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Abstract

This study aims to examine postgraduate theses focusing on technology integration in the field of mathematics education in Turkey between 2015-2023, taking into account the didactic focus classification. In this research, systematic literature review was used to address research questions. This systematic literature review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocols guidelines to ensure credibility and reliability. Two hundred fifty-five postgraduate theses were included in the study. The study used the Educational Research Publication Classification Form to examine theses years, methods, and didactic focus classification. The technology, theory, and learning areas discussed in the theses were examined according to the categories created by the researchers. Descriptive and content analyses were employed in the data analysis. As a result of the study, it was determined that the theses focused more on Categories 5.1, 5.3, and 5.2. Category 5 was handled every year between 2015 and 2023. Qualitative and mixed research methods were employed extensively in these theses. Dynamic geometry software was used more in theses. Numbers and Operations, Geometry and Measurement, Numbers and Algebra, and Geometry learning areas were focused more frequently in thesis.

Introduction

Integrating technology into mathematics education effectively supports students in interpreting mathematical concepts (Ince-Muslu & Erduran, 2021) and enhances academic performance and engagement (Ali et al., 2023; Hanifah et al., 2025). NCTM (2000) emphasizes technology as one of the six principles of mathematics education. Employing specific mathematics education technologies for the discussed content supports students in comprehending mathematical concepts and their relationships (NCTM, 2015). Additionally, according to NCTM (2014), technology can improve the quality of teachers' teaching activities and enhance students' learning in mathematics. A growing body of literature acknowledges the potential of digital technologies to improve learning outcomes in mathematics education across various content areas (Verbruggen et al., 2021). Research indicates that students worldwide often face challenges in comprehending mathematical concepts in schools (OECD, 2019), highlighting the significant role that technology can play in addressing this issue (Dockendorff &Zaccarelli, 2024).

The teacher plays a crucial role in the integration process (Mishra & Koehler, 2009; Ertmer, 1999). Effective technology integration requires knowledge of tool usage and the implementation of pedagogical strategies that support the use of technology in mathematics education (Dockendorff & Zaccarelli, 2024). It is important to consider student characteristics and outcomes when integrating technology (Kimmons et al., 2020). Willingham (2012) explained, "Changes in the educational system are irrelevant if they do not ultimately lead to changes in student thought" (p. 155). The Technology Pedagogy and Content Knowledge (TPACK) framework, widely used in many studies, involves understanding the complex relationships among students, teachers, content, technologies, and practices (Archambault & Barnett, 2010). According to Koehler and Mishra (2005), "Good teaching is not simply adding technology to the existing teaching and content domain. Rather, the introduction of technology causes the representation of new concepts and requires developing a sensitivity to the dynamic, transactional relationship between all three components suggested by the TPCK framework" (p. 134). Teacher, student, content, pedagogy components, and interactions are essential to successful technology integration. Teacher, student, content, pedagogy, and interaction components are essential to successful technology integration. In this study, the didactic triangle, focusing on these three components, was used to examine postgraduate theses in the field of mathematics education.

Didactic Focus Classification (DFC)

The three main components on which technology integration models are based —the concepts of teacher, student, and content— can be characterized as the three main actors of the learning process. These actors are based on a simple triangle first introduced by Johan Herbard in the 19th century (Lampiselkä et al., 2019). The didactic triangle reflects the relationships between the three main actors in the teaching process: content, student, and teacher (Figure 1(a)). The learning process occurs between the student and the content, and the teacher's pedagogical knowledge and actions structure the process (Kinnunen et al., 2016). Classifications based on the interactions of these three main actors (learning-teaching process components) are called Didactic Focus Classification (DFC). The underlying DOS classification is based on the studies of Kinnunen (2009), Kinnunen et al. (2016), and Lampiselkä et al. (2019).

This study employed DFC to investigate whether the three essential components of the learning process and their interactions were addressed in postgraduate theses focused on technology integration and which interactions between the components were given more emphasis. The traditional didactic triangle is transformed by adding a fourth component of technology to construct the didactic tetrahedron (Ruthven, 2012). This recognizes that digital technology has become crucial in teaching practice (Dockendorff & Zaccarelli, 2024). When applying the model to technology integration, Kinnunen argues that the technology must be considered context, as represented in Figure 1(c) (Berglund & Lister, 2010). Postgraduate theses focusing on the integration of technology were evaluated within this scope.

The eight main categories in DFC (Figure 8(b)) comprise the original didactic triangle components (content, teacher, and student) and the interactions between these components (e.g., the student-content relationship). Three subcategories (Category 5) were used for student-content interaction, and four (Category 7) were used for teacher-student-content interaction. Detailed information about the categories and subcategories of the DOS is presented in Table 1. This study evaluated three components and their interactions in postgraduate theses focusing on technology integration.

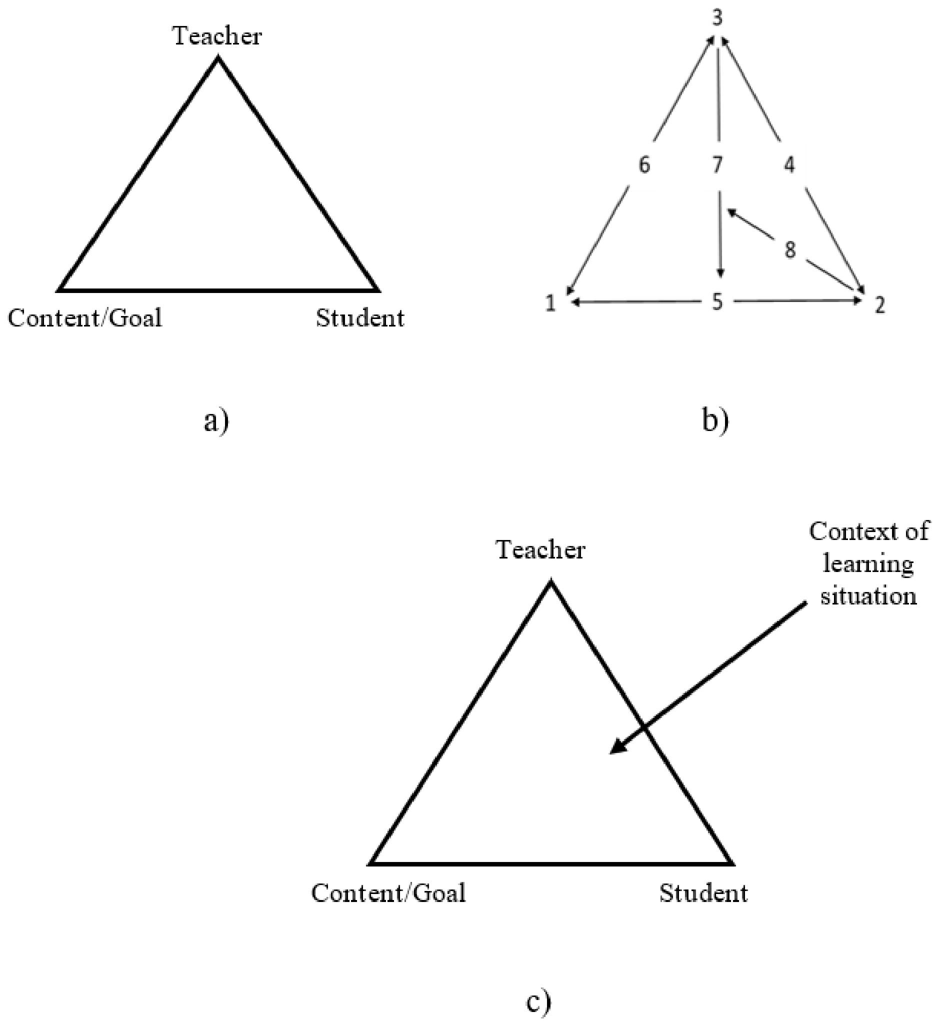

Figure 1. a) Herbart’s Didactic Triangle (Peterssen, 1989), b) Didactic Triangle with Interactions (Lampiselkä vd., 2019), c) with Technology Component Attached (Berglund & Lister, 2010)

Literature Review

Recent trends show a significant increase in research on the effective use of technology in mathematics education (Ali et al., 2023). Critical syntheses of these studies are important for managing and informing this growth (Hwang et al., 2023; Young, 2017). A systematic literature review (SLR) validates current practices, resolves inconsistencies, identifies emerging patterns, exposes and guides future research directions, and suggests recommendations to support decision-making regarding the integration of technology in mathematics education (Munn et al., 2018). Researchers have recently established strict standards for analyzing diverse learning experiences using technology. This clarifies variables such as tool type, grade level, subject matter, instructional method, student support, and teacher training (Hillmayr et al., 2020). Examining these factors will provide a deeper understanding of the reported results (Dockendorff & Zaccarelli, 2024).

Table 1. The List of Didactic Foci And their Definitions (Kinnunen, 2009; Kinnunen et al., 2016; Lampiselkä et al. 2016; Authors, 2024)

Category	Name of the Didactic Focus	Definition	
Category 1	1. Goals and contents	The characteristics of the goals and/or contents of a course or study module of a degree program. The relationship between the goals and the content in one level (course, degree, general goals of education) or between different levels.	How do 9th-grade mathematics textbooks present the data unit?
Category 2	2. Students	The students' characteristics (e.g., gender, level of education, knowledge, or prior learned skills). The student's relationship with fellow students or the student community.	Do secondary school students' attitudes towards using interactive boards in mathematics classes differ significantly according to the gender variable?
Category 3	3. Teachers	The teachers' characteristics. The interactions between teachers.	What is the level of technological literacy of secondary school mathematics teachers?
Category 4	4. Relation between students and teacher	How students perceive the teacher (e.g., studies on how competent students perceive the teacher) or how the teacher perceives the students.	How do students' technology use skills affect the teacher's didactic actions?
Category 5	5. Relation between students and goals/contents	The students' actions when they strive to achieve their goals. How students perceive course goals and content.	
Category 5.1	5.1 Students' understanding of and attitude about goals and contents	How students understand a central concept in the course, or how engaging students and possible future students find the topic, degree program, or specific occupation.	What are the students' opinions about STEM activities used in teaching mathematics in middle school's 5th, 6th, and 7th grades?
Category 5.2	5.2 The actions (e.g., studying) the students do to achieve the goals	Students' actions include all actions or lack of actions related to learning and achieving the goals.	How does teaching the subject of absolute value using an interactive whiteboard affect students' cognitive learning?
Category 5.3	5.3 The results of the students' actions	The outcome of the study process, e.g., a study that includes a discussion of the learning outcomes after using a new teaching method.	Is there a significant difference in spatial skills between the experimental group that carried out STEM activities with Minecraft and the control group that followed traditional teaching at the 7th-grade level regarding pre-test and post-test scores?
Category 6	6. Relation between teachers and goals/contents	How teachers understand, perceive, or value different aspects of the goals and contents.	What are the teacher evaluations of technology-supported mathematics learning environments designed for deaf students?
Category 7	7. Teachers' didactic actions	The relation of the teacher(s) of student(s) to the goals and content of a	

Category	Name of the Didactic Focus	Definition	
		course.	
Category 7.1	7.1 Teachers' conceptions of students' understanding of/attitude to goals/contents.	What teachers think about how students understand goals and content, as well as what students' attitudes are towards these goals and content.	What are teachers' opinions about student attitudes toward using dynamic mathematics software?
Category 7.2	7.2 Teachers' conceptions of students' actions towards achieving goals	Teachers' perceptions of students' actions (e.g., studying).	What are teachers' views on students using educational technologies while doing homework?
Category 7.3	7.3 Teachers' didactic activities	Teachers' didactic actions (e.g., lecturing, providing a learning environment, and assessment methods).	What do teachers do to ensure classroom management while using EBA?
Category 7.4	7.4 Teachers' reflections on their own didactic actions	To what degree do teachers think the new teaching method was successful.	How do mathematics teachers evaluate their didactic performance in teaching mathematics supported by dynamic geometry software during the pandemic?
Category 8	8. Relation between students and teachers' didactic actions	How the students feel about the teachers' didactic actions (e.g., course feedback)	What are students' opinions about teachers' classroom management in online systems used in distance education?

In literature, Hanifah et al. (2025) examined mathematics education studies using the TPACK framework, focusing on the challenges encountered during the process, the impact of TPACK on teaching processes, and the resulting findings. Hidayat and Firmanti (2024) systematically reviewed the studies conducted in Indonesia focusing on academic achievement, attitude, and engagement in technology integration. They analyzed the studies according to the technologies used, their impact on academic achievement, attitude, and engagement, the problems encountered by educators during the integration process, and the recommendations made. Li et al. (2024) investigated 50 TPACK studies concerning primary mathematics education published between 2005 and 2022. They evaluated the studies based on their year of publication, findings, data collection strategies employed, TPACK instrument characteristics, and aims. They tried to reveal the research trends between these years. Kholid et al. (2023) investigated studies based on the TPACK framework, categorizing them by year, country, subject, technology used, teacher beliefs related to technology integration, and the challenges they faced. Ali et al. (2023) conducted a systematic review focusing on the use of technology in remote and online learning environments. They examined the impact of technology integration on student engagement and academic achievement in mathematics education. Fung and Maat (2021) explored studies focusing on teachers' perceptions of technology integration, examining the country, research methods, sample, year, and research topic of each study. However, a comprehensive SRL needs to include more information on the instructional process actors (students, teachers, content), research methods used, the technology employed, theories underlying the studies, and the interactions between these components in studies based on technology integration in mathematics education. Such an analysis can effectively reveal overlooked components and interactions in the integration of technology.

Rationale and Importance

This study focused on Türkiye, which was chosen not merely because of its status as a developing country but for several reasons. Firstly, Türkiye has undergone numerous curriculum revisions since 2009, demonstrating a dynamic educational evolution that mirrors the shift towards integrating technology in education. Türkiye ranked 32nd in mathematics among OECD countries (Ministry of National Education, 2024a). In PISA applications, the rates of students reaching the minimum and upper-performance levels in mathematics are 61.3 and 5.4. The mathematical process subscales Formulation, Usage, Interpretation, and Reasoning scores are below the OECD average (Ministry of National Education, 2024b). This situation indicates a clear and pressing need to explore innovative solutions to enhance educational practices.

Demb and Funk (1999) observed that postgraduate theses play a central role in evaluating the quality of master's programs. This connection is closely tied to the quality of a nation's education system (Şen, 2013). A Master's degree enables undergraduate students to advance their educational level by developing themselves and gaining experience; a doctoral education comprises more professional and in-depth studies that contribute significantly to the relevant field (Durak et al., 2022). In this context, theses completed at the postgraduate level in the field of mathematics education could be more decisive in evaluating and revealing the understanding of technology integration in the country.

Kinnunen et al. (2016) emphasize the importance of a holistic understanding of the instructional process in achieving quality education. This study aims to examine postgraduate theses focusing on technology integration in the field of mathematics education in Türkiye between 2015 and 2023, taking into account the DFC. This research's contribution extends beyond Turkey's local context, offering insights and implications of global significance. It can guide researchers on which instructional process actors and interactions to focus on during the technology integration process. Additionally, impressive results can be achieved by evaluating technology integration in mathematics education by considering all its components. The results can guide researchers in identifying which learning areas require focus on the interactions between instructional process actors, which theories should be given greater importance, and which research methods should be employed to examine these interactions. The research questions addressed in the study are as follows. In the postgraduate theses conducted in the field of mathematics education between 2015-2023 focusing on technology integration:

1. What is the distribution by year?
2. What is the distribution by DFC categories?
3. What is the distribution of DFC by year?
4. What are the DFC categories considered together?
5. What is the distribution of DFC categories according to research methods?
6. What are the technologies considered?

Method

In this research, SLR was used to address the research questions. SLR is a method for systematically and comprehensively reviewing current literature in an organized manner (Bano et al., 2018; Hidayat & Wardat, 2024). It employs transparent and repeatable techniques at each stage to identify and assess relevant research (Higgins et al., 2011). It is a rigorous and detailed process that involves collecting and synthesizing published empirical studies of acceptable quality using systematic criteria to minimize researcher bias and ensure clarity in the process (Bano et al., 2018; Newman & Gough, 2020). This SLR followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocols (PRISMA-P) guidelines to ensure credibility and reliability (Moher et al., 2015) (see Figure 2). PRISMA-P is used to specify the methods for conducting the review.

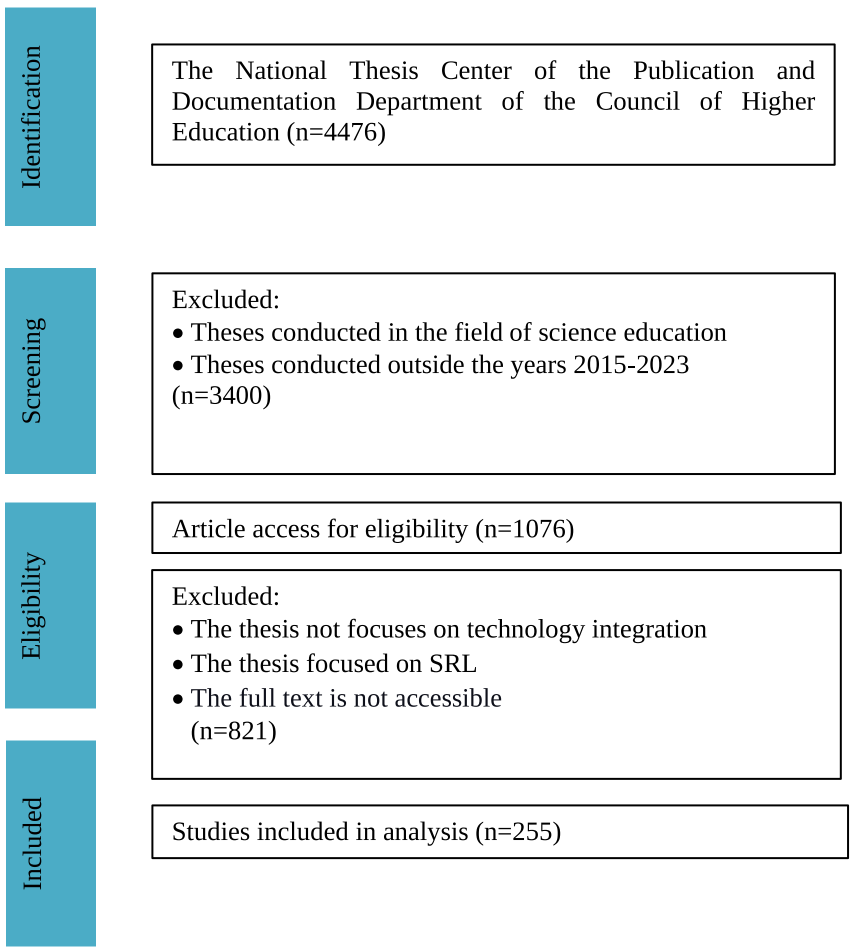

Figure 2. . Flow Diagram of the Proposed Searching Study

Literature Search and Selection Process

This research covered postgraduate theses on technology integration in mathematics education in Turkey between 2015-2023. They were published in the National Thesis Center of the Publication and Documentation Department of the Council of Higher Education. Search terms used when scanning: ("technology integration" OR "technology-enhanced" OR "educational technology" OR "instructional technology" OR TPACK OR TPCK OR

"Technological Pedagogical Content Knowledge" OR “information and communication* technology” OR digital* OR computer * OR electronic*) AND (math*education)). During the scanning process, a total of 4476 theses were initially reached. The criteria taken into consideration when deciding which theses to include in the research are shown in Figure 2. Considering these criteria, it was decided to include 255 postgraduate theses in the study. Of the theses included in the study, 41 were at the doctoral level, and 214 were at the master's level. Theses at the master's level constitutes 83.92% of the theses examined.

Data Collection Tool and Process

The study used the Educational Research Publication Classification Form (EAYSF) to examine theses years, methods, and DFCs (Sözbilir et al., 2012; Oktay et al., 2024). In order to examine the learning areas addressed in the theses, the learning areas included in the primary and secondary education programs of the Ministry of National Education (MoNE) were considered (MoNE, 2018a; MoNE, 2018b). For primary education learning areas, theses were classified according to the learning areas of a) Numbers and Operations, b) Algebra, c) Geometry and Measurement, d) Data Processing, and e) Probability. For secondary education learning areas, theses were examined according to the learning areas of a) Numbers and Algebra, b) Geometry, and c) Data, Counting, and Probability. To classify the technologies addressed in the theses, the technologies mentioned in all theses were first listed, and then common themes were identified by the researchers. Various categorizations were made regarding the technologies used in different studies. However, in this study, the researchers made the classification to provide more specific suggestions regarding the technologies used (see Table 3). Two field experts examined the categories created. The researcher prepared data entries via Google Forms according to EAYSF. The researchers determined the categories, and the data were transferred to an Excel file.

Data Analysis

First, numbers, years, titles, and types of theses were entered into the Google Form created for the research. According to the categorizations in EAYSF, the research methods, instructional actors, and interactions between these were subjected to descriptive analysis. The years of theses and instructional actors addressed in theses, according to DFC, were determined and then presented in graphs. The learning areas addressed in the theses were also subjected to descriptive analysis according to the learning areas specified in the MoNE curriculum. To examine the technologies addressed in the theses, the technologies mentioned in all theses were first analyzed, and common categories were identified using content analysis. The obtained categories were transferred to tables using descriptive statistical techniques. In the research, cross-tables were used to examine the instructional actors, as well as the technologies addressed according to learning areas, and the instructional actors addressed together. However, in many of the theses, more than one teaching actor, technology, and learning area were considered. Therefore, this situation should be taken into account in the overall total in the tables.

Quality Assessment

The included studies were reviewed to confirm that they contained descriptions and details of research objectives, methodology, participants' demographics, intervention, analysis, and results. During the data collection and analysis phase, two expert coders assisted the researchers with reliability checks during data search and coding. The assistance of two experts with doctoral degrees in instructional technology and research, as well as content analysis skills, was sought. A two-stage reliability analysis process was carried out among the experts. In the first phase, an evaluation was made to determine whether these were suitable for the study. Based on the theses determined as a result of the examination, 20 were randomly selected in accordance with the study's criteria. Two experts independently evaluated them. The experts determined that the theses included in the study were entirely consistent. The theses were evaluated in line with the research questions in the second phase. Two experts randomly selected and independently evaluated 10 of the 255 theses included in the study. The degree of reliability between the experts was calculated as Cohen's Kappa (0.84) (McHugh, 2012). Thus, the reliability of the data collection and analysis process was ensured.

Findings

Distribution of Postgraduate Theses by Years

Figure 3 reflects the number of postgraduate theses focused on technology integration in mathematics education between 2015 and 2023.

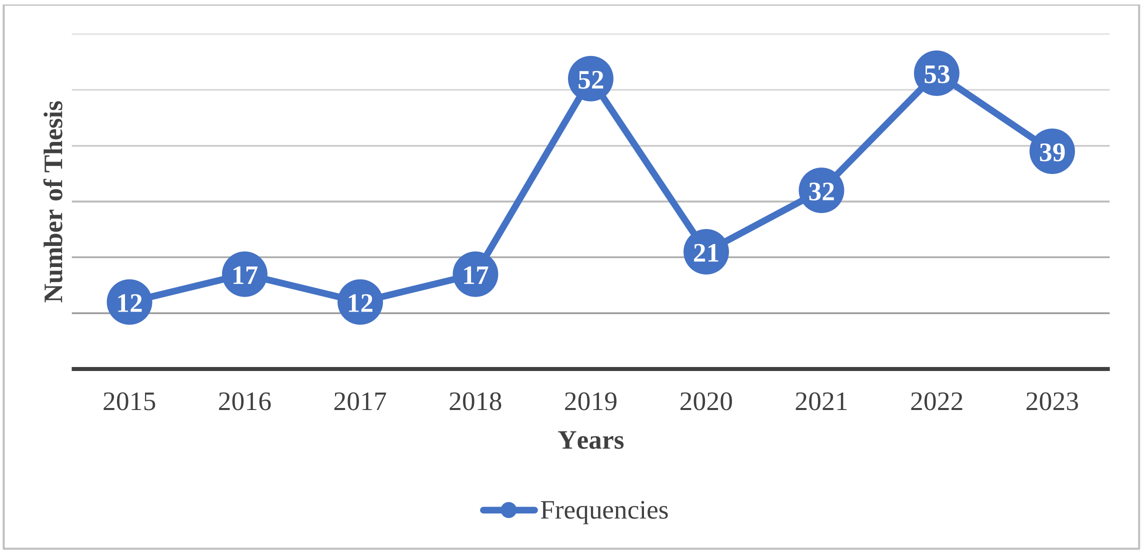

Figure 3. Distribution of Postgraduate Theses by Years

When Figure 3 is examined, only a few studies focused on technology integration were conducted in mathematics education between 2015 and 2018. However, the number of postgraduate theses focusing on technology integration significantly increased in 2019 (f = 52) and 2022 (f = 53). It increased continuously between 2020 (f=21) and 2022 (f=53) and started to decrease again in 2023 (f=39).

Instructional Actors Considered in Postgraduate Theses

Figure 4 presents the instructional actors examined in postgraduate theses.

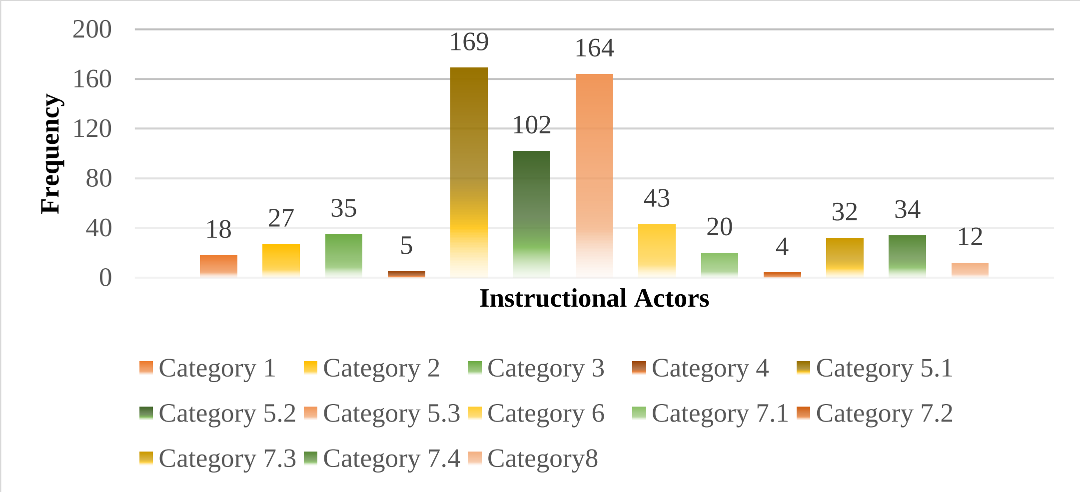

Figure 4. Distribution of Postgraduate Theses by Instructional Actors

When Figure 4 is examined, it is seen that the theses focus primarily on Category 5.1 (f=169), 5.2 (f=102), and 5.3 (f=164), which are the subcategories of Category 5 (f=435). Category 6 (f = 43) and Category 3 (f = 35) were the most frequently examined instructional actors after Category 5. The theses also focused on Category 7 (f = 90), which includes teacher-student-content interaction. In particular, Categories 7.1 (f = 20), 7.3 (f = 32), and 7.4 (f = 34) were further discussed. Category 1 (f = 18) and Category 2 (f = 27) were also among the actors examined. Category 8 (f=12), Category 4 (f=5), and Category 7.2 (f=4) were less examined in the thesis. When evaluated in general, it is understood that Categories 5, 6, and 7, which focus on the interactions between the components of the learning process, are given more priority in postgraduate theses.

Instructional Actors Considered in Postgraduate Theses by Year

Figure 5 presents the instructional actors examined by year in postgraduate theses.

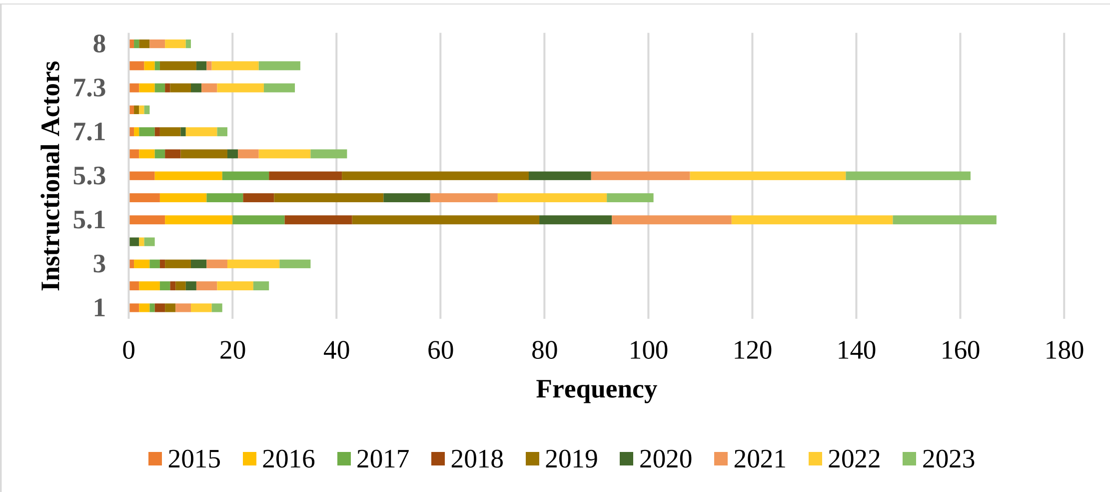

Figure 5. Instructional Actors Considered in Postgraduate Theses by Year

When Figure 5 is examined, Categories 1, 2, and 3 were considered in studies conducted primarily in 2022.

Categories 5.1, 5.2, and 5.3 were mainly addressed in 2019, and although these rates decreased after 2021, they are higher than before 2019. Category 5 has been considered in more studies each year than other categories. Categories 7.1, 7.2, 7.3, 7.4, and 8 were examined in more studies in 2022. When evaluated in general, it is noteworthy that all categories were considered in the studies in 2022-2023. It is understood that after 2019, Category 3, 6, 7.1, 7.2, 7.3, 7.4, and 8 were handled more in theses.

Instructional Actors Considered Together in Postgraduate Theses

Table 2 presents the frequencies of the instructional actors discussed together in postgraduate theses. When Table 2 is examined, it is seen that theses focusing on course content and curriculum are examined in all categories except Category 4. Categories 5.1, 5.2, and 5.3, which focus mainly on student-content interaction, were examined in theses focusing on students. Category 2, which focuses on student characteristics, was also considered along with these categories. Category 3, which focuses on teacher characteristics, was evaluated in conjunction with Category 6, which primarily focuses on teacher-content interaction, and Categories 7.1, 7.3, and 7.4, which focus on student-teacher-content interaction.

Table 2. Frequency Values for Instructional Actors Discussed Together in Postgraduate Theses

Instructional Actors Discussed Together in Postgraduate Theses	Category 1	Category 2	Category 3	Category 4	Category 5.1	Category 5.2	Category 5.3	Category 6	Category 7.1	Category 7.2	Category 7.3	Category 7.4	Category 8
Category 1		2	1		7	6	4	7	1	1	2	3	1
Category 2			3	2	20	7	13	3	3	1	3	1	4
Category 3				2	3	2	5	22	10	1	16	16	4
Category 4					1	1	1						
Category 5.1						76	114	5	3	1	4	5	3
Category 5.2							4				1		
Category 6									1		3	4	
Category 7.1											1	2	
Category 7.2												2	

Instructional Actors Considered in Postgraduate Theses according to Research Methods

Table 3 presents the instructional actors considered in accordance with the research methods employed. When Table 3 is examined, it becomes clear that Category 1 was discussed in both the case study (f = 7) and design-based (f = 6) research methods. Category 2 was primarily addressed through case study (n=8) and survey (n=5) research methods. Category 3 was mainly evaluated using the case study (f=14, f=3) research method. While examining Category 5.1, case study (f = 53), intervention design (f = 52), action research (f = 15), and teaching experiment (f = 14), various research methods were employed. While examining Category 5.2, the most commonly used research methods were case study (f = 54), action research (f = 13), teaching experiment (f = 15), and intervention design (f = 10). Category 5.3 was researched using quasi-experimental (f = 27), intervention design (f = 52), case study (f = 36), action research (f = 12), and teaching experiment (f = 12) designs.) research methods. Category 6 was mainly examined using the case study (f = 21) research method. While Categories 7.1, 7.2, 7.3, 7.4, and 8 related to the interaction of teacher-student-content are discussed, the most frequently used method was the case study (f=11, f=4, f=17, f=19, f=5).

Table 3. Instructional Actors Considered according to the Research Methods

Research Methods	Category 1	Category 2	Category 3	Category 4	Category 5.1	Category 5.2	Category 5.3	Category 6	Category 7.1	Category 7.2	Category 7.3	Category 7.4	Category 8	Total
Experimental	**-**	**1**	**-**	**-**	**8**	**2**	**33**	**-**	**-**	**-**	**-**	**-**	**-**	**44**
Quasi-experimental	-	-	-	-	7	2	27	-	-	-	-	-	-	36
Pre-experimental	-	1	-	-	1	-	6	-	-	-	-	-	-	8
Non-Experimental	**-**	**8**	**7**	**-**	**6**	**1**	**2**	**4**	**-**	**-**	**2**	**3**	**-**	**33**
Correlational	-	3	3	-	2	-	1	2	-	-	-	-	-	11
Survey	-	5	4	-	4	1	1	2	-	-	2	3	-	22
Interactive	**9**	**10**	**19**	**4**	**83**	**83**	**60**	**25**	**14**	**4**	**23**	**24**	**7**	**365**
Phenomenological	-	1	3	1	1	-	-	3	3	-	-	2	-	14
Case study	7	8	14	3	53	54	36	21	11	4	17	19	5	252
Grounded theory	-	-	-	-	-	1	-	-	-	-	-	-	-	1
Narrative research	-	-	1	-	-	-	-	-	-	-	1	1	-	3
Action research	1	1	1	-	15	13	12	1	-	-	4	1	-	49
Teaching Experiment	1	-	-	-	14	15	12	-	-	-	1	1	2	46
Analytical	**3**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**3**
Document analysis	3	-	-	-	-	-	-	-	-	-	-	-	-	3
Mixed	**6**	**8**	**9**	**1**	**72**	**16**	**69**	**14**	**6**	**-**	**7**	**7**	**5**	**220**
Explanatory sequential	-	1	1	-	8	-	7	2	-	-	-	1	-	20
Exploratory sequential	-	-	1	-	1	-	1	2	1	-	-	-	-	6
Convergent	-	2	3	-	4	2	3	2	1	-	1	1	1	20
Intervention design	-	3	1	-	52	10	52	2	2	-	1	2	-	125
Design-based research	6	1	1	-	4	3	4	3	1	-	2	1	2	28
Mixed-Others	-	1	2	1	3	1	2	3	1	-	3	2	2	21
Total	**18**	**27**	**35**	**5**	**169**	**102**	**164**	**43**	**20**	**4**	**32**	**34**	**12**	**665**

Technologies Covered in Postgraduate Theses

Table 4 presents the technologies discussed in postgraduate theses. When Table 4 is examined, it is seen that dynamic geometry software (Geocebra, Cabri, Desmos) (f = 92), EBA (f = 38), educational video and video development tools (f = 25), game and gamification tools (Kahoot, Minecraft, Socrative, Quizziz, Wordwall) (F = 21), design-drawing tools and technologies (Tinkercard, ThinkerPlots, Isometric Drawing Tool) (F = 13), robotic-coding tools and technologies (Scratch) (F = 14) was used mainly in postgraduate theses. These technologies were primarily used in the learning areas of Numbers and Operations Geometry and Measurement, Numbers and Algebra. When Table 4 is examined, it is noteworthy that dynamic geometry software is predominantly used in postgraduate theses in mathematics education. Different technologies are included in various theses, but generally, ready-made applications and software are used.

Table 4. Technology Used and Learning Areas Considered in Postgraduate Theses

Technology	Primary Education Learning Areas					Secondary Education Learning Areas			Unspecified	Other	Total	Percentage
	Numbers and Operations	Geometry and Measurement	Algebra	Data Processing	Probability	Numbers and Algebra	Geometry	Data, Counting and Probability				
Dynamic Geometry Software	3	38	2	-	-	17	28	2	10	2	92	25.91
Education Information Network (EBA)	7	9	4	-	-	4	2	1	11	-	38	10.70
Educational Videos, Video Development Tools	7	4	1	-	-	3	3	-	5	2	25	7.04
Games and Gamification Tools	3	5	1	-	-	4	1	-	7	-	21	5.91
Robotics-Coding Tools and Technologies	6	1	3	-	-	-	-	1	2	1	14	3.94
Design-Drawing Tools and Technologies	-	3	1	3	-	-	2	-	4	-	13	3.66
Interactive Whiteboards	1	3	-	-	-	3	1	1	3	-	12	3.38
Data Analysis and Calculation Programs	1	-	-	2	-	2	1	2	4	-	12	3.38
Presentation and Presentation Development Tools	2	-	1	-	-	2	1	-	3	-	9	2.53
Software developed by the	2	1	2	-	-	-	1	-	3	-	9	2.53

Technology	Primary Education Learning Areas					Secondary Education Learning Areas			Unspecified	Other	Total	Percentage
	Numbers and Operations	Geometry and Measurement	Algebra	Data Processing	Probability	Numbers and Algebra	Geometry	Data, Counting and Probability				
researcher												
Simulations, Virtual Manipulatives	2	1	2	-	-	-	-	1	3	-	9	2.53
Learning Management Systems	1	1	-	-	-	1	-	1	3	1	8	2.25
Education Platforms	1	3	2	-	-	1	-	-	-	-	7	1.97
Web Sites	1	1	1	-	-	-	2	-	2	-	7	1.97
Animations and Animation Development Tools	1	1	1	-	-	1	-	-	1	-	5	1.40
Augmented Reality	1	1	1	-	-	-	-	-	2	-	5	1.40
Video-conferencing Technologies	-	1	-	-	-	2	-	-	1	-	4	1.12
Mobile Applications	-	1	1	-	-	-	-	1	1	-	4	1.12
Social Media	-	1	1	-	-	1	-	-	-	-	3	0.84
Digital Story Development Tools	2	-	-	-	-	1	-	-	-	-	3	0.84
Enriched e-book	-	1	-	-	-	1	-	-	1	-	3	0.84
Other	2	5	1	-	-	4	1	2	6	-	21	5.91
Not Used	3	1	-	-	-	-	-	1	20	6	31	8.73
Total	**46**	**82**	**25**	**5**	**-**	**46**	**43**	**13**	**92**	**12**	355	100.00

Discussion

Distribution of Postgraduate Theses by Years

As a result of the study, the number of postgraduate theses focusing on technology integration significantly increased in 2019 and 2022. The decrease resumed in 2023. The increase in postgraduate theses, especially between 2019 and 2022, may be attributed to the growing prominence of technology and distance education during the Covid-19 pandemic. Following 2022, the decrease in the pandemic's impact may have reduced the effect of technology on mathematics education. In addition, the fact that technology use was prioritized in the MoNE curriculum published in 2018 led to a shift in the focus of postgraduate theses to technology integration after 2018.

In literature, Hanifah et al. (2024) found that the number of studies focusing on media use in mathematics education increased between 2019 and 2021, decreased in 2022, and increased again in 2023. Li et al. (2024) reviewed TPACK studies concerning primary mathematics education published between 2005 and 2022. They determined that articles focused on technology integration in mathematics education increased after 2014, and most studies were conducted in 2019. Kholid et al. (2023) revealed that 18 of the 25 studies published between 2018 and 2022, focusing on the TPACK framework, were conducted in 2018, 2019, and 2020, while the number of studies decreased to two in 2022. Although this study focused on postgraduate theses, it points to conclusions similar to those of SRL studies that examine research articles. When evaluated in general, technology integration has gained importance with the pandemic (Fung & Maat, 2021). The number of studies decreased after 2022. However, it will not be lower than before 2019. In other words, technology integration will continue to maintain its importance (Hanifah et al., 2024; Jabar et al., 2022) globally and in Türkiye.

Instructional Actors Considered in Postgraduate Theses

As a result of the study, it was determined that the theses focused more on Categories 5.1, 5.3, and 5.2. This situation highlights the importance of students' interaction with content in technology integration within mathematics education. In the study, the other most used instructional actors in the theses, although less than Category 5, were Category 6, 3, 7.4, and 7.3. This situation highlights the importance of focusing on teachers, who are another critical component of the teaching process, as well as their interaction with the content and technology-focused practices.

Since students' perceptions of technology integration impact their academic performance (Nair, 2021), Category 5.1 may have been studied intensively in theses. Davies and West (2014) defined technology integration as the pedagogically sound use of technology to enhance teaching and learning practices, emphasizing effectiveness. Therefore, Category 5.3 may have been used more intensively in theses to evaluate the effectiveness of the technology compared to traditional methods. Mishra and Koehler (2006) emphasized that teachers must acquire sophisticated knowledge to use technology by assessing the features of the teaching content, teaching methods, and the educational context. Therefore, theses that want to evaluate technology integration in this context may have focused more on Category 6, 7.3, and 7.4.

Research has shown that using technology to promote meaningful learning goals has a positive impact on learning (Chien et al., 2016; Stegmann, 2020). According to Ertmer (2005, 1999), technology adds value to the curriculum not by its "quantitative changes," such as "doing more of the same in less time," but by its "qualitative changes," such as "accomplishing more authentic and complex goals." Therefore, categories 5.1, 5.2, 7.3, and 7.4, which focus on students' opinions, actions, or teachers' instructional practices and teachers' reflections on their practices, may also be the focus of theses. When evaluated in general, it can be stated that saturation has been reached in theses focusing on students and learning outcomes. However, there is a need for these studies on teachers, their instructional practices, and the reflections of both teachers and students on the process, as well as content development. This may be due to the need for more emphasis on such interactions in technology integration definitions and the difficulty of the data collection process.

Instructional Actors Considered in Postgraduate Theses by Year

As a result of the study, it is seen that Category 5 was handled every year between 2015 and 2023. After 2019, Category 3, 6, 7.1, 7.2, 7.3, 7.4, and 8 were handled more in theses. Especially today, technology integration prepares students for the demands of the modern workforce by equipping them with basic digital literacy skills and exposing them to current technologies (Eden et al., 2024). In addition, the essence of education is to improve learning outcomes and ensure equal opportunities (Eden et al., 2024; Masnawati & Kurniawan, 2023). Therefore, technology integration efforts prioritize students and meet their needs. In literature, Akram et al. (2022) stated that technology-integrated teaching and learning satisfy students' learning needs and help teachers align their teaching approaches with global standards. Teachers' teaching practices are greatly influenced by their pedagogical beliefs. Therefore, the technology integration process is also significantly related to teachers' perspectives on the nature of teaching and learning in a classroom (Akram et al., 2022; Hardman, 2019).

Mailizar and Fan (2020) state that the effectiveness of technology integration in the teaching and learning process depends on how teachers select and manage technology resources in classroom activities, as well as the teaching strategies they integrate into the classroom. For this reason, studies that include teacher-content-student interaction (Category 7) in technology integration may have increased, especially after the pandemic. However, the number of studies that include students' opinions, feelings, and thoughts about teachers' instructional activities and the development of learning environments for mathematics education is limited. This may be due to the difficulty of the data collection process, as student feedback on technology integration is not currently at the forefront of research, and its importance needs to be better understood. The fact that the development process of digital learning environments requires interdisciplinary work may have led to Category 1 being emphasized less.

Instructional Actors Considered Together in Postgraduate Theses

As a result of the study, it was determined that Categories 5.1, 5.2, and 5.3 were generally considered together, and Category 2 was also considered, although in small numbers. In theses where Category 3 was considered, Categories 6, 7.1, 7.2, 7.3, 7.4, and 8 were generally evaluated together. However, Category 4 is associated with very few categories. According to Eden et al. (2024), technology should be viewed as a means to enhance teaching and learning rather than an end in itself. Davies and West (2014) stated that the adequate and appropriate use of technology only occurs when students utilize it for educational purposes. Thus, technology integration in theses may have been addressed intensively from the perspective of students and teachers. In educational research, it is natural and essential to obtain teachers' views on students' learning outcomes and actions, as well as students' views on teachers' teaching activities. However, Category 4 examines the views of teachers and students on their characteristics. For this reason, it may not have been considered much in theses. Shulman (1986) defined pedagogical content knowledge (PCK) as knowledge related to "the way of representing and formulating the subject that makes it comprehensible to others… an understanding of what makes the learning of specific topics easy or difficult" (p. 9). Therefore, while examining Category 7, which focuses on the teacher's instructional activities, Category 6, which includes the teacher's views on content, may have also been considered.

Instructional Actors Considered in Postgraduate Theses according to Research Methods

Category 5, the most discussed instructional actor in theses, has generally been addressed with case studies, action research, teaching experiments, and intervention design methods. When examining Category 5.3, quasi-experimental, case study, and intervention design methods have been preferred more. Categories 3, 6, 7, and 8 have generally been evaluated using the case study method. When considering Category 1, the design-based research (DBR) method has been the preferred approach. When evaluated in general, qualitative and mixed research methods have been used intensively in theses.

A qualitative approach is primarily concerned with enhancing understanding and explaining statements and events (Chua, 2014). Qualitative research offers a flexible approach that is well-suited for the data collected in the study, particularly regarding observations and behaviors (Mohamed et al., 2022). Since the studies conducted in Türkiye mostly involved the application of technology in instructional processes and the examination of its results, qualitative determination of the situation based on students' opinions was common (Gul & Sözbilir, 2015). As discussed in the theses, Categories 5 and 7 focus on students' and teachers' opinions, perceptions, reflections, and actions; naturally, qualitative research methods are predominantly used in these categories. Case studies are vital in reality and essential for understanding specific situations and providing in-depth analysis and portrayal (Olsson, 2018). These studies may have focused on case studies in education settings because they can be used to gain a holistic perspective (Krusenvik, 2016). In addition, unlike experimental designs, case studies can also simplify the process of answering related "what, why, and how" questions, including why an intervention should be preferred and what its limitations are, without compromising the generalizability of results (Crowe et al., 2011). Since Categories 5, 6, 7, and 8 examine teachers' and students' experiences, perceptions, and learning outcomes regarding the use of specific technologies in teaching mathematics subjects, it is natural to use the case study method (Övez et al., 2022), In Category 5.3, the quasi-experimental method may have been preferred because this method focuses on the cause-effect relationship between dependent and independent variables under appropriate control conditions to determine the technology's effect on learning outcomes (Siedlecki, 2020). Yohannes and Chen (2023) claimed that the mixed-methods approach is essential for understanding students' learning situations directly from the data and their perspectives through post-class interviews. Therefore, mixed-method approaches may be preferred, especially when considering Categories 5.1, 5.2, and 5.3. According to Lv et al. (2023), mixed research methods are recommended for future research to comprehensively evaluate the impact of integrating mathematics and technology on students' learning achievements.

Category 1 primarily focuses on creating a digital learning environment in these studies, with a particular emphasis on technology integration. However, the number of theses completed under Category 1 is limited. Therefore, DBR may have been used more when examining this category. However, Amiel and Reeves (2008) suggested that DBR will help educators understand the full potential of learning technologies. Yohannes and Chen (2023) noted that this design could be a more effective approach for technology-enhanced learning environments to identify the successes and challenges of innovative approaches in real-world settings. This situation shows a need for studies focusing on Category 1 and the DBR method.

Technologies Covered in Postgraduate Theses

As a result of the study, it was determined that Dynamic Geometry Software (DGS), especially GeoCebra, was used more in postgraduate theses. DGSs are followed by education information networks (EINs), educational videos, video development tools, games, gamification tools, design and drawing tools, and robotics and coding tools and technologies with regard to usage intensity. As a result of the study, it was determined that mathematics education researchers generally prefer ready-made content or platforms that are easy to develop content. Postgraduate theses were mostly considered in the areas of Geometry, Numbers and Operations, and Numbers and Algebra. The fact that the researchers could not develop a learning environment on their own caused them to determine the learning areas in line with the scope of ready-made content or content development tools. Drijvers (2020) emphasized the importance of collaborative software development for math environments. Ali et al. (2023) found that digital storytelling, video lectures, mobile learning environments, and augmented reality improve student engagement and achievement in math, recommending their integration into teaching.

One particularly popular DGS, GeoGebra, integrates geometry, algebra, arithmetic, calculus, statistics, and spreadsheet features into a user-friendly platform, making it suitable for mathematics education at all levels, from elementary school to university (Belgheis & Kamalludeen, 2018; Hohenwarter et al., 2009). Furthermore, GeoGebra finds applications in various mathematical fields, enabling students to articulate and substantiate their thoughts and reasoning while connecting mathematical concepts to real-world situations through modeling (Muslim et al., 2023; Yohannes & Chen, 2023). Moreover, teachers and students have efficiently used GeoGebra due to its tutorial support, which facilitates user understanding (Za'ba et al., 2020). Notably, the Ministry of National Education in Turkey has recommended incorporating DGSs and information and communication technologies into the secondary school mathematics curriculum, which may explain the prevalent use of DGS, particularly in theses (Ince-Muslu & Erduran, 2021).

Education Information Network (EIN) is a national educational social education platform providing educational content (e-content, e-book, audio, video, visual elements, animations, interactive activities, e-tests, e-exams, e-trials) to teachers and students by taking into account more than one learning style in the education (Ertem-Akbaş, 2019). Since EIN is a national platform that was frequently used during the pandemic, the effectiveness, deficiencies, and advantages of the platform in mathematics education may have been evaluated in theses, and suggestions for necessary improvement studies may have been presented.

Educational videos allow teachers to slow instructional interactions and closely examine what occurred (Sherin & Han, 2004). Educational videos offer various benefits, including preparing students for lessons, capturing their attention, providing motivation, and facilitating the comprehension of new and complex concepts (Sen, 2022). These advantages led to increased use of educational videos and video development tools in mathematics education research.

Well-designed math games that offer various levels of engagement can increase students' interest by involving behavioral, cognitive, and emotional interactions (McEwen & Dub'e, 2016; Tsai et al., 2012). Creating and designing a game in class can also enhance programming and creativity skills, while playing existing games can help teach and develop artistic creativity (Martinez et al., 2022). Apart from these benefits, incorporating games into mathematics education helps motivate students, develop higher-order thinking skills, and reduce cognitive load (Chen et al., 2021). As a result, games have been extensively studied as a technology in various theses.

Recommendations

This study was conducted with 255 postgraduate theses based on SLR. The study covers postgraduate theses conducted between 2015-2023 in mathematics education. In line with the results obtained from the study, the following suggestions were made;

- Categories 6 and 7, which focus on the roles of teachers in the integration process, can be included.
- Priority can be given to Category 1, which focuses on developing interdisciplinary content in mathematics education.
- Including research questions related to all sub-dimensions of Category 7 while working with teachers can provide a more detailed examination of the integration process.
- Especially when examining Categories 5,7, 8, mixed and qualitative research methods can provide an in-depth examination of the integration process.
- In studies addressing Category 1, using DBR as a basis can provide the development of qualified learning environments.
- Technology integration studies can be included, especially for Algebra, Data Processing, and Probability learning areas.
- In order to increase the practical contribution of technology, emphasis can be given to STEM studies.
- Increasing interdisciplinary research to use the most appropriate technology for the determined content in mathematics education can facilitate the management and execution of the research process.

Note

Theses examined within the scope of the study are available at the following link:
https://docs.google.com/document/d/1jtKwy0Wq_4-jJv5Y3IyzA0zodDENuIM_r3OQrtGQfbg/edit?usp=sharing

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