INSTRUCTIONAL TECHNOLOGIES RESEARCH TRENDS IN SCIENCE EDUCATION DISSERTATIONS: A CONTENT ANALYSIS

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This paper aimed to reveal trends in doctoral dissertations produced in Türkiye in science education using instructional technologies. Ninety-five doctoral dissertations were included in the study, carried out in a document review design between 2010-2022. As a result, the most used educational technologies was STEM. The most studied science topics were socio-scientific issues. Dissertations mainly focused on academic achievement, attitude, and perception variables. The most used method was the mixed research methods. As a result of the analysis, it was determined that content analysis and t-tests were used most frequently, secondary school students were often studied in dissertations, and purposive sampling was preferred.

Keywords: Content analysis, Instructional technology, Research trends, Science teaching.

INTRODUCTION

Science Teaching and Technology

It is necessary to consider some aspects of the philosophy of science to teach science. Values and assumptions about the nature of science include the idea of conceptualizing a subject, independence of thoughts, creativity, experimentation, an empirical basis, subjectivity, testability, and cultural and social embeddedness (Akerson et al., 2018). Accordingly, science education aims to teach science concepts meaningfully and teach students how to use them daily (Cepni et al., 2006). Besides learning science concepts, science education was enriched in the 21st century (Chowdhury, 2016) regarding the sustainability of science teaching (Murphy, 2022). Recent efforts to reform science education emphasized that students must develop their knowledge and skills for success in the twenty-first century (Guzey et al., 2016). Therefore, it is necessary to provide students with opportunities to use and apply 21st-century skills in science teaching.

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On the other hand, science teachers need to understand how their knowledge about the nature and applications of science (Miller et al., 2018) affects students' lives and shapes their learning (Larkin, 2022). Teaching science concepts correctly to students directly affects the world in which they perceive it. For example, taking science courses in secondary school is valuable for students' goals, such as science, technology, and engineering, which they will tend to study in higher education (McGee, 2021). Accordingly, it can be said that STEM applications can affect students' career choices (Kier et al., 2014). Therefore, while providing students access to science subjects (Meyer et al., 2016), their affective and behavioral aspects should be considered, as well as their cognitive aspects, since each student's motivation and way of learning science is different. To access these science subjects, students use technology besides teaching methods. In addition, science literacy (Oreskes, 2021) also includes understanding technology (Cajas, 2001). Appropriate use of technology enables teachers to create a flexible learning environment to meet students' diverse needs in science learning. Therefore, teachers should be aware of the opportunities provided by technology using appropriate learning activities for students to achieve their learning goals (Kerawalla et al., 2009).

In recent years, using digital technology easily allows students to have an exciting and realistic experience by providing rich, interactive, engaging context and visualizing concepts with 3D display aid views (Alfalah, 2018). In addition, since science subjects are microscopic and macroscopic, it is helpful to use technology to visualize, scale, and downgrade the topics to the student level. Over the past 25 years, information and communication technologies have successfully impacted science teaching and learning (Linn, 2003). In other words, it is a known fact that the effect of technology use in teaching and learning has a variety ranging impact in the field of education. Technology contributes to students further improving their cognitive skills and building knowledge in curriculum settings. It can be said that using information technology as an essential active learning method in the curriculum (Algoblan & Alkhayal, 2010) is effective in science teaching. For example, studies focusing on the effectiveness of computer-based learning found that it helps students conceptually understand science (Cirkony et al., 2022; Rutten et al., 2012). Instructional technologies such as multimedia-based learning support students' and teachers' understanding of complex abstract phenomena (Mintz et al., 2001). In addition, instructional technologies contribute significantly to science teaching in primary and secondary schools (Kulik, 2002).

According to the literature, the effects of technology-supported learning on some variables like academic achievement (AlAmmary, 2012; Banda & Nzabahimana, 2023; Carle et al., 2009), attitude (Göktepe Körpeoğlu & Göktepe Yıldız, 2022) and motivation (Laurens-Arredondo, 2022; Lin & Wu, 2021; Van Vo & Csapó, 2023; Ziden et al., 2022) were investigated. And the result of the studies found that technology-supported learning has positive effects on these variables. In other words, combining technology and a constructivist approach can positively affect students' understanding of science and their attitudes toward learning science (Su, 2008). It was determined that students have a generally positive but limited attitude toward the concept of technology (Ankiewicz, 2019a).

Based on these advantages of technology, tech designers in science education adapted instructional materials according to developments of student understanding. For example, designers offer the users task-specific technology features by adapting technology to disciplines such as physics, chemistry, and biology. Namely, developers can integrate visualization tools into molecules, crystals, soil structures, or chemical reactions (Linn, 2003). In other words, with the help of 3D graphics software, educators can build a new visual language that bridges the concrete world of nature with the abstract world of concepts and models, as in this example (Mintz et al., 2001). Therefore,

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technology can be expected to be integrated into the science curriculum. In another example, computer simulations offered opportunities to science students, like modifying the properties of the models so that students could observe the results by presenting theoretically simplified models of real-world phenomena, such as a frictionless world where the laws of Newtonian physics were more pronounced (Kulik, 2002).

Similarly, some experiments are dangerous and harmful to teach students in the laboratory. Instead of a real lab, these dangerous experiments can be comfortably done in the virtual laboratory, and students can see the details of the experiments without danger. For example, a teacher can use a simulated frog dissection instead of a fact dissection (Kulik, 2002). Another example (2022) developed a material with augmented reality about weak interactions between particles that is microscopic and difficult to see with the naked eye, making the subject three-dimensional and enabling students to visualize the subject in their minds. In addition, magnetic resonance imaging can display a three-dimensional image of the human body on the computer in medicine. Moreover, physicists have created three-dimensional computer models to describe the atom's internal structure (Mintz et al., 2001). Astronomers often create video animations to model theories about the creation of the universe (Mintz et al., 2001).

Through animations, another type of instructional technology, students can perform learning effectively by animating models to express the details of a chemical or physical process after creating molecular models (Chang et al., 2010). Moreover, the life cycle of an insect can be taught to students through animation (Hoban & Nielsen, 2013). Using animations, which represent concepts related to the states of matter that are difficult to see with the naked eye, can be effective in the dynamic elements of their conceptualization (Yaseen, 2018). Journeys through virtual simulations of the macroscopic solar system and the Milky Way through virtual reality can help students bridge the gap between the concrete world of nature and the abstract world of concepts and models (Mintz et al., 2001). Virtual reality can be used to simplify the complexities of the ecosystem topic (Dickes et al., 2019). Virtual reality (VR) can also provide travel within the cell at the microscopic level and even examine organelles that would be only a micron or less in eukaryotic cells (Bennett & Saunders, 2019). In brief, digital environments are modern learning environments that enable students to develop their technological literacy and critical thinking skills throughout their daily learning activities (Kong, 2014).

Knowing what and how science educators, classroom teachers, and students use technology is essential (Wang et al., 2012). They stated that technology is attractive, intriguing, and high-level thinking, and because of these properties, teachers use technology in science teaching (Sunal et al., 2008). Individual interest in technology education is related to both the cognitive component and behavioral dimension (Svenningsson et al., 2021). In other words, the cognitive aspect affects the emotional aspect and positively affects the behavioral (Ankiewicz, 2019b). Science educators play a significant role in creating computer-mediated curriculum models that educate a community of students inside and outside the classroom (Gabric et al., 2005). Because of the importance of instructional technologies in science education, they have been used to teach science subjects in dissertations in recent years.

LITERATURE REVIEW

Van Schoors et al. (2021) conducted an analysis study on the effect of digital learning used in primary and secondary education between 1995 and 2020. As a result of the study, they revealed that this type of learning has a positive trend in learning outcomes. Di Natale et al. (2020) examined eighteen experimental studies to investigate the effect of the immersive virtual reality-based intervention on achievement

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and learning motivation between 2010-2019. The results show that VR can support different activities and experiences that enhance learning and motivate students to achieve their educational goals by eliciting their interest and commitment to learning materials. Altinpulluk (2019) investigated fifty-eight articles using augmented reality, one of the educational technology types, in education between 2006-2016. As a result of the study, there has been an increase in the number of publications since 2013, revealing that it reached the highest level in 2016. Also, it determined that AR can be used with all disciplines and positively affects education in terms of academic success and learning motivation. Orhan and Men (2018) examined thirty-two studies on academic achievement and twenty-five studies that met the criteria between 2007 and 2017 on the effect of web-based teaching on science course success and attitude towards science courses. The study revealed that using the Web-Based Teaching method in science education positively affected students' academic achievement and attitudes toward the course. Bayraktar (2001) investigated how computer-assisted instruction (CAI) influenced student success in secondary and university science education compared to traditional teaching in the USA between 1970-1999. As a result of the study, it was stated that computer-assisted instruction was significantly effective in student success. Dubé and Wen (2022) analyzed the effectiveness and trends of educational technology in education between 2011-2021 using bibliometric analysis. The results suggest that mobile and analytics technologies trended consistently across the period. There was a trend towards maker technologies and games in the early part of the decade, and emerging technologies (e.g., VR) are predicted to trend in the future.

Each country toward technology is positive and different Autio et al. (2019) just as Türkiye (Pamuk & Peker, 2009). Accordingly, in recent years, several types of educational technology have been used in dissertations in science education. Especially understanding trends in dissertation research can show young researchers and their faculty advisors which science topics, technological varieties, and variables interest them. This research aims to contribute to other scientific studies conducted using instructional technologies by examining the studies done in the last twelve years. In addition, it effectively presents the potential changes in the methodological trends of studies conducted in a field over time. Given recent developments in instructional technologies, this paper attempts to provide an overview of new national innovation systems research trends. It helps to identify the main study themes and research lines that provide scientific information about the present and future of educational technology. Moreover, this paper will become a source of inspiration for new research using technology in science education by examining dissertations comprehensively and in a detailed way (Gündüz et al., 2022). In addition, it is significant that advances in science and the results of studies communicate to large audiences (Bush et al., 2019). This study focuses on using technological material types in science education doctoral dissertations completed between 2010-2022. These dissertations investigated variables studied, science topics, method trends, technological material types, sample populations, and data analysis methods, data collection tools.

The following research questions were determined to examine the trends of educational technology in the doctoral dissertations produced in science education in Türkiye between the years 2010-2022:

1. What are the used material types of instructional technology in dissertations?
2. What are the *science topics* in dissertations on using specialized materials in science education?
3. What kind of variables are *investigated* in dissertations?
4. What are *the methodological trends* in dissertations?
5. What is the most used *data collection tool in dissertations on* technological materials in science education?

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6. What are the most chosen *sample sizes, sample populations, and sampling methods* in dissertations?
7. What are the most preferred *data analysis methods* in dissertations?

METHOD

Content analysis, one of the qualitative study methods, was used in this study. Content analysis is a research technique coding Stemler (2015) from data based on their context by examining articles in published reports, newspapers, advertisements, books, web pages, magazines, and other forms of documentation (Krippendorff, 1980; Prior, 2014). This paper examines the science subjects, research method, types of instructional technology materials, types of samples, data collection tools, data analysis types, and variables.

Scope of the Study

Doctoral theses are significant studies contributing to the development of a scientific field; they are also based on original research and are more comprehensive and longer-term than other studies (Yildirim, 2020). Therefore, doctoral theses are expected to contribute something new to the field. Dissertations are a rich and unique source of information and research work (Bhat et al., 2014). One of the reasons for choosing the field of instructional technology in science education as the scope of the study is that this field is interdisciplinary. In addition, produced doctoral theses can also give information about current research topics in that country. In other words, it can also give ideas about the contents of the articles made in the country where the doctoral theses were made.

The sample of this research consists of 95 doctoral theses completed between 2010-2022. The National Thesis Center in Türkiye was used for thesis selection. The sample was determined by criterion sampling. Before 2010, very few dissertations used technology in science education, and it was decided to examine after 2010 for data richness. Data criteria include using instructional technology, production in the last 12 years, and science education. The keywords used were "science department," "science education," "education," and "technology."

Data Coding and Analysis

In this study, the Publication Classification Form by Göktaş et al. (2012) was used for selecting doctoral theses. Five sections of this form were used. In addition to this form, science subjects and the type of technology were added to this form by the author. The form consists of seven parts: (1) methodologies, (2) samples, (3) technological material type, (4) science subject, (5) variable type, (6) data collection tool, and (7) data analysis type.

Content analysis was used to examine the method, sample type, data collection tool, data analysis method, science subject, technological material type, and distribution of variables in doctoral theses. Two specialists in science education conducted the data analysis. Also, descriptive statistics were used in this study.

Each doctoral thesis reached was read several times by the researcher. In different time, researcher read doctoral thesis again to ensure the data's consistency. After reading the data, they were entered into the previously determined form by researcher different time. The researcher compared the data they entered. It was reviewed the differences that emerged because of the comparison. After this process, the analysis of the data was reported. Findings were demonstrated using descriptive statistical techniques such as frequency, percentage, and graph.

FINDINGS

Used Material Types of Instructional Technology in Science Education

The used material types for instructional technology in science education were ex-

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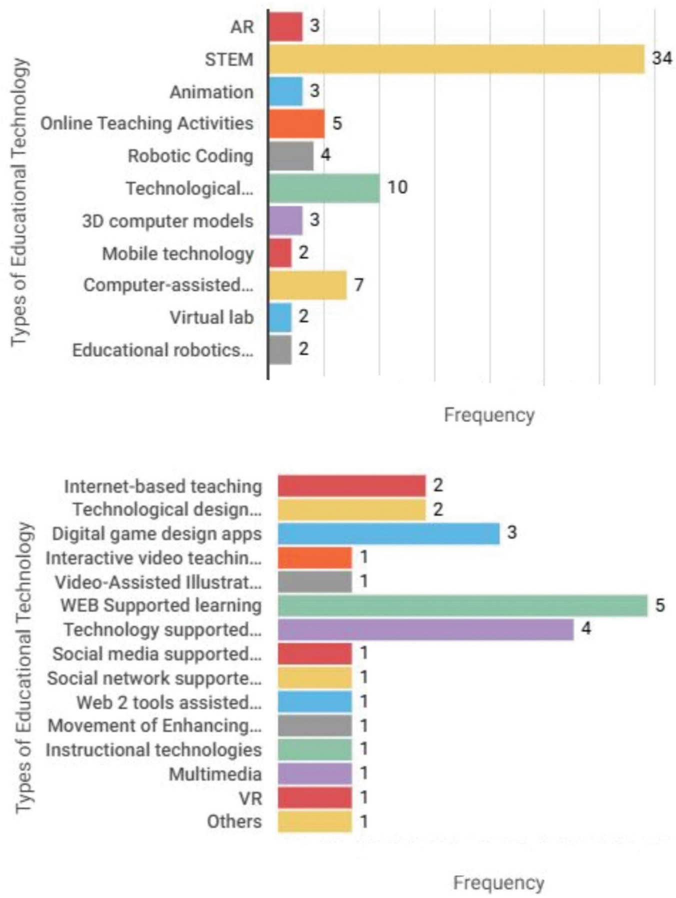

FIGURE 1

Frequency of Used Material Types of Educational Technology

amined in the reviewed dissertations. STEM (Science, Technology, Engineering and Mathematics) (f = 34), TPACK (Technological Pedagogical Content Knowledge) (f = 10) and computer-assisted materials (f=7) were the most-preferred options. In addition, some dissertations were used "Online Teaching Activities" (f=5), "WEB supported learning" (f=5), AR (Augmented Reality) (f=3), digital game design apps (f=3), 3D computer models (f=3), Technology supported learning (f=4), animation (f=3). The less used technological materials in dissertations were VR (Virtual Reality), multimedia, instructional technologies, social network supported learning, social media supported learning, video assisted illustrated learning, digital story, interactive video teaching method, and Web-2 tools (see Figure 1).

As shown in Table 1, the most common educational technology used in dissertations was STEM in 2020, and it has increased from 2016 to 2020. Using educational technology materials in dissertations began to increase since 2014. Over the years, the variety of educational technologies used in dissertations has been increasing. Moreover, TPACK in 2012 and computer-assisted materials in 2014 began to use in dissertations. Online teaching activities in 2014, Web supported learning in 2010 and digital game in 2014 were started to prefer in

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TABLE 1

Frequency of Used Material Types of Educational Technology from 2010 to 2022 s

Kinds of Technological Tool	*Year*												
	2010	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*
AR									1	1		1	2
STEM							2	2	6	7	9	7	1
Animation			1	1		1							
Online Teaching Activities					1					1	1	1	1
Robotic Coding											3	1	
Technological Pedagogical Content Knowledge		1			2	2	1	1		2		1	
3D Computer Models											1	1	1
Mobile technology				1	1								
Computer-assisted materials					2		1	2		2			
Virtual lab						1						1	
Educational Robotics activities											1	1	1
Internet-based teaching				1								1	
Digital story									1				
Technological design activities										1			1
Use of tablets											1		
Digital game design apps					1			1	1			1	
Video-Assisted Illustrated Activities							1		1				
Web Supported Scıence Materıal	1	1			1	1			1				
Technology Supported Learning									1			1	
Socıal Network Supported Learning									1				
Socıal Medıa Supported Learnıng				1									
Interactive video teaching method							1						
Web 2 tools assisted teaching						1							
Movement of Enhancing Opportunities and Improving Technology Project							1						
Instructional technologies						1							
Multimedia									1				
VR													1

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TABLE 2

Frequency of Use of Material Types of Educational Technology From 2010 to 2022

2010	WEB Supported learning (n=1)
2011	WEB Supported learning (n=1)
2012	Animasyon (n=1), TPACK (n=!)
2013	Animation(n=1), Mobile technology(n=1), Internet-based teaching(n=1), Social media supported learning(n=1), Mobile technology(n=1)
2014	Online Teaching Activities(n=1), TPACK(n=2), Computer-assisted materials (n=2), Digital game design apps(n=1), Web Supported Scıence Materıal(n=1), Mobile technology(n=1)
2015	Animation(n=1) TPACK(n=2) Virtual lab(n=1) Web Supported Scıence Materıal(n=1) Web 2 tools(n=1) Instructional Technologies(n=1)
2016	STEM(n=2) TPACK(n=1) Computer-assisted materials(n=1) Video-Assisted Illustrated Activities(n=1) Interactive video teaching method(n=1) MEOITP(n=1) Digital game design apps(n=1) Video-Assisted Illustrated Activities(n=1)
2017	STEM(n=2) TPACK(n=1) Computer-assisted materials(n=2) Digital game design apps(n=1)
2018	AR(n=1) STEM(n=6) Digital story(n=1) Digital game design apps(n=1) Video-Assisted Illustrated Activities(n=1) Multimedia(n=1) Socıal Network Supported Learning(n=1) Technology Supported Learning(n=1) Web Supported Scıence Materıal(n=1)
2019	AR(n=1) STEM(n=7) Online Teaching Activities(n=1) TPACK(n=2) Computer-assisted materials(n=2) Technological design activities(n=1)
2020	STEM(n=9) Online Teaching Activities(n=1) Robotic Coding(n=3) 3D Computer Models(n=1) Educational Robotics activities(n=1) Use of tablets(n=1)
2021	AR(n=1) STEM(n=7) Online Teaching Activities(n=1) Robotic Coding(n=1) TPACK(n=1) Computer Models(n=1) Virtual lab(n=1). Educational Robotics activities(n=1) Digital game design apps(n=1) Technology Supported Learning(n=1)
2022	AR(n=2) STEM(n=1) Online Teaching Activities(n=1) Computer Models(n=1) Educational Robotics activities(n=1) Technological design activities(n=1) VR(n=1)

dissertations. Also, robotic coding in 2020, virtual lab in 2015, and AR in 2021 were carried out on science topics in dissertations.

Science Topics Studied in Dissertations

As illustrated in Figure 2, the most studied science topics with educational technology were socio-scientific issues (f=9), human body systems (f=8), electrical energy (f=7), electricity (f=7), structure and properties of matter (f=6), cell (f=6), acid and base (f=5), mirrors (f=5). In addition, chemical equilibrium (f=3), simple machines (f=3), photosynthesis (f=3), absorption of light (f=3), cell division (f=3), molecule (f=3), respiratory system (f=3), force and motion (f=6), solar system (f=4), sound (f=4), a world of living things (f=4), matter and heat (f=3) were studied common. Also, least studied science topics were physical and chemical changes (f=1), 3heat and temperature (f=1), ohm's law (f=1), magnetic field (f=1), induced current (f=1), electrolysis (f=1), transformer (f=1), mitotic division (f=1), friction (f=1), vitamins, fats, carbohydrate, proteins (f=1), reproduction, growth and development (f=1), density of matter (f=1), natural resources (f=1), chemical reactions (f=1), separation of mixtures (f=1).

As shown in Table 3, science topics were the most studied with STEM in dissertations. Among these topics using with STEM were human body systems, socio-scientific issues, force and motion, physical and chemical changes, solar system, sound, support and movement system, human and environment, force and energy, electrostatic, electrical charges, cell, astronomy, mirrors and reflection, electric cir-

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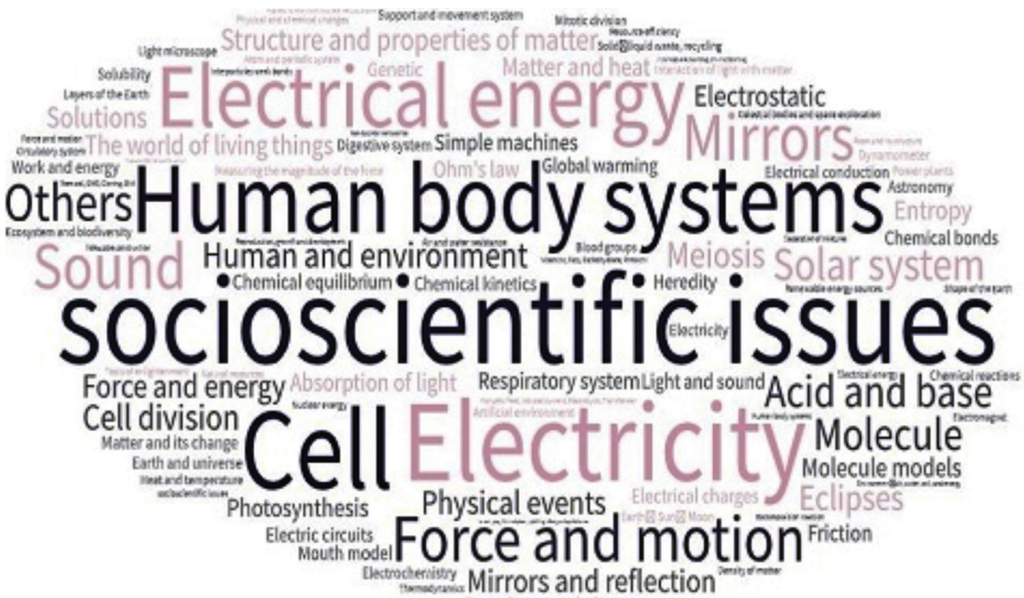

FIGURE 2

Frequency of Studied Science Topics in Dissertations.

TABLE 3

Distributions of Used Science Topics with Kinds of Technological Materials in Dissertations

Kinds of Technological Tools	*Science Topics*
AR	Cell, Cell division, Light microscope, Interparticles weak bonds.
STEM	Physical and chemical changes, Eclipses, Solar system, Force and motion, Human body systems, Sound, Support and movement system, Human and environment, Force and energy, Electrostatic, Electrical charges, Socioscientific issues, Cell, Structure and properties of matter, Measuring the magnitude of the force, Light and sound, Electricity, Astronomy, The world of living things, Friction, Simple machines, Mirrors and reflection, Absorption of light, Electrical energy, Physical events, Work and energy, Electrical conduction, Reproduction, growth and development, Electric circuits, Earth and universe, Matter and heat, Celestial bodies and space exploration, Mirrors, Ecosystem and biodiversity, Environment-air, water, soil, and energy, Acid and base, Chemical reactions, Genetic, Renewable energy sources, Atom and periodic system, Power plants, Nuclear energy.
Animation	Force and motion, Structure and properties of matter, Cell division, Acid and base, Solutions, Decomposition reaction, Chemical equilibrium, Entropy, Electrochemistry, Heat dissipation and insulation.
Online Teaching Activities	Human body systems, Cell, Mitotic division, Meiosis, Electricity.
Robotic Coding	Human body systems, Force and motion, Support and movement system, Human and environment, Force and energy, Electrical charges, Light and sound.
Technological Pedagogical Content Knowledge(T-PACK)	Matter and its change, Heat and temperature, Electricity, Celestial bodies and space exploration, Renewable energy sources, Electromagnet, Magnetic effect of electric current, Conversion of motion energy into electrical energy, Atom and its structure, Others.

(Table continues on next page)

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TABLE 3
(Continued)

3D Computer Models	Chemical bonds, Atom models.
Mobile technology	Electricity, Photosynthesis, Blood groups, Ohm's law, Manyetic field, Induced current, Electrolysis, Transformer.
Computer-assisted materials	Mirrors, Mirrors and reflection, Absorption of light, Measuring the magnitude of the force, Molecule, Respiratory system, Sound, Solar system.
Virtual lab	Thermodynamics Electricity
Educational Robotics activities	Force and energy, Lever types, inclined plane, spinning wheel, pulley and screw,
Internet-based teaching	Molecule models, Solid-liquid waste, recycling Interaction of light with matter Pure substance and mixtures Heredity Cell division Measuring the magnitude of the force Meiosis Molecule Layers of the Earth Earth- Sun- Moon Cell Mouth model Respiratory system Digestive system
Digital story	Others
Technological design activities	Solar system, Sound, Molecule, Mirrors and reflection, Absorption of light, Electric circuits, Shape of the Earth, Artificial environment, Tools of enlightenment, Dynamometer, Density of matter, Telescope construction, Air and water resistance, Solid-liquid waste, recycling, Mirrors, Resource efficiency.
Use of tablets	Others
Digital game design apps	Vitamins, Fats, Carbohydrate, Proteins, Photosynthesis, The world of living things, Electricity, Structure and properties of matter, Human and environment, Solar system, Force and motion, Human body systems
Video-Assisted Illustrated Activities	Structure and properties of matter, Separation of mixtures.
Web Supported Scıence Materıal	Circulatory system, Acid and base, Matter and heat, Photosynthesis, Respiratory system, Support and movement system, Human body systems
Technology Supported Learning	Cell, Structure and properties of matter, Electrical energy.
Socıal Network Supported Learning	Molecule, Solubility, Chemical kinetics, Solutions, Molecule models.
Socıal Medıa Supported Learnıng	Human body systems.
Interactive video teaching method	Work and energy.
Web 2 tools assisted teaching	Cell, Stem cell, GMO, Cloning, DNA
MEOITP	Others
Instructional technologies	Electricity, Force and motion, Human body systems
Multimedia	Matter and its change
VR	Light microscope

cuits, mirrors. In addition, TPACK was used with topics such as electrostatics, matter and its change, heat and temperature, electricity, celestial bodies and space exploration, renewable energy sources, and electromagnet. Moreover, computer-assisted materials were preferred to teach the absorption of light, molecules, respiratory system, sound, solar system, mirrors, and measuring the magnitude of the force. Web-supported learning was used for learning support and movement systems, human body systems, respiratory system, cells,

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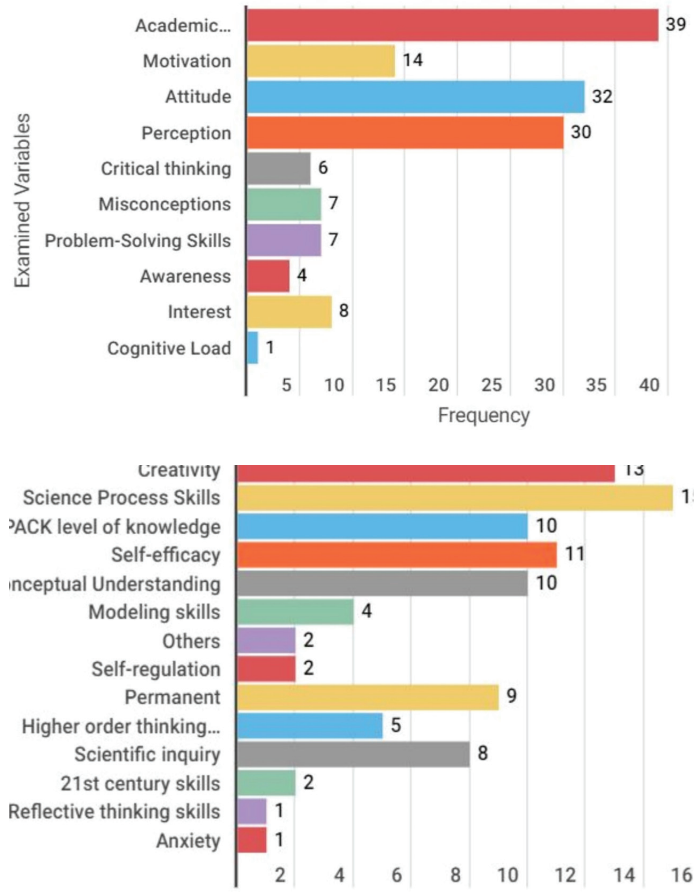

FIGURE 3

Frequency of Investigated Variables in the Dissertations

photosynthesis, matter and heat, circulatory system, acid, and base. Examined variables in the dissertations on the use of technology in science education. Computer-assisted was chosen to teach mirrors, absorption of light, mirrors and reflection, measuring the magnitude of the force, molecule, respiratory system, solar system.

Examined Variables in Dissertations

The investigated variables were detected, and results are shown in Figure 3. One study investigated multiple variables. The results indicate that the most examined variables are "academic achievement" (f = 39; 41 %), "Attitude" (f=32; 33 %), and "Perception" (f=30; 31 %). In addition, many other variables such as science process skills, motivation, creativity, self-efficacy, conceptual understanding, interest, problem-solving skills, misconceptions, modeling skills, permanent, science inquiry, 21st century skills, higher order thinking skills, reflective thinking skills, anxiety and cognitive load were all examined in the reviewed dissertations. As well as evaluation of in-service training was also investigated.

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TABLE 4

Research Methods from 2010 to 2022

Methods	*2010–2022*	
	N	*%*
Mixed methods	48	50
Quantitative methods	14	15
Quantitative methods	33	35

Method Trend

As shown in Table 4, 50% of the dissertations used mixed methods, 33% used quantitative design, 15% used qualitative design. Some studies did not indicated kind of mixed research methods (13.8). The most preferred mixed methods were mixed embedded design (27.3%), sequential mixed method (4.21%), and mixed methods intervention design (2.11). Among the quantitative methods, quasi-experimental design was the most used design (25.26%) (see Figure 4). Figure 5 illustrates that between 2013 and 2018, there were only six dissertations used qualitative design.

Data Collection Tools

As shown in Table 5, interviews (24%), questionnaires (22%), achievement tests (13%), observations (11%), assessment test (10%), documents (6%), concept test (6%), other (4%), diary form (3%), rubric (2%), survey (1%) were used in the dissertations. The distribution of data collection tools over the years, the use of questionnaires increased in the year from 2012 to 2013, 2015 to 2016,

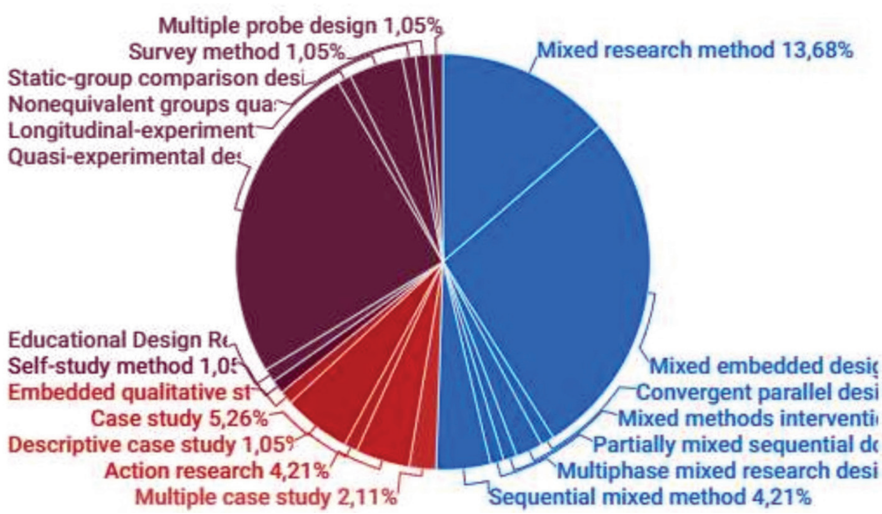

FIGURE 4

Using Kinds of Research Methods

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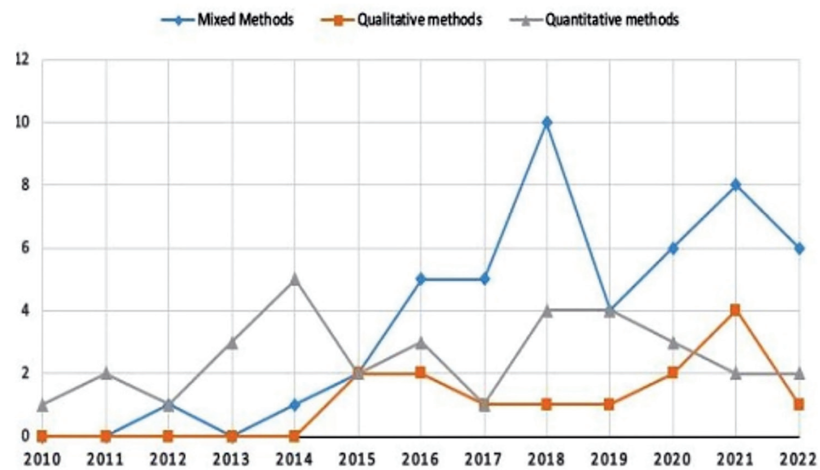

FIGURE 5

Research Methods by Year

2017 to 2018, and 2020 to 2021. Interviews were used most commonly in 2018 and 2021. In addition, academic achievement tests were applied mostly in 2018. The frequencies of the data collection tools and their distribution by year are illustrated in Figure 6.

Sampling Populations, Methods and Sizes

As shown in Table 6, purposive sampling was the most commonly preferred sampling method. The convenience sampling method has started to be used since 2012. Regarding the distribution of sampling methods over the

TABLE 5

Use of Collection Tools

	2010–2022	
Use of Collection Tools	*N*	*%*
Achievement test	39	16
Observations	34	15
Surveys	2	1
Documents	19	8
İnterviews	74	31
Concept test	11	3
Diary form	9	4
Others	13	5
Assesment test	30	13
Rubric	6	3

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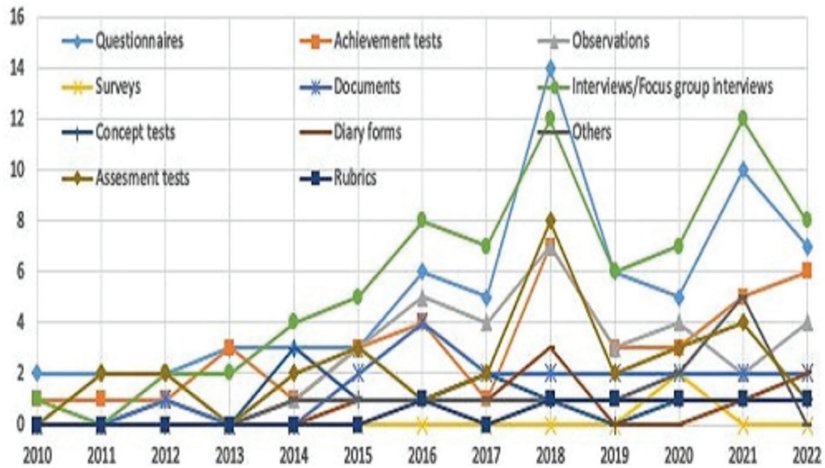

FIGURE 6

Frequency of Use of Data Collection Tools by Year.

TABLE 6

Use of Sampling Methods

	2010–2022	
Use of Sampling Methods	*N*	*%*
Random sampling	26	27
Convenience sampling	22	23
Purposive sampling	30	32
Not indicated	17	18

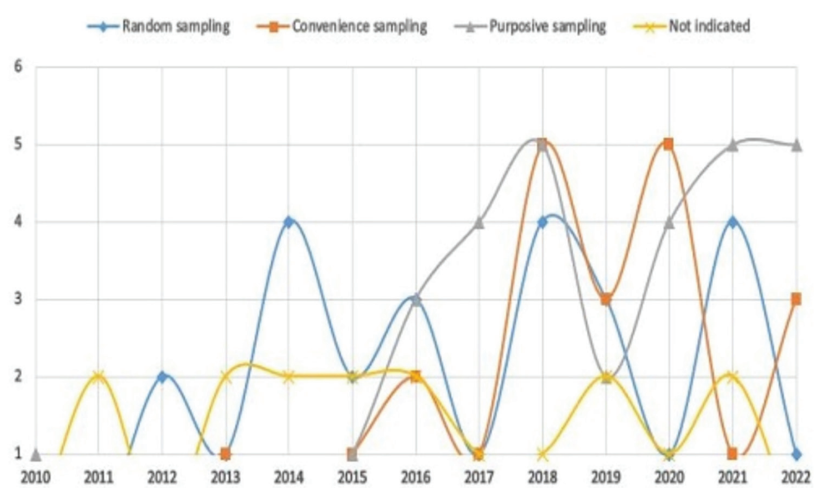

FIGURE 7

Use of Sampling Methods by Year.

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TABLE. 7

Frequency of Use of Sampling Groups in Dissertations

Sampling groups	*2010–2022*	
	N	*%*
Science teachers	6	6.3
Undergratuate (Pre-service science teachers)	31	32.6
Primary (5–8th grade)	54	56.8
Primary (1–4th grade)	1	1.0
Secondary (9–12th grade)	3	3.1

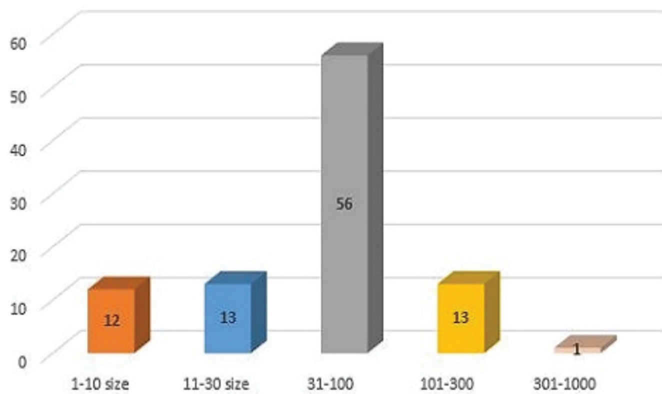

FIGURE 8

Frequency of Use of Sample Sizes in Dissertations.

FIGURE 9

Distribution of Sampling Groups over Year

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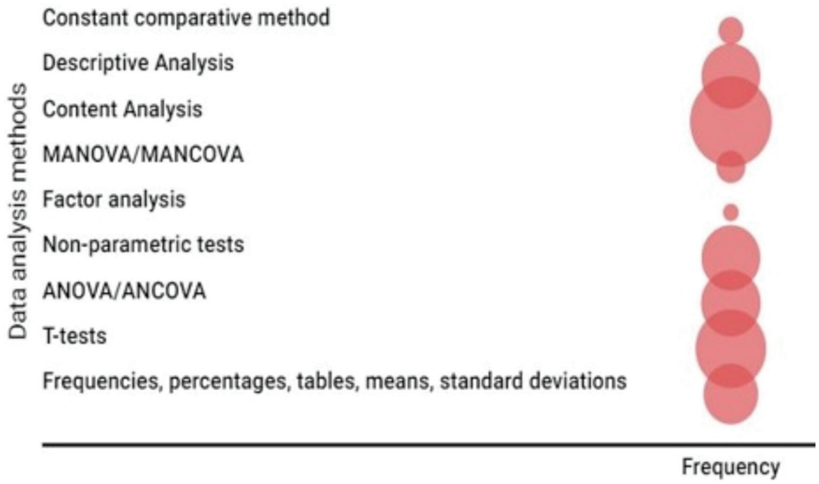

FIGURE 10

Distribution of Data Analysis Methods in Dissertations

years, purposive sampling began to increase in use from 2014 to 2018, and 2019 to 2022 (see Figure 7). The 31–100 group (58.9%) was the most used sample size in dissertations, as shown in Figure 8. While primary (5–8th grade) students (56.8%) and undergraduate (Pre-service science teachers) (32.6%) were commonly preferred, the least preferred as sampling groups were science teachers (6.3%), primary (1-4th grade) (1%), and secondary (9–12th grade) students (3.1%) (see Table 7 and Figure 9).

Data Analysis Methods

As shown in Figure 10, the most carried out data analysis methods were content analysis (69.4%), t-tests (50.5%), ANCOVA/ANOVA (34.7), descriptive analysis (33.6%), and non-parametric tests (33.6%). The most preferred inferential techniques were t-tests, qualitative analysis was content analysis.

DISCUSSION

This study revealed the doctoral dissertations produced in science education in the last twelve years using instructional technology by content analysis. Content analysis showed that the most used material types of educational technology in dissertations were STEM, TPACK, computer-assisted materials, online teaching activities, Web-supported learning, AR, digital game design apps, 3D computer models, technology-supported learning, and animation. These technology materials help students to understand macroscopic-microscopic or visible science subjects that they encounter in daily life. Moreover, students can visualize science subjects in their minds by observing them in three-dimensional ways through these technology materials. Students especially can achieve permanent learning by interactively using technology materials.

The analysis showed that dissertations primarily used STEM. The innovation of STEM education is a widely endorsed pathway to preparing the twenty-first-century workforce by nurturing talent and developing innovation and creativity skills (Mafugu et al., 2023; Moore et al. (2015), can be effective in comprehending science subjects. In summary, integrating technology and engineering into school education can improve student learning and increase student achievement with STEM activities (Brophy et al., 2008). That

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is why authors preferred to use STEM in their dissertations. Specifically, STEM was used to teach science topics such as human body systems, socio-scientific issues, force and motion, physical and chemical changes, solar system, sound, support and movement system, human and environment, force and energy, electrostatic, electrical charges, cell, astronomy, mirrors, circuits and mirrors, reflection, and electric. In addition, TPACK is most used and integrated into education. TPACK has become the center of technology education and teacher professional development research (Chai et al., 2013). Furthermore, computer-assisted material is the most preferred material in doctoral dissertations and is reported to affect students' abilities and skills in scientific research. In addition, it is stated that using computers gives students self-confidence and helps them to discover the interactions between the components of complex phenomena (Ramjus, 1990). Also, it is stated that 3D computer modeling technology helps students understand abstract concepts and events and supports their development in terms of scientific understanding of phenomena (Keating et al., 2002). Besides, AR has been one of the most impressive applications in information technologies in recent years, used in dissertations and frequently used in science teaching (Cabero-Almenara & Roig-Vila, 2019). AR offers rich environments that appeal to different sensory aspects of students. Accordingly, AR is quite effective in science teaching (Cai et al., 2014; Chang & Hwang, 2018; Kerawalla et al., 2006).

Another result is the most studied science topics using educational technology that were socio-scientific issues, followed by human body systems, electrical energy, electricity, structure and properties of matter, cells, acids and bases, and mirrors. Among them, the most studied subject is socio-scientific issues. If the content of a subject is related to science and has a place and importance in society makes it a socio-scientific issue (Eastwood et al., 2012). Since socio-scientific issues are open-ended, with multiple solutions to problems and no definitive answers (Sadler, 2011), it can support effective learning by supporting students' creativity and products with the unique perspective of each individual or group. Indeed, science subjects are often among the most studied fields, as their content is quite abstract and includes topics with macroscopic or microscopic scale. Guan et al. (2022) and Gao and Live Sun (2020) indicated similar conclusions in their systematic review of the use of technology materials in education.

Moreover, the results indicate that the most examined variables were academic achievement, attitude, and perception. These results are consistent with Bacca et al. (2014) and Yildiz et al. (2020). They found that one of the education technology materials is the most used for learning gains. In addition, since interest in technology starts before the age of 14, the most studied variable is the attitude to provide a better understanding of the factors affecting students toward technology between the ages of 12–14 (Ardies et al., 2015). Nevertheless, results show that interviews, questionnaires, and achievement tests were the most frequently adopted instruments used to collect data in dissertations. This result is similar to the studies of Guan et al. (2022) and Altinpulluk (2019).

One of the results of this study was regarding research methods. The most used method was the mixed method. And the most preferred often mixed methods were mixed embedded designs. This result parallels the systematic reviews of Fu and Hwang (2018) and Kara et al. (2019). The mixed method is based on pragmatism, one of Greene's scientific research philosophies (2007). The reason it is practical is that individuals tend to solve problems by using both numbers and words and frequently use them because they combine deductive and inductive thinking (Creswell & Crack, 2015). Therefore, mixed methods research is preferred to understand the natural world. However, unlike the results of this study, Fitt et al. (2009) examined that the most used method is quantitative in doctoral dissertations, and Anderson et al. (2021) investigated that the most used method is qualitative. The most used

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designs in studies were quasi-experimental design, one quantitative, embedded mixed design, one mixed, and the case study, one of the qualitative methods. This result is per the study of Alkraiji and Eidaroos (2016).

Moreover, results show that purposive sampling is the most common method. Another analysis result is sample type, which was most preferred to work with secondary school students. This result is like the systematic analysis of Arici et al. (2019). It was preferred to study in doctoral dissertations with a sample number of 31–100. This result parallels Bacca Acostaet (2014), which investigated a systematic review of AR applications, and Gao, Live Sun (2020), with a systematic review of the use of STEM education. This result is unsurprising since doctoral dissertations are studied with a sample of secondary school students.

The analyses performed showed that content analysis was frequently used in doctoral dissertations. This result was similar to the systematic analysis reported by Gündüz et al. (2022). Then, the t-test was the most used. This finding parallels the study of Yildiz et al. (2020), who stated that the t-test was mainly preferred in the analyzed studies.

LIMITATIONS AND RECOMMENDATIONS

The findings of this study are limited to 95 doctoral dissertations and content analyses that investigated the effects of using educational technology in science education in Türkiye. Similar studies in different countries can be compared to provide a significant perspective on using educational technologies in science education. Other studies that use educational technology materials in different disciplines from science were not included in this study. The most preferred samples were secondary school students in doctoral dissertations. For this reason, it is significant to diversify the sample scope of the effectiveness of educational technology materials by studying diverse types of samples. It is recommended to specify the reasons for choosing science subjects in doctoral dissertations and to associate these reasons with the characteristics of educational technology materials.

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