposure for Literacy

As has already been laid out, museums are spaces for discovery, innovation, interrogation, encouraging agency and exploration of not just objects but also the very missions of the organization. In today's modern world museums' missions have shifted, with ICOM redefining the definition of a museum in 2022. But this shift includes looking at digital literacy as a core competency for museums and libraries to focus on with their public, as handed down by the United States Congress.

The Consolidated Appropriations Act of 2022 directed the Institute of Museum and Library Services to explore ways to improve information literacy within communities, including through the creation of the Informationliteracy.gov website, as well as establishing and leading an Information Literacy Taskforce to develop guidance, instructional materials, and national strategies for libraries and museums to improve information literacy skills within communities.

On June 27, 2024, the Institute of Museum and Library Services (IMLS) debuted InformationLiteracy.gov, as a website with specialized tools and resources specifically for museum and library professionals to engage with their diverse communities in developing "critical information literacy skills." As acting director of IMLS at the time, Cyndee Laundrum stated, "we want to empower these trusted library and museum professionals who play a critical role in helping improve digital, financial, and health literacy to serve the needs of diverse communities" (IMLS, 2024).

It's important to note that digital literacy is a relatively new concept, emerging out of the 1990s during the era of internet revolution that also brought about crowdsourcing and museum digital experiences like online catalogues. In 1997, Paul Gilster, a historian and educator first coined the term "digital literacy," arguing that digital literacy went beyond just the skills need to use technology, focusing on it being about "mastering ideas, not [computer] keystrokes" (Glister, 1997). In popular use, the word literacy goes beyond its educational understanding as the ability to read, write, and use arithmetic, it is increasingly seen as a synonym for skill, competence and proficiency. Though digital literacy was primarily and initially viewed as the functional skills and competencies that people needed in order to use computers and the Internet, in the 2010s and beyond it has taken on a more expansive definition to be the skills needed to participate in digital environments.

As early as 2015, JISC (a non-profit in the UK focused on tertiary education, research and innovation as a digital, data and technology agency) defined digital literacy as "the capabilities which fit someone for living, learning and working in a digital society" (JISC, 2015). As indicated above, this is the definition of digital literacy that will be used going forward as it is this definition that prioritizes the three capabilities that most often now define the goals of digital literacy. These capabilities are, 1. The ability to engage in participatory culture, 2. To be a lifelong learner, and 3. To manage a professional digital identity. All three of these capabilities are reflected already in many of the missions of museums with their publics. Importantly, this is not just focused on digital natives, but the public at large.

A "digital native" or the "net generation" has been tossed around as terms for decades to describe Millennial, Generation Z, Generation Alpha, and even now Generation Beta, as a person who has been born or brought up during the age of digital technology, having a familiarity with computers and the Internet from an early age. However, it is important to note that this is already a biased understanding of generations that does not account for the digital divide, the income disparity or technical debt that have prevented many regardless of age from experiencing these technologies; but also it does not account for older generations who may have better relationships and literacy with technology due to their lived experiences. Importantly, regardless of age, digital literacy primarily should focus on the need to be able to develop socially responsible digital practices, and contribute to these practices in one's own personal, work, and learning lives (Brown, 2024).

This emphasis on lifelong learning, and participatory culture, demonstrate the strong background that museums and libraries already have to do this digital literacy work effectively. It is not just objects that museums house that matter, as stated previously by Falk, the primary value created by museums for the public exceeds their function as a "warehouse" and instead rely on supporting public learning and education, and providing access to cultural assets that inspire creativity, foster identity-building and civic pride (Falk et al., 2025). And this is why crowdsourcing, and the participatory museum, also needs to move away from being centered on objects and towards digital literacy as a primary mission.

This follows trends in digital preservation that call for a critical reflection and approach to preservation, one that acknowledges risks to be informed, but not averse. The key call from this movement is the need to remain agile, continue debates and further accumulate knowledge on a field that is responding to frequent and quick changes. In many ways this is the same challenge that has been articulated above and emphasizes the need for institutions to adopt digital literacy into their programming.

This follows trends in digital preservation that call for a critical reflection and approach to preservation, one that acknowledges risks to be informed, but not averse. This critical reflection on digital preservation will be revisited in this volume, particularly in calls for optimizing for climate impact, but for now the key call from this movement is the need to remain agile, continue debates and further accumulate knowledge on a field that is responding to frequent and quick changes. In many ways this is the same challenge that has been articulated above, and emphasizes the need for institutions to adopt digital literacy into their programming.

For example, a February 2025 report of the Microsoft Copilot AI programming lays the groundwork for the importance of digital literacy exposure (Bajkowski, 2025). The Australian Centre for Evaluation looked at the implementation of the Copilot generative AI product as tested within the Treasury and found that when they gave trial participants access to Copilot the participants reported concerns about reliability and accuracy of the responses produced by Copilot. Not only did they report these concerns however, some participants actually stopped using Copilot after this guided dive into the platform.

"After a few early tests, there seemed to be obvious errors which reduced my confidence in using co-pilot [sic] for this purpose" a trial participant observed. Not only did the experience leave participants with reported difficulties and concerns around prompt engineering, with difficulties reported in finding the correct prompt language to use, unhelpful outputs from prompts, and low-quality outputs produced; but this study found an almost tenfold increase in disinterest in Copilot from users. Guided exposure to the platforms' limitations and capabilities seemed to provide inoculation to the hype of the AI platforms, with 59% of trial users reporting

they reckoned the technology was of little to no use; prior to the experiment only 6% of these participants had indicated their views of the technology was little to no use.

Tag Along with Adler Pilot Project

The Tag Along with Adler project ran on the Zooniverse platform from 23 March 2021 until 12 March 2022. As each of the 11 subject sets was retired, the textual data and verification task data was processed, allowing evaluations of the 1,090 images. Over the year the Tag Along with Adler project (BrodeFrank, 2024) ran, the project had 3,557 registered volunteers, with 6,976 individual participants. A part of this project included introducing participants to AI generated descriptors, tags, of collections, through a verification task called "Verify AI Tags." AI already underlies many routine aspects of our lives, and part of the inclusion of AI tags in this project was specifically to raise with project participants the ways in which these tags are instrumental to their daily search and discovery taste, often in ways they do not realize.

Results

Reviewing the literature, it is evident that machine vision and AI tagging have become advanced enough to detect subject matter and objects depicted across various content types including painting, photographs, and cultures. They have been used by various institutions already to expand and enrich existing metadata tags.

One standing question has been "just how well does machine vision do? Can it offer accurate tags? Is the metadata generated useful, and correct?" According to research by Electronic Frontier foundation, a group measuring the progress of artificial intelligence, the error rate had fallen from around 30% in 2010 to approximately 4% in 2016, making it on par with human classification accuracy (Ciecko, 2020). Still, there are recognized issues with AI and machine vision that keep institutions from readily adopting it. Not only are these AI models limited in their ability to process complexity, but they are still trained by humans. The importance here is to recognize that, by switching to a machine, bias is not removed. In fact, it is trained into it.

For the purposes of this project, I opted to use the iMet Collection Attribute Classifier and the Google Cloud Vision API taggers precisely for this reason. I chose these two tagging models specifically because they have been trained using more images than the Adler Planetarium had access to, and both are publicly available for use by any institution. I also selected them to reflect a tagging model specifically trained for museum collections (the iMet Collection 2019), and one that was trained with millions of images and would be most similar to the algorithms encountered by users in their daily lives doing image searches online (Google Cloud

Vision API). In summation, the inclusion of AI tags was done to expose project participants to this emerging technology and both its positives and negatives, but also to gauge various questions including:

> 1. How does exposure to AI tags affect the tags a user creates?, 2. How accurate do users find AI-generated tags?, 3. Do users favor terms created by a museum-specific tagger or a generalized image tagger?

It should be noted that the inclusion of AI tags did entice user engagement. The "Verify AI Tags" workflow consistently saw 2-3x the engagement of the "Tag Images" workflow, demonstrating the draw AI, automation, and algorithms can have on users. Additionally, results from this workflow demonstrated the difference in models and the importance of selection of AI models in project workflows. About 58% of the AI-generated tags, or 4,420 tags, were generated by the Google Cloud Vision API tagger, with the iMet tagger having generated 3,183. Despite accounting for approximately 58% of the total tags generated, the Google Cloud Vision API tags accounted for 86% of the tags verified by the volunteers, demonstrating a strong preference of the volunteers for the visually descriptive language of the Google Cloud Vision API to the more museum-cataloger language prevalent in the iMet tagger. In fact, volunteers verified just shy of 50% of the terms created by the iMet tagger vs. verifying 80% of the tags generated by the Google Cloud Vision API.

In a 2021 published report from the Library of Congress that explored the range of projects the Digital Strategy Directorate and its Digital Innovation Lab (LC Labs) have undertaken, including those in crowdsourcing, a similar approach to combining machine learning technology and crowdsourcing was conducted (Averkamp, 2021). A main research question for the Library of Congress was how machine learning and crowdsourcing could be used in tandem to create engaging, ethical, and useful data enrichment activities for cultural heritage institutions. Through testing using the U.S. Telephone Directory Collection, the Library of Congress team found that 75% of participants offered overall positive responses, indicating that they found it worthwhile for the Library to combine machine learning with volunteer contributions, and that they would in fact be willing to volunteer for further initiatives.

Similar to the appeal that the "Verify AI Tags" workflow appeared to have for Zooniverse users of the Tag Along with Adler project, the Library of Congress team noted that 50% of their users stated that knowing the Library was incorporating a combined approach to integrate machine learning and human knowledge had a positive impact on their motivations to volunteer. Furthermore, even the volunteers who explicitly noted a distrust for machine learning and AI indicated that knowing such technology was being incorporated into human-centered crowdsourcing would not deter them from volunteering in projects as long as the tasks and content remained engaging.

The ability to use crowdsourcing projects as a way to not only enrich collections information and increase entry points to collections, but also as a way to engage and build relationships with the public and the audiences of the institutions (i.e. digital literacy) is the most promising avenue of this technology. With this in mind, it is important to analyze the qualitative data provided in the Tag Along with Adler TalkBoard comments and survey responses. Breaking these down, it is possible to see major themes within the communications expressed as well as to see specific examples of engagement taking place throughout the course of the projects. In particular I want to highlight communications that are centered around AI.

18% of user comments on the Zooniverse TalkBoards were asking for help or clarity around the AI programs used in the "Verify AI Tags" workflow. Comments often questioned the effectiveness of the models to tag collections and served as effective conversation starters for Adler staff to engage with volunteers. Additionally, the qualitative survey appended to the project also saw comments on the AI models shown here:

> "A real eye-opener to see how far apart AI and human perceptions are!"
> "Intriguing process to consider descriptions. AI-generated were often not useful."

These comments demonstrated the interest that volunteers had in AI technology but also the importance of addressing AI technology's limitations with guests. As it was a noted reason for including AI tags within the Tag Along with Adler project, these comments helped to demonstrate the need for institutions to really communicate about these emerging technologies with their audiences as there is clearly a disconnect between the promises made for these technologies and the actual execution and limitations they currently have. As shown previously by the report of the Library of Congress, incorporating AI technologies into crowdsourcing projects, as done here, has the promise to introduce this technology's potential benefits and limitations, providing both an enticement to the project and a learning opportunity. When considered with the Australian Centre for Evaluation report on Microsoft Copilot, and the IMLS initiative encouraging museums and libraries to take on digital literacy tasks, this is an important task for the participatory museum of the 2020s.

Conclusion

As Cameron and Kenderdine critiqued, museums often promote their missions and purpose as being places for life-long learning, but when it is felt by populations that the museum is controlling knowledge and gatekeeping expertise, a patronizing attitude is felt and goes against the grain of the agenda. With the public used to having individual agency literally at their fingertips during this internet age, it is important for the museum's self-

directed learning to support this in ways that framing crowdsourcing as an engaging, self-driven experience can do.

By adopting a mission around using collections items, crowdsourcing projects, and programming to expose digital literacy concepts like bias, algorithms, and more, institutions have a new ability to become essential to life-long learning geared towards this second quarter of the 21st century.

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Authors Information

Jessica BrodeFrank
https://orcid.org/0009-0008-4788-9376
University of Illinois Chicago
801 S Morgan St., UIC Library 4-122 MC 234,
Chicago IL 60607
United States of America

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Information and Communication Technology (ICT) Usage in Secondary Schools

Josta Lameck Nzilano
University of Dar es Salaam, Tanzania

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Abstract

This study explores the heads of schools' experience of Information and Communication Technology (ICT) usage in secondary schools in Dar es Salaam, Tanzania. Specifically, the study examined the contribution of ICT and the factors affecting their use of ICT for administrative activities based on the experience of the heads of secondary schools. The study adopted a single case study design for qualitative research. Purposive sampling was used to obtain nine heads of secondary schools and data collection involved semi-structured interviews, observations, and documentary review methods. Thematic analysis was used to process the data and results appeared in the form of quotes and theme descriptions. The findings indicated that heads of schools are highly motivated to use ICT in school administration, as it supports financial tasks, enhances communication, facilitates record keeping, and processing students' examination results. The issues related to the digital divide, shortage of ICT facilities, technophobia, internet connectivity, inadequate funding, power supply, and technical support at school affected the heads of schools to use ICT in school administration. Findings recommended establishing regular ICT training, improving ICT facilities, ensuring sufficient funding and reliable internet services, and involving diverse stakeholders to address the situation. The study suggests the need for studies to examine the competence and readiness of heads of schools on the use of ICT for managing public funds. Additionally, investigating ICT use among institutional management leaders across levels of the educational system is recommendable

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Corresponding Author: Josta Lameck Nzilano, josta.nzilano@udsm.ac.tz

Introduction

The adoption of information and Communication Technology (ICT) in education is an important theme that has attracted debates from educators, researchers, and other education stakeholders in different places around the globe. Debates are pressed by the new era of technological innovation in the education sector through globalization. The influence of globalization demands in the education sector has made different educational institutions transform their operations of administrative and routine activities from analog to digital form. Different studies have been conducted in the education sector ranging from elementary to tertiary education examining different perspectives and transformations taken by educational authorities and stakeholders including teachers, parents, and students in the adoption of ICT in education to improve the quality of education (Mandari, 2018; Malekani, 2018; Mbalamula, 2014; Mwalongo, 2011; Nkata & Dida, 2020; Hamoud & Nzilano, 2024). The present study aimed to explore the perceptions of heads of secondary schools about using ICT in addressing administrative activities to meet the expectations of the school and educational stakeholders.

In the past two decades, the use of ICT has spread widely, resulting in significant reforms in the administration and management of schools (Juma et al., 2016; Omotayo & Chigbundu, 2017). Hence, these technologies are transforming teaching and learning and playing a crucial role in the administration and management of educational institutions (Irene, 2020; Ghavifekr et al., 2013; Malero et al., 2015).

Countries with developed economies such as the United States of America, Australia, Netherlands, and Britain, succeeded earlier in integrating ICT in school administration and management practices that have improved education quality (Mulinge, 2020; Amutha, 2020). For example, the United States of America started using computer technologies to enhance efficiency of school office operations including staff and students' records keeping since late 1970s (Forrester, 2019). Since Sweden began investment in ICT, motivation of heads of schools, and provision of training for school administrators, the county has made a significant impact on the education system (The Organisation for Economic Co-operation and Development - OECD, 2015). For instance, the heads of schools played the role of mobilizing and coordinating resources to accomplish the school and educational expectations (Mwambo, 2019; Olowonefa, 2022). With the use of ICT, the school administrators are intended to promote the efficiency and effectiveness of school managerial and administrative activities (Qureshi & Abro, 2016). Thus, the use of ICT is inevitable for the school heads to increase productivity and perform their duties effectively (Oluoch, 2016). ICT facilitates information processing, decision-making, storage and communication of information (Mwambo, 2019; Karanja, 2018). Although, developed countries succeeded to integrate technology in the management and administration of schools, still ICT has not been effectively utilized to achieve the core functions of school administration. In the USA for instance, the adoption of different database by the school administrators to support administrative functions

made it difficult for them to manage the data storage systems (Forrester, 2019). Same in Germany, the school principals use ICT frequently for communication with top authorities, still, ICT appeared to be not effective to create presentations and communicate academic for administrative purposes (Tulowitzki et al., 2022). Likewise, Malaysian school principals demonstrated limited extent of ICT usage to address issues of school administration due to insufficient knowledge and skills in ICT and as an alternative turned to analog systems. (Ghavifekr et al., 2013; Qureshi & Abro, 2016).

In developing countries, studies revealed that the use of ICT for secondary school administration is limited as Midoro (2013) reports found that in Africa the majority of school administrators including heads of schools demonstrated limited knowledge and skills of ICT use. For example, in Nigeria, school administers in public secondary schools used manual systems for students' registration and record keeping because of limited ICT facilities such as computers, internet connectivity, scanners, and electricity supply which affected the school performance of administrative activities (Abraham & Bariyaa, 2020; Abdullahi et al., 2020; Kalu et al., 2017).

At the beginning of the 21st century in East Africa, ICT integration in teaching and learning has increased together with the use of ICT for school administration and management activities (Irene, 2020). For instance, the use of ICT is considered in the Kenyan Development Vision 2030 (David et al., 2019) and the National ICT policy of 2006 to expand ICT usage at all levels of the education sector (Njeru, 2020). Moreover, realizing the roles of ICT in educational management and administration. The Kenyan government established the National Education Management Information System (NEMIS) to deal with administrative activities in the country's system of education (Karanja, 2018). Although the government has made this efforts, there are many school administrators who perform their roles and duties using the analog systems. (Irene, 2020). For instance, Mulinge (2020) found that most heads of schools in Kenyan public secondary schools lack adequate ICT skills to use NEMIS in managing school finances, instead, they used ICT to monitor the attendance of students in classrooms, making the school timetable, and supervision of teachers at school (Njeru, 2020). Similarly, the use of ICT in education in Tanzania started in the late 1960s and early 1970s, when the Ministry of Education collaborated with the Radio Tanzania Corporation to deliver educational programmes primary and secondary education levels (Hare, 2007). Tanzania since then has made several initiatives and reforms to integrate ICT in the education system and responding to the national development goals and global agenda of the sustainable development goals (Hare, 2007). To achieve this mission, in 1990s Tanzania among 53 countries in Africa collaborated with several international agencies to invest and promote access to ICT in the education systems. The situation made Tanzania to initiate the national ICT policy in 2003 and revised it in 2016 to ensure that the country achieve the national development goals through the use of ICT (United Republic of Tanzania-URT, 2016). In light of this, the current national policy for the provision of education and training supports the integration of ICT in education to achieve academic, managerial and administrative tasks (URT, 2014). This

situation has motivated several researchers to explore the experience and practices of school administrators in using ICT to implement administrative activities in educational institutions including secondary schools.

Despite the government initiatives in Tanzania to ensure the use of ICT in facilitating school administrative functions, the literature has demonstrated that there is limited use of ICT in secondary schools for administration (Mandari, 2018; Malekani, 2018; Mbalamula, 2014; Mwalongo, 2011; Nkata & Dida, 2020). The literature revealed that ICT usage is limited to some administrative activities including writing of letters, registering students, and preparing day-to-day school timetable (Mwalongo, 2011). Moreover, heads of schools were ineffective in using ICT for implementing the EMIS such digital technology is underutilized in school management and administration and many public secondary schools had inadequate ICT infrastructure (Mbalamula, 2014). Despite these studies, many heads of these schools rely on manual systems to administer several administrative tasks (Mandari, 2018; Mbalamula, 2014; Nkata & Dida, 2020). Arguably, the over-dependence on manual system among school administrators is more likely to affect their efficiency and effectiveness in the performance of administrative tasks and the potential quality of education.

Purpose of the Study and Research Questions

The purpose of the study was to explore the perceptions and experiences of heads of schools in using ICT to achieve the administrative functions of government secondary schools in Tanzania, especially Dar es Salaam. The study is guided by two research questions that include:

1. What are the roles of ICT in school administration as perceived by heads of schools?
2. What are the perceived factors affecting the heads of schools in using ICT for administrative activities?

Methodology

Research Approach and Design

This study employed a qualitative research approach to explore the heads of schools' perceptions regarding the use of ICT in the administration of government secondary schools in Dar es Salaam. The researcher used the approach to obtain comprehensive knowledge about the perception of the phenomena and the rationale of those perceptions in the context (Gay et al., 2012). This study employed a case study design, emphasizing on the views, opinions, and feelings of school heads about ICT usage in the administration of government secondary schools in Dar es Salaam. A case study design provides the chance to explore or gather rich and holistic data concerning the phenomena (Ary et al., 2010). The case for this study is the perceptions of heads of schools based on their narratives and practices and experience in performing their roles as heads of schools in

government secondary schools. The unit of analysis captured narratives and responses of the heads of schools from their secondary school settings. The selection of the case study design motivated the researcher to gain rich information concerning the perception of the secondary schools' administrators concerning ICT usage in school administration. Additionally, the case study design facilitated information collection from different sources and the triangulation of methods.

Sample and Sampling Procedures

The purposive sampling procedure facilitated the selection of heads of schools based on schools equipped with ICT facilities and ICT integration history in administrative practices. This technique was chosen because works well with the design and is common to the design (Gay et al., 2012). In this case, nine out of 51 heads of schools selected from '**A**' to '**I**' Tanzanian government secondary schools within Dar es Salaam. The size of the sample depends on the information saturation as collected from nine heads of schools. According to (Ary et al., 2010), the data are considered sufficient when there is no more additional information to gather from the nine participants. Dar es Salaam was considered due to its abundance of government secondary schools with a long history of integrating ICT into pedagogical and administrative tasks. The heads of schools in this area appeared to use ICT in their administrative tasks compared to other secondary schools and had enough information to address the study problems.

Data Collection Methods

The study adopted the semi-structured, documentary and observation methods of data collection.

Semi-Structured Interview Method

The semi-structured interviews were used to gather perceptions from participants. The method allowed free expression of participants 'perceptions about using ICT in secondary school administration. Information collected about the feelings and views of heads of schools concerning the daily practice of ICT usage at work. The interview with each head of school involved 30 to 45 minutes and the duration was sufficient to obtain enough information. Hence, the researcher ensured that each participant has provided consent to be voice-recorded, and interviewed before the interview session and for the provided information.

Documentary Review

Documentary reviews involved school plans, financial records, and school minutes as per the objectives of the study and information to supplement the interviews. The schools' plan and minutes helped to determine the extent to which ICT has been a priority in the school context. In addition, the school agenda, plans, and minutes

were examined to determine the extent to which ICT supported the heads of schools to attend on-the-job training or workshops, perform administrative tasks, and improve the quality of secondary education.

Observation Method

The observation checklists were used to assess the actual ICT facilities available in offices and classrooms. The researcher observed and recorded the availability or absence of ICT tools in the administration of school activities. The observed items included school printers, desktop computers, scanners, internet bandwidth, television receivers, digital cameras, projectors, fax machines, and photocopiers. ICT tools were considered present if the school's office had sufficient facilities, and they were considered absent, they were insufficient. The observation method supplemented more information not obtained by either interviews or documentary reviews.

Data Analysis Strategies

The researcher employed thematic data analysis to process the documentary transcripts interviews, and observation based on Braun and Clarke's (2006) model that provided systematic qualitative data processing. The thematic analysis process involved six steps including data familiarization, coding, and labeling data, creating themes, comparing datasets and themes, defining and naming the themes, organizing and arranging themes for a report write-up. The outcome of thematic analysis is presented in the form of narratives and quotations for interpretation.

Findings and Discussions

Perception of Heads of Schools about the Roles of ICT in School Administration

Considering the roles of ICT in the administration of selected secondary schools in Dar es Salaam, the findings are presented and discussed in line with key school administrative functions.

Managing Financial Activities

The heads of schools as key informants (KI) in the present study noted that the available ICT facility promoted budgeting, processing, and record-keeping of school finances. As one of the respondents indicated that 'using computer application software such as Excel program. I can record and process financial activities, prepare statements, and shared easily with the educational authority. At the moment, we are not preparing manually the financial data' (KI, School F, August 2023).

Another respondent supported: 'The ICT use has assisted me to ensure that the financial resources, the transactions, the recorded database, and transparency creation of schools, particularly to audit financial reports of schools' (KI, School **E**, August 2023). These findings implied that the heads of schools perceived positive use of ICT in facilitating financial activities at school. They further perceived that using computer-assistive technologies including the Excel program supported the management of financial tasks. They acknowledged that without ICT facilities such as computers, their work of monitoring, auditing, and preparing school financial budgets and reports would be difficult. Findings corroborated previous studies, which indicated that ICT is useful in achieving administrative functions (Mwambo, 2019). These studies reflected the use of ICT for preparing balance sheets, payment slips, and financial audit reports (Mwalongo, 2011), monitoring budgets, controlling financial transactions and expenditure records, and maintaining financial records through automatic recording and analysis of school finances using spreadsheets (Mwambo, 2019).

Facilitating Communication

The use of technological tools including mobile phones to access social media platforms like e-mail, Facebook, phone calls, text messaging, and WhatsApp appeared to be common among heads of schools to communicate issues affecting the school to different stakeholders. As one of the respondents argued:

I admit the use of ICT simplifies communication in the administrative process. Using digital tools including WhatsApp, and e-mails make information communication easy for my staff at school, even during my absence. For example, I created WhatsApp groups to help parents and teachers to communicate their information related to the development of the school (KI, School B, October 2023).

Additionally, ICT played the role of communicating to the public about the status and opportunities available at school to attract more customers. As one of the respondents indicated, 'the administrative activities in schools plays several roles to deliver school services effectively. For example, the Website and the Facebook of the school have been assisting communication and promoting the image of school' (KI, School E, October 2023).

These findings resonated with previous studies conducted in Germany, Nigeria, and Uganda that ICT was frequently used to communicate information to educational authorities within and outside the country (Tulowitzki et al., 2022), to teachers, parents, and educational partners to improve administrative performance (Omotayo & Chibundu, 2017), to managerial level in higher educational administration (Juma et al., 2016). Supporting these study's findings, Karanja (2018) noted that ICT development in schools facilitates communication of information among various stakeholders via email, video conferencing, and social media, which improves heads of school's administrative functions.

Keeping Records

Information and communication technology have contributed to the storage of administrative and academic records at school. The findings indicated that heads of schools perceived that ICT advances in schools helped to address their problems of data storage. One of the respondents explained:

ICT tools assisted us in the storage of different records in our school. We acquired the school database some time ago, now we use computers to store students' records. We simply click the student's name and registration number to access their records within a few seconds (KI, School D, October 2023).

Another respondent added: 'In the previous, the school managed manually huge amount of records that were at risk of losing. Undoubtedly, ICT advancements made things possible and we can store, retrieve, and transfer information cheaply or without any cost' (KI, School I, October 2023). As per these findings, the heads of schools revealed that ICT facilities have played a significant role in facilitating the storage of records related to administrative and academic practices in secondary schools. The findings corroborate studies by Ghavifekr et al. (2013) who emphasized the multifaceted role of ICT use in various administrative tasks, ranging from data storage to decision-making, and by Abdullahi et al. (2020) who discovered the effective use of ICT to address challenges related to mismanagement of records easy access to comprehensive school records. In addition, the findings reflected Olowonefa's (2022) studies which found that ICT supported school principals to securely store and retrieve school data.

Processing of Students' Results

The study's findings indicated that the heads of schools acknowledged the value of using computer-assistive technologies such as MS Excel in facilitating the processing of student's examination reports. As one of the respondents emphasized:

The school has just obtained computer software to help us process students' results. The software helps us to generate results of students from the raw score automatically and share the students' results with parents easily via smartphones. Before the software, we printed results on paper and sent them to parents through their children. Today, parents can access the results through their smartphones reducing the possibility of parents queuing in school offices (KI, School D, October 2023).

Similarly, another respondent argued that 'ICT has simplified preparation of examination reports. We can compute the marks and grades of the student by using Microsoft Excel software. Not like before, we wasted a

lot of time to prepare reports of students manually' (KI, School **A**, October 2023). These findings concur with studies by Juma et al. (2016) who noted how ICT improved the performance of school administration in processing students' examination results in higher education in Uganda, and by Olowonefa (2022) who revealed the role of ICT in improving data collection and facilitating information retrieval. These findings reflected what Mwalongo (2011) discovered that teachers and school administrators used ICT for academic and administrative activities including preparing examination reports of students. Thus, the findings implied that the manual activities of teachers and administrators have been automated to speed and ease their teaching and administrative performance in secondary schools.

Factors Affecting ICT Usage for Administrative Activities

The findings revealed factors that heads of schools perceived to limit their use of ICT effectively in addressing school administrative activities.

Inadequate ICT Knowledge and Skills

The findings revealed that the school administrators lacked enough knowledge and skills in ICT, and this situation affected them to use ICT effectively in performing administrative roles at school. The findings generated from the interviews demonstrated limited practical knowledge and skills among heads of schools due to a shortage of continuous training on ICT literacy. The narratives from interviews indicated that the government had limited training programmes to equip school administrators or heads of schools with ICT competencies. For example, one of the respondents narrated:

I was involved in the training session organized by the government. The training in ICT was not enough to make us competent as we remained novice users of computers. In the recent training workshop on ICT integration in the system of education for the school administrators, the trainers disengaged the feelings of trainees by emphasizing the system operations rather than providing comprehensive ICT training to address administrative tasks (KI, School **A**, October 2023).

Similar sentiments were echoed by another respondent:

The truth is that the training on ICT was not satisfactory because it did not address expectations. The heads of schools are expected to master several computer applications. Additionally, the training was given two days for the heads of schools to master the ICT skills such as PowerPoint presentation, Ms. Word, and Ms. Excel (KI, School **E**, October 2023).

Furthermore, another respondent explained: that the government expects to use ICT for the administration of school activities at low training costs. I used my secretary who is competent in computer application to perform other administrative tasks (KI, School **G**, October 2023). The quotes above reveal the view that the ICT training was inadequate to equip the heads of schools with the necessary computer application skills. For instance, the heads of schools needed more time to learn particularly the spreadsheet and word processor. These findings corroborated with Abdulahi et al. (2020) studies that the provision of enough training time to school principals enhances the acquisition of more relevant ICT skills and knowledge. Furthermore, heads of schools perceived that the government implemented ICT training that focused on theories rather than the practice of computer application (Hamoud & Nzilano, 2024). Equally, the findings reflected Mwalongo's (2011) observation that the heads of schools demonstrated limited knowledge and skills in using Microsoft Office, which is common to the management and administration of educational activities.

Further, these findings revealed that heads of schools were dissatisfied with the in-service ICT training programmes provided by the school administration, which appeared to be ineffective and less practical. Moreover, the findings revealed that school administrators who faced the challenges of using computers to deal with administrative tasks, they delegated those tasks to their secretaries who were computer literate. Arguably, the heads of schools were expected to be conversant with computers because nowadays several administrative tasks such as sharing reports and minutes, and official letters to other authorities or fellow staff members require electronic systems. This view is acknowledged by Afshari, et al (2012) that effective performance of administrative activities requires heads of schools with knowledge and skills of ICT. These findings align with studies by Abraham and Bariyaa (2020) and Imasuen and Abinuomo (2022) noted that principals of Nigerian secondary schools in remote and town areas showed limited ICT skills, especially using computers to monitor students' results, school resources, and inventories. Moreover, the findings of this study concur with studies by Irene (2020) in Uganda who noted that lack of ICT knowledge and skills limited the effective use of ICT in secondary school administration. Likewise, the findings reflected those of Malekani (2018) and Mwangasi (2019) who revealed that heads of schools demonstrated limited usage of ICT in managerial and administrative tasks in Tanzania. Same, Mandari (2018) noted that heads of schools in Tanzania lacked ICT training opportunities, which made it difficult for them to manage school administrative activities. This situation implied that the heads of schools in Tanzanian secondary schools are argued to other avenues such as computer-based resources to learn about ICT instead of relying on the government alone for the training

Shortage of ICT Facilities

The study's findings revealed that heads of schools were not effective in the coordination of administrative activities because of limited ICT facilities. Additionally, the heads of schools showed that technologies such as

scanners, fax machines, laptops, projectors, photocopies, and printers were inadequate in secondary schools, which affected their performance of administrative activities. The heads of schools identified this as one of the factors that affect their effective use of ICT in achieving administrative activities. For instance, one of the respondents said:

My office, as you can see has one computer. I use it to create my documents. We received this computer as an aid from the internet services company. Given the various administrative tasks, the computer aid is not enough because we need the Microsoft Office package to complete the computer applications (KI, School **C**, October 2023).

Similarly, another respondent stated:

This school has some ICT facilities such as two printers and two computers acquired from non-governmental organizations. However, they aren't enough to help us address effectively the school administrative tasks. As big as a school like this, we need adequate ICT tools to support the administrators and teachers to accomplish their academic activities (KI, School D, October 2023).

These narratives reveal that secondary schools have a shortage of ICT facilities such as printers, photocopiers, databases, and desktop computers for heads of schools to perform their administrative roles effectively. One of the respondents in school **D** supported that the present printers and computers are not enough to meet the requirements of the academic and administrative staff at this school. Similarly, the heads of schools revealed that the present ICT facilities such as photocopiers, printers, internet services, and desktop computers in secondary schools were considered inadequate and outdated. The study noted that although some secondary schools possessed projectors, digital cameras, school websites and television, the majority of administrative and academic staff could not access the resources because some of these ICT tools were either outdated or malfunctioning. Additionally, the reviews of financial budgets and plans of some selected secondary schools **A, C**, **D**, and **H** showed that these schools hardly had any agenda focusing on the significance of integrating ICT in administrative and academic activities. The budget and school plans lacked priorities for ICT facilities and services, a situation that limited the access of heads of schools to ICT tools and using them to achieve their administrative roles. Therefore, the presence of up-to-date ICT facilities in secondary schools would increase the possibility of heads of schools enjoying the merits of ICT usage for administrative processes and contribute to the provision of quality education. These findings resonate with studies by by Karanja (2018) and Omwenga and Meremo (2019) that although Kenyan secondary schools possessed desktop computers, they experienced a shortage of ICT facilities to support administrative work. Moreover, the findings reflected the Nigerian studies (Abdullahi et al., 2020; Abraham & Bariyaa, 2020) that secondary schools had limited ICT tools

including scanners, projectors, databases, and computers, which affected the school principals both in urban and rural settings to integrate ICT effectively in administrative tasks. While studies by Mwambo (2019) in Cameroon noted that the school principals used ICT tools to achieve administrative tasks, Albugami and Ahmed (2015) in Pakistan and Quareshi and Abro (2016) in Saudi Arabia discovered that school principals lacked the necessary ICT competencies to achieve the same task effectively. Thus, the training of ICT competencies among school administrators in government secondary schools is mandatory.

Unpredictable Internet Services

Findings, as perceived by heads of schools indicated that internet problems affected their implementation of the school administrative roles. Six school administrators from nine selected secondary schools reported unpredictable internet service as one of the major factors that hinder ICT usage for school administration. One of the interviewed respondents said:

In the previous, there was a free connection to internet service from the service provider, which helped me and the teachers to accomplish our tasks smoothly. At the moment the whole school experiencing poor access to the internet service because the provider has stopped it (KI, school C, April 2023).

Based on the quotation, the secondary school administrators seemed to be struggling with ICT usage in completing their administrative roles due to unfavorable internet operation costs. Additionally, the internet service provided was reduced to the ability of the school to bear the charges. In this situation, the researcher observed that two out of nine selected secondary schools, **E** and **F** had active Wi-Fi routers, and other schools **A, C**, and **D**, had in-active routers, which were acquired from the service provider. As one of the respondents justified: 'My school has computers and other devices such as photocopiers, scanners and printers. However, there are no internet services that limit us to use ICT effectively' (KI, School I, April 2023*).* Another respondent added:

The school has purchased one printer and two desktop computers and we are using them to perform several administrative activities. However, the school lacks access to free internet making it difficult to connect the Wi-Fi of our smartphones to the school's desktop computers (KI, School G, October 2023).

The quotes demonstrate that the lack of reliable internet services posed a significant limitation to the effective use of ICT among heads of schools in performing their administrative work. A majority of heads of schools in government secondary schools report a lack of internet connectivity which sometimes forces them to rely on personal smartphones and mobile hotspots to link their computers to the internet and sustain online

administrative activities. These findings are reflected by studies supporting that who supports that ICT services are meaningless if they lack internet connection to facilitate sharing of information sharing (Tigere, 2020). Besides, the findings corroborate with Abdullahi et al. (2020) views that poor connection to internet services affects administrators, teachers, and students to use ICT to achieve their roles. Additionally, the findings are in line with Tanzanian studies that weak or unpredictable internet and electricity are crucial factors that hinder the effective integration of ICT tools in the administration of secondary school educational programs (Francis, 2017; Hamoud & Nzilano, 2024; Malekani, 2018). Internet connectivity is a critical factor to observe for effective ICT usage in Secondary Schools.

Technophobia

Heads of schools revealed that technophobia is one of the significant reasons affecting the ICT usage for administrative activities. For instance, in schools **A** and **H**, heads of schools perceived computer applications are complex and they felt not easy to adapt them for administrative work. One of the respondents asserted:

I am not at ease when asked to perform my work using computers. As of now, I do not have a computer in the office. It is something that I am not used to. At my age, I do not have the basic skills of using computers. Although, during my university and teacher training college computer courses were mandatory and taught more theories because there were few computers in the laboratory. I feel comfortable doing my work manually (KI, School H, October 2023).

Furthermore, another added:

Always I feel nervous to use computers because I fear to make mistakes. It happened once by mistake I deleted a document and I did not even know which button was pressed. we lack the passion and knowledge of computers, which affects us to use technology successfully. My second mistress and the secretary support some tasks that need to be administered by computer applications (KI, School A, October 2023).

The inference from the quotations is that fear of technology affects the application of ICT tools for school administrative work. This situation is observed as an ICT application complexity resulting from limited ICT training among heads of schools to build their confidence of using technology. Therefore, technophobia appeared to challenge the competence of heads of schools to apply ICT in performing their administrative task. Nigerian studies by Abdullahi et al. (2020) and Unachukwu and Nwankwo (2012) noted that the school principals demonstrated paucity of computer knowledge and skills, and anxiety when it comes to using ICT for administrative activities, believing that it is complex and relevant for a new generation. Moreover,

Mwalongo's (2011) findings indicated that Tanzanian school administrators and teachers perceived that ICT tools are sacred objects and are not suitable for handling administrative tasks. The situation reflects Davis's (1989) assertion that technology acceptance relies on the perceived easiness and usefulness of that technology to influence the behavioural intentions and attitudes of users. Thus, heads of schools' fear of using ICT for administrative functions are more likely to be affected by the perception that ICT is complex, sacred, and not suitable for their generation.

Shortage of Funds

The shortage of funds affected the capacity of the secondary schools to procure ICT resources such as computers, printers, and scanners. However, findings from the reviewed documents such as school budgets and strategic plans showed that the school administration has less priority for ICT integration in secondary schools. As one of the respondents noted:

This school relies on the money collected from students as tuition fees. The funds cannot afford us to procure ICT facilities. You know, nowadays ICT facilities require a significant amount of money as the school has a limited budget to afford expensive ICT facilities (KI, School D, October 2023).

The inference from this quote is that secondary schools receive government funds and collect some money from students as tuition fees, which support processes of academic and administrative activities including purchases of ICT equipment. Similarly, the evidence from the analysis of documents revealed that some schools **A, C, D,** and **H**, lacked a budget to establish and keep up ICT facilities. The implication is that ICT in schools is of less priority making it difficult for the heads of schools to integrate ICT in the performance of administrative tasks. The findings agree with studies that public secondary schools in Tanzania faced challenges to procure and maintain ICT facilities (Malekani, 2018) due to over-dependence on unrealistic government budgets to support the acquisition of ICT devices and services (Ndume et al., 2021). Unlike findings in Kenya by Oluoch (2016) who revealed the mobilization of school funds from different sources including influential individuals, politicians, and private organizations to purchase ICT resources were actively arranged by school principals. Thus, this situation suggests that the development of critical thinking competencies among school administrators and other educational authorities is of great importance in secondary schools.

Unpredictable Supply of Electricity

The unpredictable power supply was perceived by the heads of schools as an important factor that influenced their initiatives towards ICT usage in secondary school administration. In this case, three heads of schools

noted that unreliable electricity supply disappoints them in the use of ICT equipment at school. One of the respondents elucidated:

We are facing the problem of recurring power outages which influence the performance of school activities. Occasions of frequent power outages are common in our school. The awkward thing is that many secondary schools of the government lack alternative sources of energy to support the implementation of administrative tasks (KI, School H, October 2023).

Similarly, another respondent maintained:

The power outages have adversely affected the capacity of heads of schools to perform administrative work using ICT. For example, we submit urgent electronic reports when our authority such as the office of the Municipal Education Officer needs them. We are forced to submit the same reports manually due to frequent electricity failures. As a result, the problem delays the preparation of the reports and submission to the respective authorities (KI, School **I**, October 2023).

These findings reflect that the recurring electricity failure affects ICT usage in the administration of secondary schools. This situation appeared to disappoint heads of schools to use ICT, as they delayed the performance of administrative tasks and urgent communication of reports to relevant educational authorities.

The existing findings corroborate with Abdullahi et al. (2020) view that Nigerian secondary schools experienced frequent power outages which affected ICT usage for school management and storage of records. Similarly, studies by Tigere (2020) from Kwazule-Natal in South Africa reflected that frequent electricity interruptions hindered ICT integration in rural and urban secondary schools. Additionally, Irene's (2020) study concurs with the study findings by emphasizing the impact of power outages for effective ICT use for secondary school the administration in Mitooma area of Uganda. The situation of unreliable supply of electricity seems to be common in developing countries and suggests that school administrators should choose to use alternative power sources in secondary schools.

Shortage of Technical Support

The findings revealed that five heads of schools had the view shortage of technical support affects their use of ICT to coordinate administrative tasks. As one of the respondents reported:

In this school, we use computers to achieve the tasks of school. However, the computers are not in good condition as they need repairs and maintenance in software and hardware. We received a donation of old computers that are not compatible with the new computer applications (KI, School B, October 2023).

Another respondent explained:

Our school does not have reliable ICT infrastructure. We use printers and computers that are in poor condition. The computers lack repair and maintenance, and we have not had an IT expert for a long time now to service and repair our ICT facilities (KI, School **I**, October 2023).

The findings in these quotes reveal that secondary schools for a long period do not have technical experts or information technology (IT) responsible for the maintenance of ICT facilities. Since IT experts are scarce or not available in schools, the secondary school condition seems to be not favourable for the heads of schools to effectively use ICT for administrative work. The researcher's observation of secondary schools discovered a variety of ICT resources including desktop computers, photocopiers, and printers that needed serious maintenance and repairs. For example, secondary school **B, D**, and **I** had an old printer and a desktop computer to support the performance of school administrative work. The situation might have compelled some heads of schools to resort to manual systems to do their administrative roles. Moreover, the shortage of information technology experts in secondary schools of the government was perceived by heads of schools as another important factor that limits the effective utilization of ICT for school administrative work. Additionally, the absence of IT experts in many secondary schools caused high storage of outdated ICT equipment. The present findings concur with studies in Kenya by Chepkonga (2015) and Uganda by Irene (2020) who noted the shortage of ICT technical assistance affected the school principals to manage public secondary schools using ICT. Therefore, technical assistance is important for the effective operation of ICT facilities in secondary school administration.

Conclusion and Recommendations

The findings offer the conclusion that limited ICT literacy among heads of schools, shortage of ICT and internet facilities, fear of using technology among heads of schools and unpredictable supply of electricity were the crucial factors that affected the heads of schools to use ICT for administrative and academic functions. Despite the factors affecting heads of schools in using ICT tools, heads of schools perceived that ICT has improved various school administrative activities such as managing finances, communication, and academic and office records.

The study's findings have implications for the improvement of policy practices and new research opportunities. The findings call for the need of educational stakeholders' authorities, and school administrators to improve the use of ICT for school administration activities by ensuring the following: (1) supply of ICT facilities, (2) availability of information technology experts, (3) supply of reliable electricity and internet services, and (4) training heads of schools on ICT basic literacy. Further, the findings have provided the implications that since the present study was confined to the qualitative findings, a wide scope of the study that might embrace both qualitative and quantitative methods is needed to investigate the perceptions and practices of heads of schools about their ICT usage in secondary schools and other similar contexts. In addition, studies are needed to explore the heads of schools' competence and preparedness to use ICT for administrative functions including finances, records keeping, communication, publishing administrative materials, and engaging in online meetings.

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Authors Information

Josta Lameck Nzilano
https://orcid.org/0009-0003-4886-0798
Department of Educational Psychology and
Curriculum Studies, Dar es Salaam University
College of Education,
P.O. Box 2329, Dar es Salaam,
Tanzania

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Grade-7 Students' Product Promotion During an Engineering Design Task on Space Pollution Subject

Gökçe Musaoğlu
Rize Mahmut Celaleddin Okten Imam Hatip Middle School, Turkiye

Bahadır Namdar
Ege University, Turkiye

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Abstract

The aim of the study is to investigate grade-7 students' engineering design and product promotion on space pollution subject. The study was conducted with 52 students (19 female and 33 male) from a middle school in a city located in East Black Sea Region, Turkey. In this study, a holistic single case study method was used. The data was collected through worksheets, audio records, and peer evaluation forms. Content analysis was used in determining engineering design levels and content analysis and descriptive analysis was used in determining the qualities of product promotion. Results indicated that groups generally performed well in the steps of choosing the best solution, building the prototype, and presenting it. It was found that groups did not perform well in the steps of problem specification, developing solutions to the problems, and testing of prototypes. It was seen that the designed products were suitably qualified. It was found that qualities such as appearance, display, and cost of the design got higher points in peer evaluation. The groups used different strategies in product promotion. It was found that the qualities of the arguments groups used in oral presentations were successful while they couldn't perform well in quality levels of their answers. Implications were provided in line with these results.

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Corresponding Author: Gökçe Musaoğlu, gokcemusaoglu@gmail.com

Introduction

Entrepreneurship and engineering design skills are described as the basic skills expected from students in 21st century (Ministry of National Education [MoNE], 2018). Accordingly, individuals with engineering design skills are stated as individuals who identify a problem based on real world problems and design a product with interdisciplinary perspective to solve the problem (MoNE, 2018). In the program, entrepreneurial individuals are defined as individuals who solve problems, promote products, and determine cost price and sale price. Consequently, educators must implement strategies that encourage students to create solutions for problems and cultivate the abilities to present their ideas to a target audience. In recent years, STEM education provides a space for designing learning environments in achieving design and entrepreneurship skills by its interdisciplinary approach (Atkinson & Mayo, 2010; National Science Board [NSB], 2012; U.S. Department of Education, 2011). Furthermore, entrepreneurship can be transferred to learning environment through STEM education (Flanagan, 2014).

In STEM education, the engineering discipline actualizes science course learning outcomes while simultaneously developing design skills (Kolodner, 2002; Leonard, 2004). Therefore, it is necessary to use engineering design process in the integration of engineering discipline within a science course (Bozkurt Altan, 2017). While various approaches exist for the engineering design process, it has been noted that common steps include problem definition, solution identification, optimal solution selection, testing, development, and presentation (Ercan, 2014). According to Deveci (2017), students' leadership performance is enhanced when STEM education is combined with entrepreneurial thinking, which is why entrepreneurship should be incorporated into the engineering design process. In this sense, the curriculum states that students are expected to define a problem in a daily life, to think solutions to this problem, to choose the best solution, to design a product, and to calculate cost, material, and time in problem solution (MoNE, 2018). Afterwards students are expected to present the product they have designed and develop the product following testing process.

Upon examining the engineering design process and entrepreneurship separately in the literature, it becomes evident that the process of product promotion is not extensively studied in relation to entrepreneurship. There are few studies examining secondary school students' product promotion and engineering design skills by combining these two fields (Yüksel, 2019). Research indicates that seventh-grade students lack the entrepreneurship skills of their junior counterparts (Deveci, 2018; Ortaakarsu & Can, 2019). As a result, the study's sample was decided to consist of students in the seventh grade.

Literature on EDP indicated that students have difficulties in building a prototype (Çiftçi, 2018; Gök, 2019; Koç, 2019; Okulu, 2019; Soysal, 2019), engaging in shared decision making and producing ideas steps (Gök,

2019; Soysal, 2019), externalizing their design ideas (Gök, 2019; Yüksel, 2019), choosing the best solution (Özer, 2019), and executing mathematical operations (Çiftçi, 2018; Okulu, 2019). Koç (2019) notes that students had problems at the beginning, but they get better at EDP throughout the process, but they require extended period of time (Alinak Bozkurt, 2018).

When studies on product promotion process are examined, it is seen that the number of the studies conducted according to the activities defined in the program (MoNE, 2018) are limited (Deveci, 2016; Yüksel, 2019). There are studies examining students' product promotion in their entrepreneurship skills process in science (Deveci, 2016; Yüksel, 2019) whereas only one of them is related to middle school students (Yüksel, 2019). In this study conducted with middle school students, changings in students' entrepreneurship skills by using engineering design process and the way they follow while promoting a product were examined. Students designed a logo to promote their product, built an advertisement scenario and videotaped the advertisements and then they presented their products in a science fair. In this study, it was observed that students had difficulty in branding, slogan creating and using time efficiently which requires creativity, imagination and designing skill (Yüksel, 2019). In another research (Deveci, 2016) conducted on preservice teachers, entrepreneurship education modules were prepared. One of the modules included product promotion process. Deveci (2017) stated that prospective teachers had difficulty in processes such as producing new ideas, cost analysis and deciding on materials. In literature, most of the studies conducted in secondary school level are based on evaluating entrepreneurship skills (Deveci, 2018; Kurt & Bayar, 2019; Ortaakarsu & Can, 2019; Vurgun & Bektaş, 2019). It is seen that there are few studies thoroughly examining students' entrepreneurship skills in the scope of product promotion. Therefore, this study aims at examining grade-7 students' product promotion during an engineering design task on space pollution subject.

Methodology

In this study, holistic single case study method was used. In this way, we examined the students' ideas and experiences while they present their products during an engineering design process. The case study pattern, which is one of the qualitative research methods, is a situational approach getting in depth and detailed information by using various data collection means about a situation and real life (Creswell, 2013).

Participants

The study was carried out in the fall semester of the 2019–2020 academic year at an imam hatip middle school situated in an East Black Sea Region city center. There are five classes for grades 7 out of the total seventeen classes in the school. For the seventh grade, there are two classes of female students and three classes of male

students. The first writer was the science teacher for one of the two male and one female seventh-grade classes used in the study. The female class has nineteen students, one male class has seventeen, and the other male class has sixteen. The first author had three years of experience working at the study's school and has nine years of teaching experience. The first author had worked with the students on engineering design projects in the past. At the start of the semester, engineering design exercises covering the subjects were given to the new students. The first author finished the Scientix STEM education workshop, the STEM basic and advanced level trainings, and the STEM science, technology, and mathematical applications seminar.

Implementation Process

By increasing awareness and curiosity, integrating real-world problems into the engineering design process can encourage students to actively participate (Soysal, 2019). When it comes to putting STEM education into practice, astronomy topics are useful because they foster students' imaginations and pique their interest (Okulu, 2019). The topic of space pollution is chosen in this instance. The exercises were carried out in groups.

Worksheets were first distributed to the groups to ascertain their prior knowledge. Groups then received the documents containing the engineering design process. The smart board displayed the problem scenario. The issue was recognized by the groups. They began by analyzing the needs of the situation and looking for relevant solutions using computers, periodicals, and books. Once the groups had decided on the best solutions and materials based on the criteria, they created drawings of prototypes. The cost and sale prices were decided upon by the students. They then got to work building the prototypes. Following the construction of the prototypes, the groups tested their creations using the worksheet questions as a guide. The features to be improved were mentioned. They finished the processes of marketing and presenting the product at the very end. Using the provided materials, the students created a poster and gave five-minute promotional presentations. Using the peer evaluation forms, the groups assessed their presenting peers concurrently. Following the presentation, critiques and remarks were made by the other groups. The presentation's presenting groups addressed these critiques and remarks. The researcher recorded the students' voices in the interim. The engineering design cycle's "Develop" step only allotted time for the presentation and improvement suggestions. The groups were not given the opportunity to modify their designs in response to peer feedback. The implementation process of the study is shown on Table 1.

Table 1. Research Implementation Process Plan

Date	Lesson Duration	Implementation Process and Explanations
1st Week 15/10/2019-16/10/2019	40+40 minutes	• Grouping the students • Applying "What Do I Know" activity to determine the students! Prior knowledge • Starting MTS "Fight with Space Junk" activity • Taking field notes by the teacher • Examining the students' worksheets
1st Week 17/10/2019-18/10/2019	40+40 minutes	• Continuing "Fight with Space Junk" activity • Taking field notes by the teacher • Examining the students' worksheets
2nd Week 22/10/2019-23/10/2019	40+40 minutes	• Applying "Evaluate and Develop" activity • Applying "Now Advertisements" activity • Examining the students' worksheets
2nd Week 24/10/2019-25/10/2019	40+40 minutes	• Applying "Product Promotion and Marketing" activity • Examining the students' worksheets • Taking voice recordings

Data Collection and Data Analysis

Worksheets for engineering design and audio recordings were used to gather data. The "EIE-Engineering is Elementary" program's design-based science education approach and the engineering design cycle's steps were used to prepare the worksheets. During the "develop" phase of the engineering design cycle, audio recordings of students promoting their products were made.

Based on the information found in the students' worksheets and audio recordings, content analysis was utilized in this study to identify the design and product promotion processes (Yıldırım & Şimşek, 2006). The various facets of the student audio recordings' product promotion processes were examined using descriptive analysis. The engineering design process, the product evaluation, and the peer evaluation rubrics were used to analyze the engineering design levels examination. The oral introduction analysis rubric and the quality analysis of the answers rubric were used to analyze the examination of the qualities that promote the product.

Based on argumentation literature, the oral presentation rubric is divided into four categories. Only the claims are included in the first level sentences, which are categorized as "improvable." The second level evaluates the claims, justifications, and non-scientific terminology as "medium." The "good level," or third level, is

composed of arguments, assertions, and scientific terminology. Claims, justifications, backings, and rebuttals are included in the fourth level, which is rated as "very good level."

The quality analysis of the answers rubric was arranged based upon “Argumentation Quality Determination Rubric” prepared by Venville and Dawson (2010). This rubric is made of four levels. In the first level, the students give reasonless answers such as “Yes, No, or I don’t know” to the questions from their friends, this stage is organized as “improvable”. In the second level, there are reasons in the answers. This level is accepted as “medium”. In the third level the reasons in the answers are expressed scientifically and it is defined as “good”. The fourth levels, there are reasons, backings and rebuttals in the answers. This level is accepted as “very good”. This rubric was used in the analysis of the quality level of the groups’ answers.

In this study, validity and reliability were provided with Lincoln’s and Guba’s (1986) credibility, transferability, dependability, and confirmability criteria. In credibility, various data collection tools were used, the researcher and the consultant frequently had meetings to evaluate the situation. In transferability, purposeful sampling was used as sample preference, and implementation process was transferred to the reader without adding any interpretation. In dependability, the documents and the data from the voice records were compared. Interrater reliability was conducted as 74% (Miles & Huberman, 1994). In confirmability, the data was presented in quotes.

Findings

Two categories the findings for engineering design processes and the findings for product promotion processes were created from the data analysis results.

The Findings Regarding Product Promotion Processes

In this section, the findings of the content analysis of promotion stages in the groups’ engineering design worksheets and the findings of the descriptive analysis of the product promotion processes the students used during their presentations were written. Firstly, the product promotion strategies the groups used during oral presentations were examined in five categories developed by the first and the second authors beforehand (see Table 2).

Table 2. Product Promotion Strategies of the Groups

		Groups											
Categories	**Sub Categories**	**B 1**	**B 2**	**B 3**	**B 4**	**C 1**	**C 2**	**C 3**	**C 4**	**E 1**	**E 2**	**E 3**	**E 4**
Product Concept	Working Procedure	X	X	X	X	X	X	X	X	X	X	X	X
	Cost	X	X	X	X	X	X	X	X	X	X	X	X
	Sale Price	X	X	X	X	X	X	X	X		X	X	X
Technical Components	Material	X	X	X			X	X	X	X	X	X	X
Brand Positioning	Name		X	X			X	X	X				
	Slogan		X	X	X	X			X				
Communication	Specifying Colleagues	X	X										
Advertising Message	Specifying a Goal			X								X	X

When Table 2 is examined, it is seen that all the groups mentioned about their designs' working procedures while promoting their products. For example, the E4 group explained their product's working procedure as follows: "*There is a handle in our space craft. It throws a net into space with this handle and catches the space trash. It transfers them into the laser inside it. The trash is melted with the laser and put into the storage room, and then they stay there. After all the trash goes through the same process, we put them in a small cube and send them to the World.*"

It is seen that all of the students mentioned about the total cost during product promotion. For example, the B1 group explained their cost as follows: "*We used 7 giant pipes and they cost 182 liras. We used a magnet and it cost 55 liras. We used 4 aluminum plates and they cost 476 liras. We used a giant laser and it cost 660 liras. The total cost of the materials is 1408 liras.".* Only one of the groups didn't mention about the sale price during product promotion. The B3 group explained the sale price as follows: "*Our cost is 8833 liras, but our sale price is 10.000 liras. We need to give money to the workers so there is also labor cost. Thus, we sell the product for 10.000 liras."*

When the groups are examined in terms of technical components, it is seen that ten of the twelve groups mentioned about the materials they were going to use while promoting their products. For example, the C3 group mentioned their group materials as follows: "*Materials; infrared camera, 2 aluminum plates, 4 giant magnets*".

When the groups are examined according to their situations of stating design name and slogan in terms of brand positioning strategy, it is seen that five groups mentioned about their designs' names. To give an example, the B2 group explained the name as follows: "*Cosmic Cleaner, it means 'kozmik temizleyici' in Turkish*." Five of

the groups mentioned about the slogan during their presentations. For example, the B2 group explained their slogan as follows: "*Our slogan is 'Bırakın cleanlesin' and it means 'Let it clean, we don't need to do anything! It cleans by itself.*'"

When the groups are examined according to their situation of specifying colleagues in terms of communication strategy, it is seen that only two groups mentioned the names of their colleagues during their presentations. For example, the B2 group introduced their colleagues as "*Büsre, Esma, Eslem and İrem*" and B1 group introduced their colleagues as "*Gülesma, Zeynep, Hümeyra and Zekiye*".

When the groups' situations regarding their specifying a goal in accordance with advertising message strategy were examined, it is seen that three groups mentioned their goals for their designs during the presentations. To give an example, the B3 group explained their goal as follows: "*Our aim is to help space research by cleaning space. Because there will be more extensive research when space is cleaned. The desired result is to clean up at least 75% of space. In this way, the goal is to reduce space pollution increasing every year. Let's save space and make a way for future. We may not clean 100%, we may not have that much time. So we clean 75% of space as much as possible. But we aim at 100%.".* Advertising message can be defined as emphasizing the benefits of the product's features and the value of the product. In this case, it can be said that the B3 group's explanation has an advertising message.

When the groups' product promotion strategies are examined, it is seen that B2 and B3 groups used the most strategies and E1 group used the least strategies. It is observed that the B2 group that used 7 strategies made a good design and the design got high points in product design. The C4 group that got the lowest points in product design and engineering design steps evaluation used 6 promotion strategies. The E1 group that used the least promotion strategies got medium points in design evaluation. This group got good points when the qualities of engineering design steps are examined. It is seen that the other groups showed similarity when their engineering design steps level and product promotion ordering are compared. It can be said that the performance in engineering design steps has a role in determining product promotion strategies.

Below are the findings from the content analysis of promotion chapters in engineering design worksheets (see Table 3).

Table 3. Group Codes Regarding Promotional Tools

Codes	Number of Groups
Television Commercials	4
Advertising Boards	1
Social Media	3
Banner	3
Promotion Stand	1
Explanation with Slogan	2
Making a Poster	2
Internet Advertisement	2
Public Service Advertisement	1
Premiere	1
Video Shooting	1
Newspaper	1
Brochure	1
Participation in Project Competitions	1

In the findings from the answers of the question "*Which advertising methods would you use to promote your design?*", television commercials is the most preferred method and social media comes after it (see Table 3).

Table 4. Group Codes Regarding Target Audience

Codes	Number of Groups
Astronauts	3
Scientists	3
Astronomers	1
Manufacturer Aerospace Companies	3
NASA	5
Turkey Space Agency	4
Space Explorers	2
SpaceX	1
Aselsan	1

According to the findings from the answers of the question *"Who is the target audience of your design?",* five groups stated NASA and four groups stated Turkey Space Agency as their target audience. It is observed that none of the groups wrote the leading space agencies of the world such as India, China, Europe, Russia, and Japan (see Table 4).

When Table 5 is examined, it is seen that all the groups stated an advertising method for their products' promotion. Eight groups mentioned television commercials and five groups mentioned social media. Two groups each mentioned poster, newspaper, internet sites, and visual and oral communication methods while one group each mentioned promotion methods such as slogan and posters. The opinions of the C3 groups are as follows: "*We can organize a premiere and introduce the product. We can advertise on television for the ones*

who couldn't come to the premiere. We can make a poster.". The opinions of the B3 group are as follows: *"We can introduce the product in a science fair. We can prepare banners for the ones who couldn't attend the science fair."*. The opinions of the B4 group are remarkable: "*We can introduce the product by promoting on social media, displaying it in different places. It should be informative, and we should introduce the contents nicely."*

Table 5. Group Codes Regarding Promotion Tools in "Now Ads" Activity

Promotion Methods	**Number of Groups**
Banner	2
Science Fair	1
Newspaper	2
Visual and Oral Advertising Methods	2
Internet Sites	2
Social Media	5
Product Promoting Stand	1
Project Competition	1
Poster	1
Premiere	1
Public Service Advertisement	1
Slogan	1
Television	8

In the Table 6 below are the findings from the answers to the question *"How would you promote your product to your target audience?"*.

Table 6. Student Codes Regarding Ways to Follow in Promoting Their Products

Promoting Ways	**Number of Group**
Appearance	1
Introducing how it functions	1
Having high quality	2
Specifying properties with attention to detail	4
Making an ad that impresses everyone	4
NASA tour chance (Free Gift)	1
Applying to the Turkish Space Agency	2
Trying to spread as much as possible	1
Having famous and reliable people in our ad	1
Total	17

According to the Table 6, the student groups expressed the ways they would follow to introduce their products to their target audience in various ways. Four of the groups emphasized on making an advertisement that impresses everyone, other four groups emphasized on the need to specify the properties of the products, two

groups emphasized on highlighting the quality while introducing the products, two groups emphasized on the need to get in contact with several space agencies, one group emphasized on having famous and reliable people in ads and one group emphasized on the need to highlight the importance of the appearance.

The opinions of the C4 group are as follows: "*We can make lots of ads. We can apply to Turkey Space Agency. We can make ads that impress everyone. We can introduce the product by specifying properties with attention to detail*.". A similar example to this is the opinions of the E3 group. The E3 group emphasized on the importance of the properties with their expressions as follows: "*We can sale the space craft by introducing the properties of it*." It is seen that the B1 group paid attention to their product's "Durability and Appearance" factors in their opinions about the product promotion. The opinions of the E4 group are remarkable. They emphasized that they could arrange a free gift event for the target audience with "NASA tour chance" slogan.

Oral presentation quality analysis rubric develop by the researchers was used in the evaluation of the qualities of the students' arguments they used in their presentations. An example of the "very good" level regarding the evaluations of the analyzed groups is shown below (see Table 7).

Claim: We decided on 2000 liras as the sale price, we don't have any profit or loss. Reason: It costs 1295 liras. This includes labor cost. We need to make it economic for our country. Justifier: There shouldn't be loss of money a lot in our country. The cheaper it is, the more our country will develop. Thus, it is economic. Rebuttal: We sell it cheap now but there will be more profit as it develops. This explanation is scored as level 4, "very good", because it includes reason, justifier, and rebuttal.

Table 7. Quality Level of the Groups' Oral Presentations

Groups	Improvable	Medium	Good	Very Good
B1		X	X	X
B2	X	XXX		X
B3		X	XX	XXXXXX
B4			X	X
C1		X	XX	
C2	XX		XX	
C3	X			XX
C4		X	X	
E1		X	X	
E2				X
E3				X
E4			X	XX

An evaluation was made with the developed rubric to determine the quality of the answers students gave to the questions from their friends during their presentations. An example of "level 2" regarding the quality of the groups' answers was shown in this part (see Table 8).

In the answers of level 2, "medium", there are a claim and a reason supporting the claim. The groups may include their beliefs, unscientific data, and their misconceptions into their reasons while they make a claim. For example, it draws attention that it has misconception when the E2 group's claim is examined.

Question: How does the trash go to the Sun when you hit the piston? Answer: The trash will break into pieces because it will get hot as it gets closer to the Sun. Reason: It will get hot as it gets closer to the Sun.

The claim of the E2 group is correct. Its reason is acceptable. Because breaking into pieces of the trash thanks to the Sun's heat is a factor but the reason of the trash melt is not the warmth, it is the heat. The group is in level 2 because of the misconceptions. If making a claim is about convincing the other person or group, reasons should be solid. Therefore, data in reasoning sentence should be based on scientific basis and it shouldn't include misconceptions (Şahin, 2014). The students presented a reason with evidence but the reason they presented was classified as "medium" because of the misconceptions in it.

When the groups' oral presentation levels are observed, it is seen that the B3 group often used the "very good" level. It is observed that this group is one of the groups that used the most strategies in product promotion strategies shown in the Table 2. In the E1 group, no sentences were found at the "very good" level. This group is also the one that used the least strategies in product promotion strategies.

Table 8. Quality Level of the Groups' Answers

Groups	**1st Level "Improvable"**	**2nd Level "Medium"**	**3rd Level "Good"**	**4th Level "Very Good"**
B1	X			
B4			X	
C2			X	
C3	XX		X	
E1	X	X	X	
E2	X	XX	X	
E3	X		X	
E4	X	X	XXX	

No questions were asked four groups among twelve groups. When the quality of the other eight groups' answers is examined, it is seen that six groups gave Level 1 answers, three groups gave Level 2 answers and seven groups gave Level 3 answers. The B1 group has one "improvable" level; the B4 group has one "good" level;

the C2 group has one "good" level; the C3 group has two "improvable" levels and one "good" level answers. In addition to these, the E1 group has one "improvable" level, one "medium" level and one "good" level; the E2 group has one "improvable" level, two "medium" and one "good" level; the E3 group has one "improvable" level and one "good" level answers. It is remarkable that the E4 presented acceptable reasons to three questions out of five questions. It is observed that this group also made "very good" level presentations in oral presentation quality level in Table 7.

Results, Discussion and Implications

The results related to product promotion strategies, oral presentation quality and quality of the students' answers are shown under this title. The groups' promotion strategies were analyzed in terms of product concept, technical components, brand positioning, communication and advertisement message. Product concept is the stage where the product's features and differences from other products are expressed (Kaya, 2018). In the study, this stage is divided into subcategories as working procedure, cost and sale price. It can be said that all the groups showed a successful marketing strategy performance as product concept. It is thought that the working procedure, cost and selling price of the product in the poster prepared by the groups helps them to use the product concept strategy while promoting the product. It is observed that none of the groups planned for an advertisement budget. It can be said that the groups generally followed a successful strategy in financial issues except for the advertisement budget. Not having a separate section for advertisement budget in the worksheet might be the reason of the groups' not emphasizing on this issue. It is known that worksheet is an important element helping to fulfill the learning outcomes as long as it is designed well (Uslu, 2011). In fact, a teacher will not need to always emphasize important parts with the use of a worksheet of which questions and instructions are well built (Proctor et al., 1997).

When the groups are examined in terms of specifying the materials in their designs in the promotion stage within the technical components strategy, it is seen that ten groups used this strategy. Therefore, it can be said that the students generally performed successfully in the direction of technical components strategy. It is thought that emphasizing material choices and the features from the very beginning of the engineering design process helps the students specifically include technical components sections.

The groups' design names (Brand) and the slogans were examined within brand positioning strategy. All of the activities such as sticking in target group's mind, standing out from other rivals, creating a special place for the brand are called as brand positioning (Kaya, 2018). Brand is the combination of name, symbol, design, shape or all of these elements, which identify a product or products of a group of sellers and differentiate them from their rivals' products (Odabaşı & Oyman, 2002). It can be said that the five groups, that include their products'

names (Brand), have come a positive way in line with brand positioning strategy. It was found that five of the groups included slogans. Slogans, which involve attention grabbing brief writing about the product, require using creativity and design skills as well as brands do. Most of the groups were insufficient in terms of creating product name (Brand) and slogan and this might be the result of the difficulties they had in transferring these skills to the process. If it is considered that one of the features of an entrepreneurial individual is producing designs by using imagination (Deveci, 2018), it is thought that the students in the successful groups were successful in creating brand and slogan by using imagination. In his work with 5th grade students, Yüksel (2019) stated that the groups had difficulties in developing brand and slogan for the greenhouses they designed, and it is necessary to make use of STEM activities to improve the students' creativity and design skills.

Two groups included communication strategy in product promotion processes. It is seen that people who cooperate in the group appreciate each other by saying their names. This can be accepted as a promotion strategy convincing the target group. It can be said that these two groups used communication and self-confidence skills effectively in promotion strategies. The reason why the two groups used this strategy was interpreted as a positive cooperation in the group throughout the process and an expression of the effort by everyone's equal work. In his work with 5th grade students, Yazıcı (2019) states that the groups' job sharing and group members' volunteering in distribution of tasks are the reasons of the students' being successful in product promotion stage. He also states that this situation contributes positively to the students' communication and self-confidence. Communication is thought to be an important medium in promotion strategies. Student groups can be shaped accordingly to provide motivation to be able to maintain intra group cooperation and voluntary participation in the activities throughout the engineering design and product promotion process.

Advertising message is the features of the product, the value of the product and to use these with written and visual themes (Kaya, 2018). Three groups were observed to use advertising message strategy when the groups tried to express the value of the product by defining its target. It can be said that these groups used future planning skills to convince the target group to buy the product. In his study with 7th grade students within social studies course, Tarhan (2018) designed activities which help students gain entrepreneurship skills. One of the activities he designed aims to improve job plan skills. In the results part, he mentioned his students had knowledge of preparing job plan in entrepreneurship activities, the problems they might encounter and the goals.

When the findings from "Evaluate-Develop" worksheet, which includes the groups' opinions about product promotions, are examined, it is seen that most of the groups mentioned mass communication such as television and social media in the first place and then banner, poster and brochure in the second place. In the same way, the high number of television and social media codes in the findings of "Now Advertisements" worksheet

supports this result. In this case, the importance of television and social media in terms of spreading advertisements nowadays is once again seen. In addition, it can be said that social media is a growing advertisement channel and a popular advertising way which is important for students. It is thought that the students' spending time with television and social media, which are the mass communication they mostly use daily, and observing the advertisements there affect this result. In his study with university students to investigate whether social media advertisements have an impact on purchasing behavior or not, Çağlıyan et al. (2016) found out positive relation between the students' purchasing behavior and using social media. He stated that the reason of this is the youngsters' spending too much time in social media and having chance to examine the products.

In science instruction program (MoNE, 2018), it is mentioned to use newspapers, television, Internet advertisements and short movies as promotion tools to market products in developing student's entrepreneurship skills. In the results of this study, the students similarly mentioned these promotion tools while additionally expressing promotion tools such as project competitions, billboards, science fairs, banners, promotion stands, brochures and social media. It is thought that the students' participating in projects like 4006 science fairs organized in schools might influence the students' answers. It is seen that students can use their previous experiences in similar situations. TÜBITAK supported science fairs are known to provide a rich environment in developing students' skills and experiences (Doğanay, 2018). Science fairs allow students to present and introduce their designs (Roberts, 2012). Activities can be made with different promotion tools to help students gain experience in promoting activities stage of engineering design activities. When it is thought that science fairs, project competitions and science exhibitions provide students experiences and they transfer these experiences into new situations, students' promotional qualities can be improved by using these activities often.

While choosing the target group, none of the groups wrote the names of world's leading space agencies such as India, China, Europe, Russia, and Japan Space Agency. The groups generally mentioned about NASA, Türkiye Space Agency and SpaceX. This may be because of NASA's being one of the oldest space agencies, being popular and carrying out a lot of duties. On the other hand, it is remarkable that a group mentioned about SpaceX, which is a USA origin company, except for NASA. It is thought that factors like SpaceX's attracting attention for its aim to colonize Mars and building interesting spacecrafts might have an effect on the students' giving its name. Türkiye Space Agency's (TUA), which was founded in Turkey towards the end of 2018, being a popular target group among the students is important in terms of awareness. This result can be thought as reflection of a work happened in a close region of the students. Lastly, one of the groups is seen to use gift as a strategy to attract the target group. Free gifts prompt purchasing behavior instantly and quickly (Yalman & Aytekin, 2014). This might be related to the group's choosing and using the tools which attract the attention

and interest of the target group. In his work, Tarhan (2018) stated that the students used promotion skills in entrepreneurship practices.

When the quality levels of the verbal presentations of the groups are examined, arguments from every level of argumentation are detected. It is seen that most of the groups used claims, reasons, backings and rebuttals during their presentations. Only two of the groups used both backings and rebuttals in same sentences while other groups used them in separate sentences. It can be said that the groups have lacks in forming sentences with rebuttals. The students' having not many argument-based activity experiences may have an effect on this. In his work with 8th grade students, Kutluer (2020) stated that when he examined the students' argument levels by using various activities about matter cycles, the reason of the students' having difficulty in using backings and rebuttal elements could be not having higher cognitive knowledge, consideration and discussion. Students can produce higher level arguments by increasing the number of the argumentation supported engineering design process activities.

When the analysis of the groups' answers to the questions of other students during the presentations is made, a considerable amount of the groups gave level 1, short and reasonless answers to the questions. This might be because of the students' having difficulty in giving evidence-based answers. In fact, people of every group of age have difficulty in forming justified sentences according to the previous studies (Sadler, 2004). In his work with 6th grade students, Jan (2009) stated that the students had difficulty in presenting reasons to strengthen their claims. It is remarkable that none of the groups is in the level 4 which is the best level in this study. This level involves the arguments which includes backings and rebuttal. However, none of the groups included backing and rebuttal in their answers. In the findings regarding the forms of the sentences the groups used during their presentations, it is seen that only two of the groups used backings and rebuttals in the same sentences. In the study, the students' having problems in using backings and rebuttals might be because of their having not many argumentation-based activity experiences. It may be also because of not having questions which allows them to justify against opposing views in the worksheets which includes promotion process. In her work with 5th grade students, Demir (2017) stated that the students had problems in forming rebuttals in argument quality, and the reason of this might be the insufficiency in the students' model notebooks. Another issue is that four of the groups in the study weren't asked any questions. One of the reasons of it may be the groups' being shy about discussions and avoiding from looking the product with a critical eye. Researchers emphasize on the necessity of creating democratic discussion and conversation environments where the students' opinions are cared (Sadler, 2006).

Engineering design worksheets, having supportive questions, can be designed to help the students form rebuttals to defend against opposing views during promotion processes. Undoubtedly, information and

communication technologies are one of the indispensable ways of product promotion nowadays. In future studies, how students conduct product promotion processes with information and communication technologies and qualities of these can be investigated.

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Authors Information

Gökçe Musaoğlu
https://orcid.org/0000-0002-8123-6159
Rize Mahmut Celaleddin Okten Imam Hatip Middle School
Turkiye

Bahadır Namdar
https://orcid.org/0000-0002-5076-6034
Ege University
Turkiye