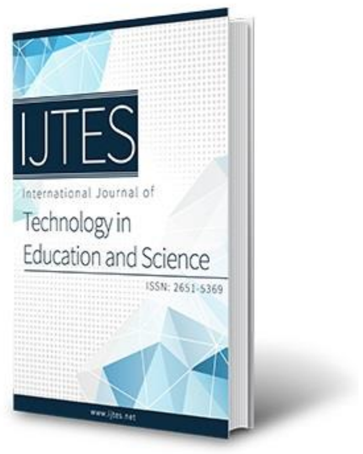

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Integrated STEM Education: A Content Analysis of Three STEM Education Research Journals

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Abstract

In this content analysis, the authors examined articles from three international STEM journals to highlight and indicate if there were any trends for iSTEM research from 2013 to 2018. Of the 296 articles analyzed in this content analysis, 41 investigated the integration of STEM disciplines. Findings revealed that integrated STEM (iSTEM) education research is often qualitative and occurs in the United States. This study also indicates an upward trend in the percentage of iSTEM education research from 2013 to 2018, and many of the articles focused on middle school students. A closer examination of the introductions, backgrounds, and literature reviews of the 41 articles revealed four explicit definitions for iSTEM education. Furthermore, STEM and Education were the most frequently used author keywords and ERIC descriptors.

Introduction

Emphasis on education in science and mathematics, and later in technology and engineering, swelled after the Soviet Union's launch of Sputnik in 1957 (Bybee, 2013). At that time, STEM education was "something innovative and exciting yet it… remained disconnected subjects" (Kelley & Knowles, 2016, p. 2). The launch of Sputnik sparked global competition and incited reforms in science and mathematics education in the United States because citizens perceived the launch of Sputnik as "a threat to American security, our superiority in science and math, and our economic progress and political freedom" (Bybee, 2013, p. 14). The United States public concerns that emerged at the launch of Sputnik were still evident almost 25 years later and voiced in the publication of *A Nation at Risk* (National Commission on Excellence in Education, 1983). The report opens with, "Our Nation is at risk. Our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world" (National Commission on Excellence in Education, 1983, p. 113). Since then, several standards reforms in education and initiatives in promoting STEM education occurred around the 1950s and continue today with global competition in mind.

Integrated STEM (iSTEM) Education

Introduction

The formal acronym of **S**cience, **T**echnology, **E**ngineering, and **M**athematics (STEM) education emerged in the

1990s, and this movement continues to grow in ubiquity and popularity (Bybee, 2018). Rather than developing learning experiences around one siloed content area of science, technology, engineering, or mathematics, STEM education now emphasizes the integration of these subjects. The interweaving of siloed STEM disciplines characterizes **integrated** STEM (**i**STEM) education into coherent lessons and learning experiences for students. It has become a focus of standards reform efforts, curriculum development, and the development of informal STEM education opportunities at varying levels of education.

Bybee (2013) described how some or all STEM silos could be integrated to make one iSTEM education lesson. By doing this, he offered clarity to the definition of iSTEM education. He defined it as 2.0 (the integration of two STEM disciplines), 3.0 (the integration of three STEM disciplines), or 4.0 (the integration of all four STEM disciplines). In addition, Bybee (2013) indicated that STEM disciplines could be integrated in many ways. For example, mathematics could be used as a tool in science; engineering concepts could be used to integrate mathematics and science concepts, or all four STEM disciplines could be integrated seamlessly into one course, unit, activity, or (Bybee, 2013).

Despite Bybee's (2013) attempt to provide examples for iSTEM education, prior studies indicated that some ambiguity remains about "what STEM education, particularly an integrated STEM education, means and looks like" (Tanenbaum, 2016, p. 3). Initiatives, such as *STEM 2026* developed in the United States, advocate for more emphasis on the integration of the STEM disciplines and call for the implementation of "integrated and interdisciplinary approaches to STEM education" with the use of "real-world situations or problems" throughout all the P–20 educational levels (Tanenbaum, 2016, p. 13). Also, the National Research Council indicated that "advocates for more integrated approaches to K–12 STEM education argues [*sic*] that teaching STEM in a more connected manner . . .can make the STEM subjects more relevant to students and teachers" (National Research Council, 2014, p. 1). Furthermore, this integrative practice would allow students to naturally make connections across the STEM disciplines. The promotion of these visions and organizations, within the scheme of economic and political competition in the world, solicits further investigation into iSTEM education.

Research

There is a "widespread movement for K–12 education to adopt and teach integrated STEM" (Nadelson & Seifert, 2017, p. 222). Scholars, practitioners, and employers request emphasizing iSTEM to develop 21st-century workforce skills, expand students' critical thinking, and promote STEM literacy (Bybee, 2013). Bybee (2018) states, "the most fundamental reason for introducing an integrated approach in school curricula is that it can provide students some opportunities to learn to apply knowledge, skills, and abilities from STEM disciplines in contexts close to what they will experience" (p. 110). Research for iSTEM education may assist administrators, educators, and other pertinent stakeholders in the field of education in building a solid foundation for students to be successful and competitive in the 21st century. For example, Becker and Park (2011) conducted a preliminary meta-analysis in iSTEM education and indicated that students "exposed to integrative approaches demonstrated greater achievement in STEM subjects" (p. 31). Li et al. (2020) also indicated that STEM education research had increased internationally. Reports such as these present a convincing argument for the need for iSTEM education and hope that research on this topic may similarly grow.

Definition

Since this content analysis aims to answer questions about iSTEM education research, this study needs to define STEM and iSTEM to clarify how the researchers chose to analyze the data and code the articles as STEM or iSTEM education research articles. The authors used a definition for iSTEM education from Sanders (2008). They contrasted this with descriptions of STEM education found in Bybee (2013) and Johnson et al. (2016) to define iSTEM education for this study. Sanders (2008) defined iSTEM education as “approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects” (p. 21). From the STEM education perspective, Bybee (2013) and Johnson et al. (2016) defined STEM as siloed fields of education. Therefore, this study defines iSTEM education as *intentional* learning opportunities in two or more STEM subject areas. While STEM education is *purposeful* learning opportunities in only one of the STEM subject areas.

Purpose of Study

This content analysis contributes a new understanding of the status of iSTEM education research by focusing on the types of iSTEM education research and where it is occurring in a globally competitive landscape. Furthermore, this study provides keywords and definitions most associated with iSTEM education articles to help future researchers consistently conduct and promote iSTEM education research. The researchers culled and analyzed iSTEM education research articles from three international STEM journals to investigate trends associated with iSTEM education research and to answer the following research questions.

Research Questions (RQ)

This content analysis asks one main overarching question: Does the literature in three international STEM journals reveal any trends in iSTEM education research from 2013 to 2018? We also identified seven sub-questions to address this research question: (RQ1.) Has there been a change in the number of iSTEM education research articles from 2013 to 2018? (RQ2.) Did STEM education research focus primarily on integrating two, three, or four disciplines? (RQ3.) In which countries have the most iSTEM education research studies occurred? (RQ4.) Who participated most often in iSTEM education research studies? (RQ5.) What methodologies and data collection methods did researchers use most often to investigate iSTEM education? (RQ6.) What keywords and descriptors did researchers use most often associated with iSTEM articles? (RQ7.) What definitions exist for iSTEM?

Methods

Content Analysis

Content Analysis “can simplify very large documents into enumerative information” (Grbich, 2013, p. 196). In this study, 296 articles, retrieved from three international journals, spanning back to their origins, were analyzed "to ascertain the trends and patterns of words used, their frequency, [and] their relationships" (Grbich, 2013, p. 190). Moreover, "content analysis is a research method for making replicable and valid inferences from data to their context, with the purpose of providing knowledge, new insights, a representation of facts[,] and a practical guide to action (Krippendorff, 1980)" (as cited in Elo & Kyngäs, 2007, p. 108). The researchers used tables, histograms, pie charts, and word clouds to illustrate and report the data.

Furthermore, specifically for this study, the authors used summative content analysis because of its power in analyzing journal articles by initially quantifying the data [and] then subjecting it to researcher interpretation (Hsieh & Shannon, 2005). During summative content analysis, "the text is often approached as single words or in relation to content. An analysis of the patterns leads to an interpretation of the contextual meaning of specific terms or content" (Hsieh & Shannon, 2005, p. 1286). Although most criticize content analysis for its positivistic characteristics, content analysis has the power to simplify substantial amounts of textual data into enumerative data. Thus, efficiently facilitating analysis of the database (Grbich, 2013). The researchers chose content analysis because it allowed them to glean information from an extensive database of STEM education research and provide an overview of the research from three international iSTEM education journals.

Data Collection

Procedures and Timeline

During the summer semester of 2019 (Table 1), the third author required the four remaining authors to conduct a content analysis to investigate what STEM education trends were evident in recent peer-reviewed literature. The authors compiled a list of 74 journals in a shared Google Sheets file and verbally reviewed them to determine their applicability and relevance to this content analysis study. Next, the authors used purposeful sampling (as defined by Creswell, 2007) to narrow the list of 74 journals to four based on the following criteria. The journal needed: (1) to claim to have a focus on at least three of the four STEM silos, (2) to be international in scope, and (3) to be peer-reviewed. Based on the selection criteria, the researchers selected four journals: *Journal of STEM Education: Innovations and Research*, the *International Journal of STEM Education (IJSE*), the *International Journal of Education in Mathematics, Science, and Technology* (*IJEMST*), and the *Journal of Research in STEM Education* (*J-STEM*).

After this primary selection, the four students chose one of the four journals to investigate further until their next meeting. The researchers filled in predetermined codes (the code descriptions are available in Table 2) for twenty articles from their selected journal. At the following meeting, the authors decided to include one more criterion for journal selection: the complete publication history must be less than ten-years-old. This criterion eliminated the *Journal of STEM Education: Innovations and Research* (initial publication in March 2000). The authors could investigate the remaining journals from their genesis to the summer of 2018.

The authors used their time during their final meetings to delimit their data and finalize the datasheet. They also determined that each student researcher would need to examine about 78 articles each. Finally, the student researchers also found that most of the articles explicitly expressed the codes in the title or abstract.

Table 1. Summary of STEM Education Research Journal Content Analysis Procedures

Date	Tasks for Content Analysis
June 4, 2019	Created shared Google Sheet to facilitate database generation and analysis
	Searched for STEM education research journals
June 11, 2019	Reviewed list of STEM education research journals
	Decided on criteria for selecting journals
	Narrowed the list of journals based on the criteria
	Began article codes collection (most recent 20 articles)
June 13, 2019	Reviewed columns for article codes sheet
	Eliminated and added columns of codes
	Further narrowed list of journals based on publication years
	Divided the remaining articles amongst the doctoral students
June 25, 2019	Delimited data with peers
	Added columns of codes
July 23, 2019	Finalization of content analysis database
	Peer review content analysis paper
August 1, 2019	Findings and final content analysis papers finalized

STEM and iSTEM Defined for Article Coding and Analysis

Bybee (2013) stated, "I have found it most useful to read or listen for the context within which STEM is used. In a sense, the context clarifies the meaning of STEM" (p. x). Therefore, in some cases, the authors had to look past the title and abstract to determine if the study was iSTEM education or not. For example, Barrett et al. (2014) reported that one purpose of their paper was to characterize their interdisciplinary STEM module in detail. Their study described how the module incorporated meteorology (science) and engineering together to benefit student learning.

The authors did not discuss integrating technology or mathematics for this module. Instead, the participants in this study were students enrolled in a STEM camp. If the investigators had only read about the STEM camp, this might have been miscoded as iSTEM. Instead, the authors appropriately coded it as iSE.

Another study by English and King (2015) described an initiative at an elementary school in Australia to incorporate an engineering component into an aerospace problem that was already rich in science, technology, and math proponents. The authors coded this study as iSTEM in the spreadsheet due to the purposeful incorporation of engineering within science, technology, and math.

Contraposition to iSTEM is STEM. An example of STEM education research is a quantitative study by Griese et al. (2015). These authors focused on engineering and students' learning strategies in science, technology, engineering, and mathematical courses. The students reported learning strategies for these courses taught separately from each other. Therefore, the authors coded this article as STEM.

Table 2. Spreadsheet Codes and Definitions

# Codes	Code	Definition
1	*Article Count*	A tally of the number of articles included in the spreadsheet.
2	*Article Title*	The title was copied from the article and pasted into the spreadsheet.
3	*STEM* or *iSTEM*	The presence of science (S), technology (T), engineering (E), or math (M) education explicitly discussed in the context of the article. These designations are taught in isolation and are considered siloed. The letter *i* before any combination of the coded acronym stands for integrated.
4	*Year of Publication*	The year the article was published.
5	*Authors*	The named author(s) of the published article.
6	*Keywords*	The keywords designated by the author(s).
7	*Descriptors*	The descriptive terms designated by the ERIC database. *J-STEM* articles were not assigned ERIC descriptors, and these cells in the spreadsheet were left blank.
8	*Research Design*	The use of quantitative, qualitative, or mixed methods within the article.
9–10	*Participants*	There were two columns listed under participant information: *Type* and *Number* of participants. Administration, teachers, students, or a mix of these three were codes listed under *Type*.
11–15	*Setting*	There were five columns under setting information: *Country*, based on location(s) of author(s); *School Setting*, urban, suburban, or rural; *School Type*, private, public, or mix; *Classroom Setting*, informal (outside of regular school hours) or formal (inside of regular school hours); and *Education Level*, elementary, middle, secondary, or postsecondary.
16	*Data*	There were two columns for *Data Type*, surveys, academic records, artifacts, and other and *Study Type*, appropriate methods for qualitative, quantitative, or mixed-methods data analysis.
17	*Title of the Journal*	The name of the journal
18	*Article Abstract*	The article's abstract.
19	*Article Type*	Practitioner, Research, or other type.

One might argue that engineering is integrative by nature. However, the researchers defined iSTEM as the *purposeful* integration of the STEM subjects. The article by Griese et al. (2015) did not explicitly indicate that engineering was a means by which STEM subjects were integrated. Instead, the articles discussed the content areas of science, technology, and mathematics as separate courses the engineering students were attending at the time of this study. The authors coded and eliminated articles, such as this one, from further analysis and discourse since they wanted to focus on iSTEM.

Data Characteristics

Table 3 gives a brief description and article count for the 296 articles pulled from the three journals analyzed in this study. *IJEMST*, on average, publishes 24 articles a year, *IJSE* publishes around 23 articles a year, and *J-STEM* publishes about 10 articles a year. It also appears that *J-STEM* publishes two issues a year. Finally, in the summer of 2019, *J-STEM* and *IJEMST* had not released the most recent volumes in their entirety. Therefore, for consistency, the students reviewed all articles from the start of each journal to the end of 2018.

Table 3. Journal Title and Description and Article and Year Count

Journal	Journal Description	# Articles	# Years
IJEMST	Quarterly publication	24	2013
	Peer reviewed	24	2014
	No publication fee	24	2015
		24	2016
		24	2017
		26	2018
		146	6
IJSE	Annual publication	10	2014
	Peer reviewed	17	2015
	Publication fee	14	2016
		28	2017
		44	2018
		113	5
J-STEM	Annual/Bi-annual	11	2015
	publication	7	2016
	Peer reviewed	4	2017
	No publication fee	15	2018
		37	4

Note. There were 296 articles collected for this content analysis.

Of the 296 articles labeled as research by the journals, 35 were practitioner articles (n = 34) and a literature review (*n* = 1). These articles were eliminated from further analysis. Figure 1 depicts varying combinations of individual STEM education research articles, which were most often the studies' topics (63%).

The second-largest proportion of Figure 1 indicates the second most popular research geared towards the study of multiple STEM silos (18.4%, *n* = 48). Of the 261 research articles, the authors coded 16% (*n* = 41) of the articles as having integrated two or more STEM disciplines. (The appendix provides a complete list of these iSTEM education research articles.) Finally, educational technology, which is not a STEM discipline, was the focus of 2.3% of the articles (and not included for further analysis).

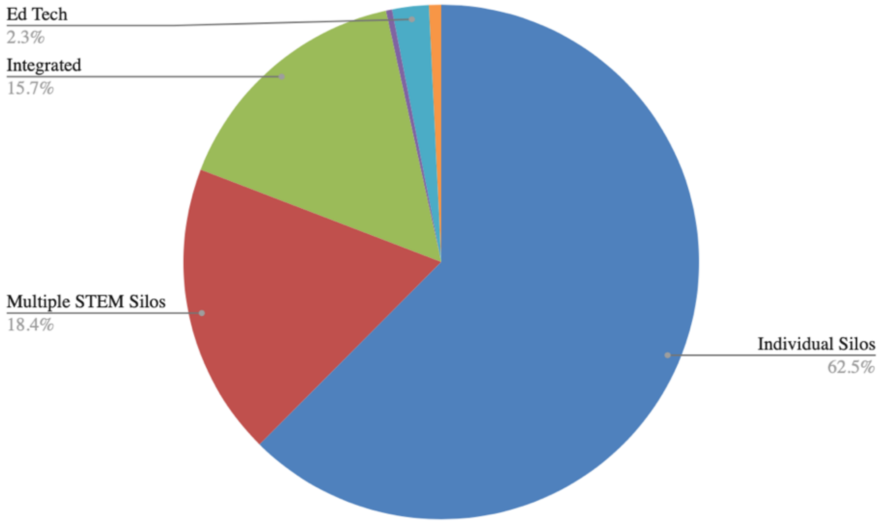


Figure 1. Percentages of *STEM* in International STEM Education Research Journals

Each of the four doctoral students selected questions they wished to investigate further for the summer class and wrote one content analysis paper each. Two of the four papers discussed the trends of STEM education and included 261 articles (both STEM and iSTEM education articles). This article combines the second set of papers that focused only on iSTEM education research trends.

Results

In the following sections, the researchers illustrated and described the data related to each sub-research question. The compilation of these findings is discussed in the conclusion of this study and addresses the main research question. This discussion includes the researchers' interpretations of the patterns and themes revealed in the data.

Research Questions

RQ1. Has There Been a Change in the Number of iSTEM Education Research Articles From 2013 to 2018?

Figure 2 characterizes an upward trend for iSTEM education articles in general. However, *J-STEM* is the only journal that consistently increased the number of iSTEM articles over the past few years. *IJEMST* had a decline in the number of iSTEM articles from 2016 (n = 3) to 2017 (n = 2) but experienced an increase once again from 2016 (n = 2) to 2017 (n = 5).

Finally, *IJSE* articles seemed to grow exponentially from 2014 to 2017. However, the number of *IJSE* article numbers sharply declined from 2017 (n = 9) to 2018 (n = 5). Finally, *J-STEM* represents 20% (n = 8), *IJEMST* about 29% (n = 12), and *IJSE* approximately 51% (n = 21) of the iSTEM education research articles from the three journals.

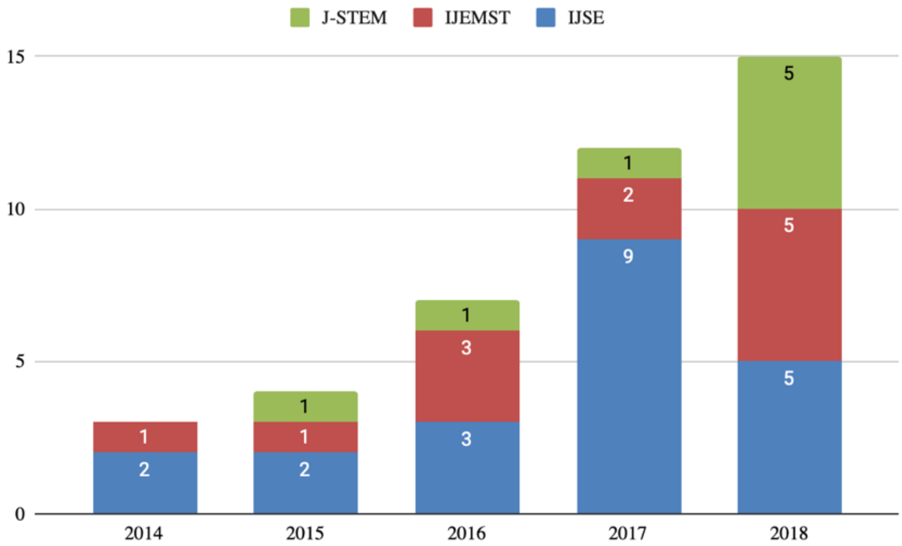


Figure 2. Histogram of iSTEM Education Research Articles

RQ2. Did STEM Education Research Focus Primarily on Integrating Two, Three, or Four Disciplines?

According to Bybee (2013), STEM integration can occur at three degrees: 2.0, 3.0, or 4.0. As Figure 3 depicts, of the 41 iSTEM disciplines articles, 4.0 STEM integration was studied most frequently (around 66%, n = 27), while 3.0 STEM integration was studied much less frequently (about 2.4%, n = 1). The 2.0 degree of STEM integration represented about 24% (n = 10) of the iSTEM education research articles. The three remaining articles, listed as *Other*, are iSTE**A**M (Integrated Science, Technology, Engineering, **A**rt, and Mathematics), iSTEM**M** (Integrated Science, Technology, Engineering, Mathematics, and **M**edicine), and iSTE**M** (Integrated Science, Technology, Engineering, and **M**edicine). They represented about seven percent of the iSTEM education research articles.

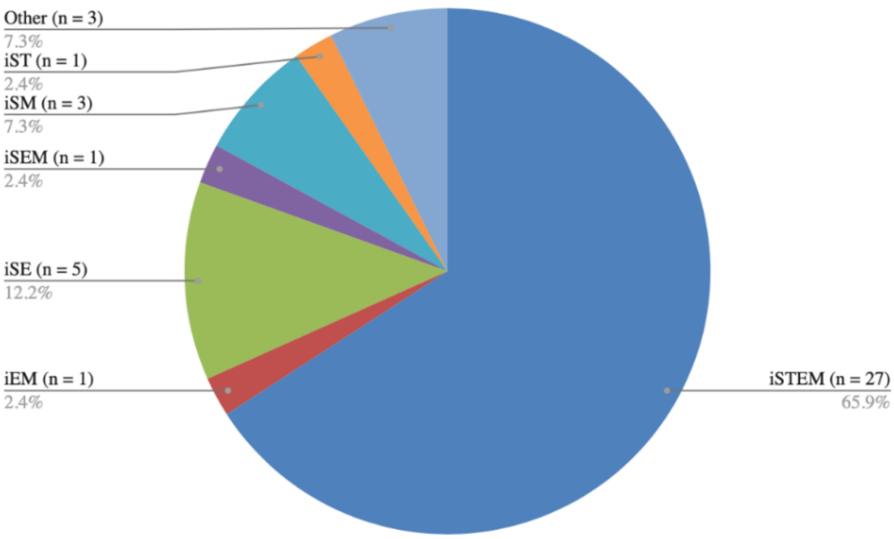


Figure 3. Frequency of Degrees of iSTEM

RQ3. In Which Countries Have the Most iSTEM Education Research Studies Occurred?

Figure 4 depicts that most iSTEM education research studies occurred in the United States, with a frequency of 32 out of 41 articles (78%). Turkey was the second most frequently investigated country, with a frequency of four out of 41 articles (10%). Uganda, Australia, Israel, the Netherlands, and Switzerland were also present in the iSTEM education research articles. However, they each displayed a lower frequency of five articles out of 41 (one article from each country). Integrated STEM education research has occurred internationally, but most of that research has been in the United States.

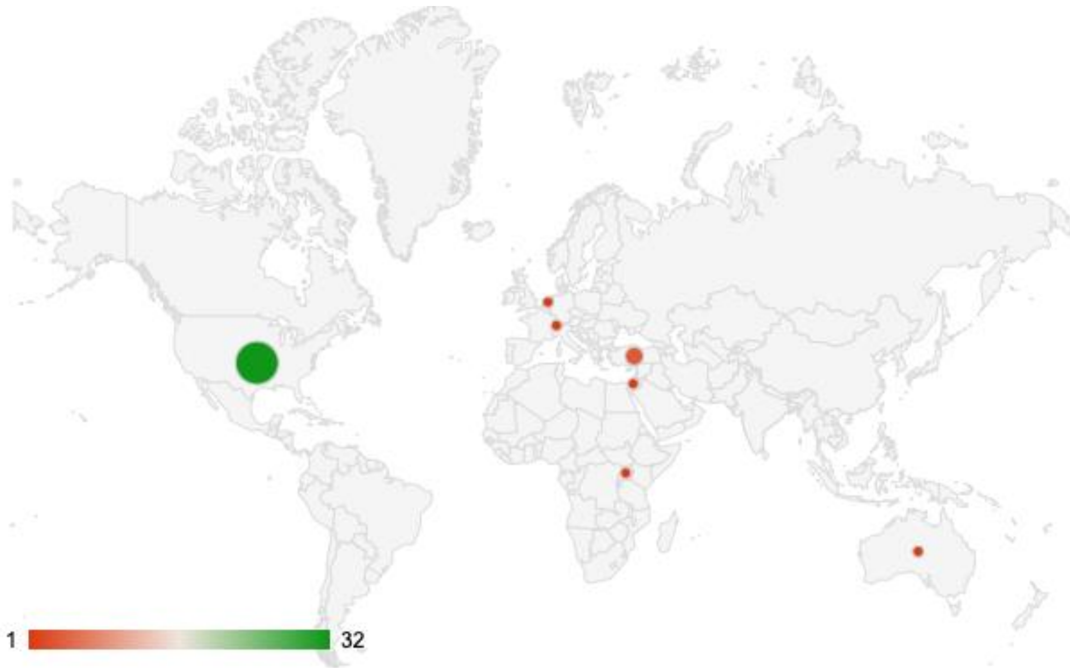


Figure 4. Countries with Studies of iSTEM

RQ4. Who Participated Most Often in iSTEM Education Research Studies?

As depicted in Figure 5, middle school students were often the subjects of research studies in iSTEM education. Fifteen of the 41 iSTEM education research articles focused on students only (37%), while 10 of the 41 articles centered on teachers only (24%). Studies often included students and teachers (17%) in the design. Studies including students represented 56% of the articles, while studies including teachers represented 47%. Finally, two of the 41 articles focused on preservice teachers (5%), while only one study (2%) included administrators as participants.

Figure 6 depicts the education level of the participants represented in the 41 iSTEM education research studies. Of the 23 studies that included student participants (students only or students and teachers), about 17% (n = 4) of the studies included participants in only elementary grades, around 35% (n = 8) included middle grades only, about 22% (n = 5) included high school grades only, and 9% (n = 2) included postsecondary students only. Finally, around 17% (n = 4) of the articles included a combination of middle and secondary grade students.

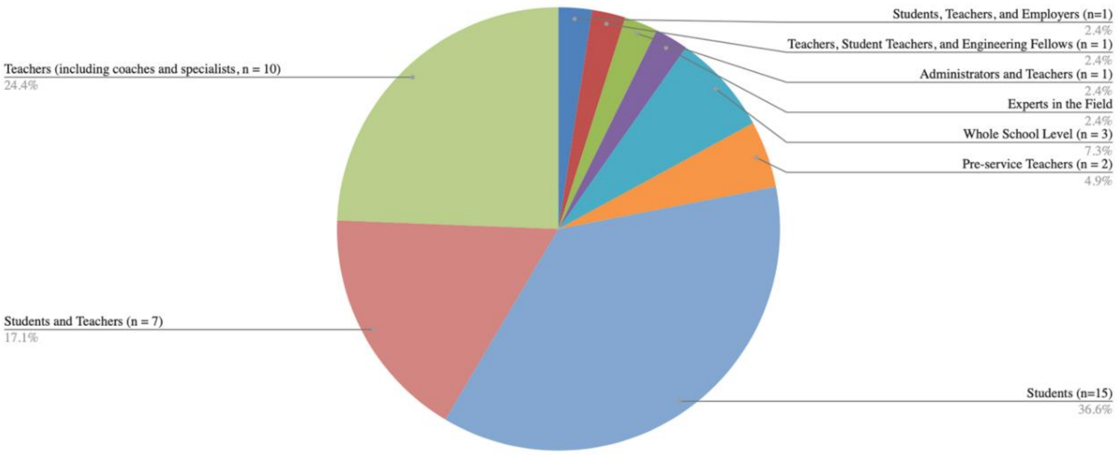


Figure 5. Percentage of Participant Types

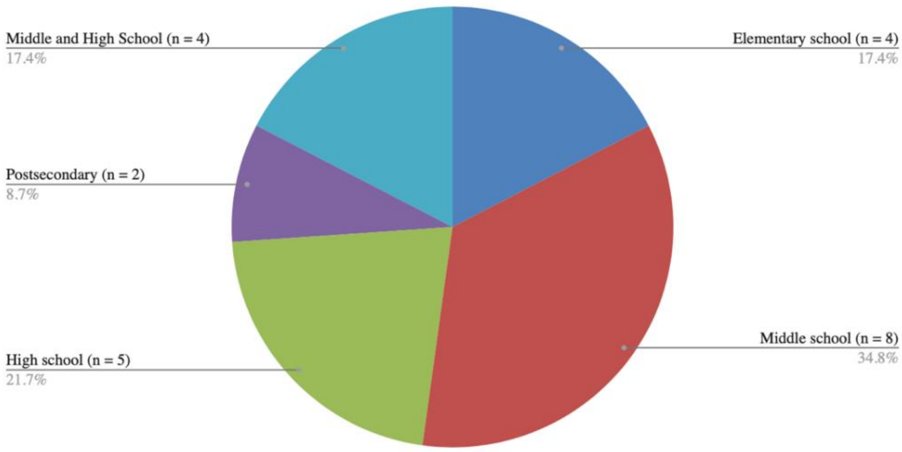


Figure 6. Percentage of Education Levels of Student Participants

Figure 7 illustrates the percentage of teacher participants by grade level.

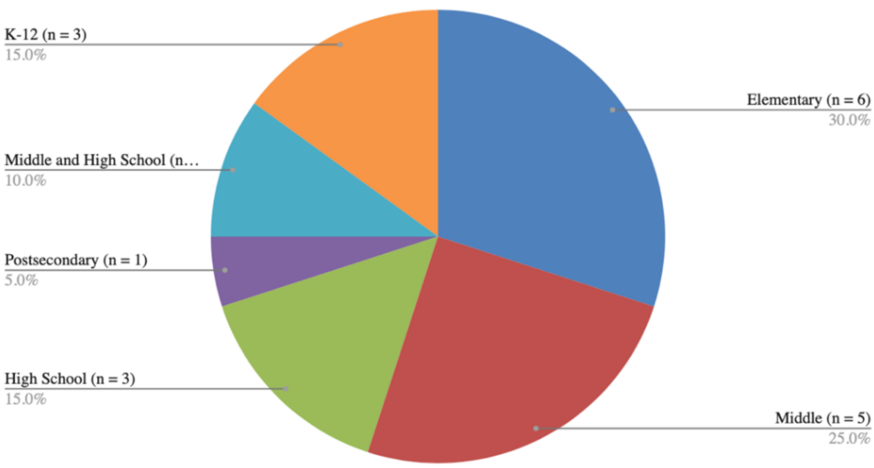


Figure 7. Percentage of Education Level Taught by Teacher Participants

Teachers were included as participants in 20 of the 41 studies (49%) and were most often studied if they taught elementary grades only level (30%, *n* =6). Of the remaining 14 studies, five (25%) were at the middle grades only level, three (15%) were at the high school grades level, one (5%) was at the postsecondary level, two (10%) included both middle and secondary levels, and three (15%) studies included all grades: K–12.

RQ5. What Methodologies and Data Collection Methods did Researchers Use Most Often to Investigate iSTEM Education?

As seen in Figure 8, qualitative research study designs occurred most frequently in studies of iSTEM education. The least frequently used study design was theoretical. Of the 41 iSTEM education research studies, seven were mixed-methods studies, 29 were qualitative, four were quantitative, and one was a theoretical study.

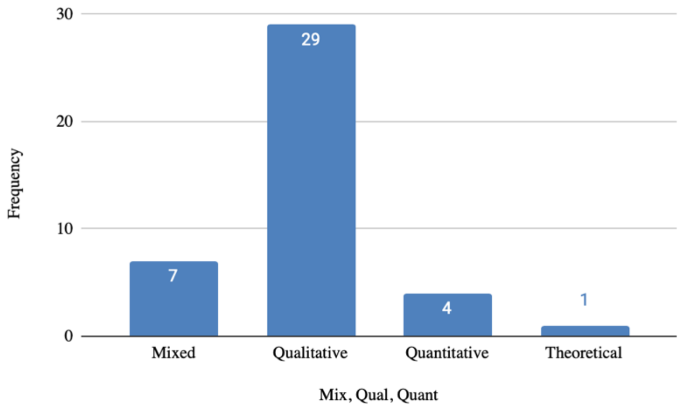


Figure 8. Study Types in iSTEM Education Research Journals

Figure 9 depicts the most frequently used data collection method in the 29 qualitative iSTEM education research studies.

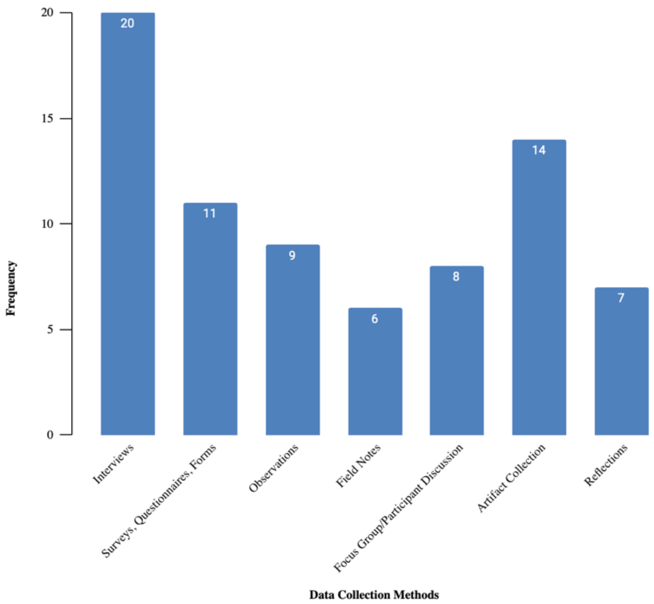
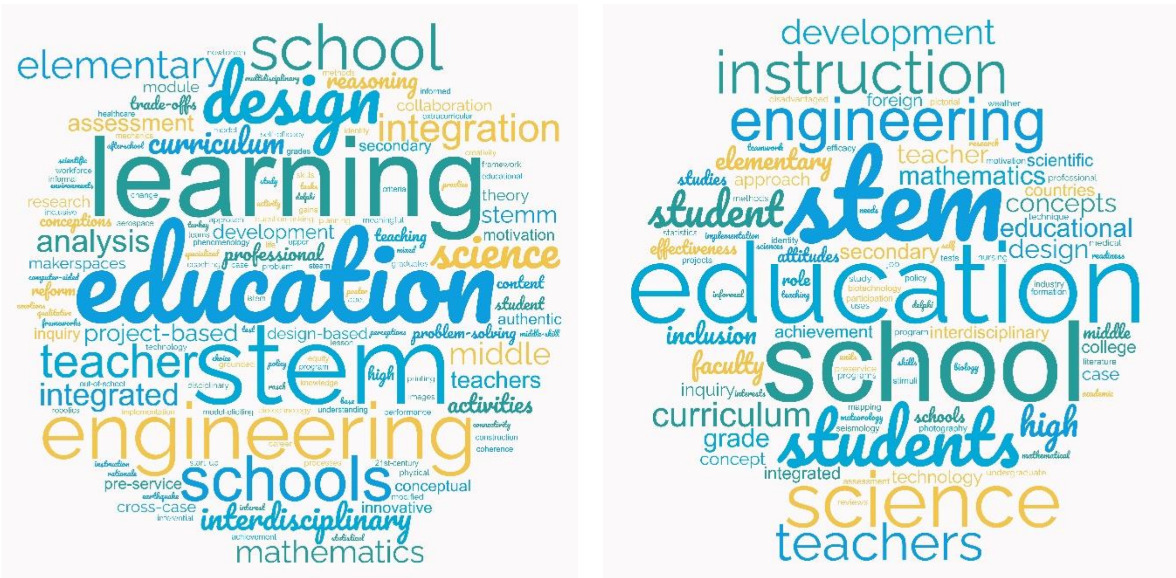


Figure 9. Data Collection Methods Used in iSTEM Education Research Studies

These methods were interviews (n = 20, 69%). Other frequently used data collection methods included surveys, questionnaires, and forms (n = 11, 37%); observations (n = 9, 31%); field notes (n = 6, 21%); focus groups or participant discussions (n = 8, 28%), artifact or document collection (n = 14, 48%), and reflections (n = 7, 24%).

RQ6. What Keywords and Descriptors did Researchers Use Most Often Associated With iSTEM Articles?

Word clouds help analyze qualitative data such as keywords and descriptors (Cherrstrom et al., 2016). Therefore, in Figure 10, the authors used word clouds to display the most frequently used keywords and descriptors. The size of the words represented in the two clouds positively correlates with the number of times the keyword or descriptor appeared in various iSTEM articles. Finally, three articles did not report keywords, and the ERIC database does not assign descriptors to *J-STEM* articles. Therefore, the keywords word cloud included 38 articles, and the ERIC descriptor word cloud included 33 articles for these analyses. Even though this content analysis focused on iSTEM research, *STEM* and *Education* are the two most frequent words that appear in the word clouds. The authors used *STEM* (n = 40) more often than *Education* (n = 27), and the ERIC database assigned the descriptor *Education* (n = 38) more often than *STEM* (n = 24). To a lesser extent, terms associated with iSTEM education did not occur as frequently.



Keywords *Descriptors*

Figure 10. The Most Often Occurring Keywords and Descriptors

Keywords and descriptors associated with iSTEM appeared less often and are hard to see in the word clouds depicted in Figure 10. Therefore, the author conducted a word search in the datasheet for associated iSTEM education keywords or descriptors and created a table of these terms (Table 4). The author did not include keywords or descriptors that required further article analysis. For example, STEM Schools and Biotechnology were too ambiguous or too narrowly defined and required further reading to determine how these terms were associated with iSTEM education. Table 4 lists the terms associated with iSTEM education in alphabetical order and includes the word counts of the keywords and descriptors.

Keywords (*n* = 14) that pertained to iSTEM outnumbered descriptors (*n* = 4) more than three times. There were 178 keywords and 108 descriptors. The ERIC database assigned four keywords for each article analyzed in this study. In comparison, keywords ranged from zero to eight terms. Furthermore, the keywords and descriptors *Interdisciplinary approach* and *Integrated curriculum* did not align for any of the articles. However, in one case, the author used *STEM integration* as a keyword, and *Integrated curriculum* appeared as one of the descriptors for the same article.

Table 4. Frequency and Percentage of Keywords and Descriptors

Frequency of Keywords	Percent of Keywords	Frequency of Descriptors	Percent of Descriptors	Term Associated with iSTEM
1	0.56%	0	0%	Interdisciplinary activities
1	0.56%	2	1.85%	Interdisciplinary approach
1	0.56%	0	0%	Interdisciplinary STEM
1	0.56%	0	0%	Interdisciplinary STEM module
1	0.56%	0	0%	Integration
1	0.56%	2	1.85%	Integrated curriculum
2	1.12%	0	0%	Integrated STEM
1	0.56%	0	0%	Integrated STEM education
1	0.56%	0	0%	ISTEM
1	0.56%	0	0%	Multidisciplinary education
3	1.69%	0	0%	STEM integration
14	**7.85%**	**4**	**3.7%**	**Column Totals**

RQ7. What Definitions Exist for iSTEM?

Finally, the primary author searched for a definition of iSTEM education within the 41 articles coded under iSTEM or a combination of iSTEM. About 10% of the 41 articles explicitly defined iSTEM in the introduction, background, or literature review. The four definitions are as follows.

Ntemngwa and Oliver (2018) used prior studies related to STEM and iSTEM to create their definition:

> STEM education is a pedagogical approach in which concepts and objectives from two or more STEM disciplines are incorporated into a single project, so that students are exposed to the connections among and across these concepts and/or practices, learn or apply the concepts simultaneously rather than in isolation and relate them to real life situations. In this way, students could learn to apply these concepts in authentic real-life problems, which are integrated in nature and may also acquire skills like problem solving. (Ntemngwa & Oliver, 2018, p. 14)

Akaygun and Aslan-Tutak (2016) described iSTEM as a way "to teach important ideas in subject areas while providing integration (not just connection) between disciplines" (p. 57). In another study, Slavit et al. (2016) defined iSTEM as "an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise" (p. 2). Beyond this, literature defined iSTEM as "an effort by educators to have students participate in engineering design as a means to develop technologies that require meaningful learning and an application of mathematics and/or science" (Baran et al., 2016, p. 10).

Conclusion

Findings from this content analysis indicated increased interest in iSTEM education research. This finding reflects a conclusion reported in a study by Li et al. (2020) and is in line with the calls from professionals for more research and implementation of iSTEM education. The degree of iSTEM education integration is varied. However, most studies examined the integration of all four STEM disciplines.

Based on the data from the content analysis, it is evident that iSTEM research is occurring internationally, but by far most of the iSTEM education research studies are occurring in the United States. With the fears faced by people in the United States from the launch of Sputnik and the concerns put forth in *A Nation at Risk*, the location of most iSTEM education research seems to reflect the United States' continuing concerns and interest in the promotion of iSTEM education to improve students' STEM literacy and situate the United States as a global STEM leader.

Students at the middle grades level were most often the focus of iSTEM education research studies, while administrators were only included as participants in one study. In addition, the focus of most iSTEM education research articles was student participants rather than school personnel. Since students are more likely to pursue a career in STEM if introduced to STEM in their adolescent years (Wyss, et al., 2012), these results are in line with prior studies. However, the success of iSTEM education relies on successful implementation managed by administrators and teachers. Therefore, more research involving teacher participants and especially administrator participants are needed to promote future successful and sustainable iSTEM education programs.

Qualitative methodology was the most frequently used in the research studies. The most common data collection methods were interviews, a staple in qualitative research design. This finding reflects a wider acceptance and implementation of qualitative research design methods in iSTEM educational research. Though qualitative studies are equally as important as quantitative studies, both are vital to the future success of iSTEM education and future studies should try to use quantitative measures to support the conclusions of the qualitative studies.

A small proportion of keywords and descriptors were identified as associated with iSTEM education research without having to search the article for a more contextual explanation of the keyword or descriptor. Additionally, keywords and descriptors assigned to the articles did not consistently agree on terminology associated with iSTEM education research. Beyond this, the two most common keywords and descriptors found in iSTEM articles were *STEM* and *Education*. While *Education* might yield results that include iSTEM education, the search is a broad field for future researchers to consider. *STEM* might narrow the search for iSTEM education. However, the search would still be quite extensive for researchers who wished to narrow their search to find *only* iSTEM education-related articles.

Finally, within the context of this study, definitions of iSTEM education materialized from the introduction, background, or literature reviews of three studies coded as iSTEM (Baran et al., 2016; Slavit et al., 2016; Ntemnga & Oliver, 2018;) and one study coded as iSM (Akaygun & Aslan-Tutak, 2016). Commonalities exist among the iSTEM definitions. All four definitions incorporated how subjects should be meaningfully integrated and not just connected siloed content. Two reports described how iSTEM should include real-world applications. One definition was more exclusive and mentioned only the integration of math and science using engineering concepts. However, since this is a small representation, more research is needed in this area to identify a standard definition for iSTEM education research.

Recommendations

More research should be conducted around the role of administrators in iSTEM education studies since only one article collected for this analysis represented a group of administrators as participants. Furthermore, this study limited the categories to teachers at various grade levels. Future research might investigate perspectives and atittudes of teachers' towards STEM and iSTEM "to develop a clearer understanding of thoughts across subjects" (Celebi, 2019, p. 19) and how these differences and similarities might be used to strengthen the promotion of iSTEM. In addition, more quantitative studies could be done on iSTEM research to examine the effects of iSTEM learning opportunities on large-scale achievement assessments in mathematics or science in K–12 schools. Furthermore, quantitative studies could also be performed to determine the effects of participation in iSTEM education opportunities on STEM workforce growth and preparation.

The United States continued to pursue iSTEM education research more than other countries as indicated by this content analysis, and students are most often the subjects of iSTEM education research. All these findings suggest reflection on the United States' pursuit of iSTEM education as compared to other countries. If evidence were found indicating a positive correlation between the STEM workforce based on students' participation in iSTEM education, students might be better equipped for their potential futures pursuing STEM careers.

Finally, only a few definitions for iSTEM education exist. If the aim is to identify iSTEM education literature, it will take a great deal of time to examine all the articles that would appear in a search for their use of STEM education as it might apply to iSTEM education research. Furthermore, research on iSTEM education is growing. With this growth comes the responsibility for researchers to be more consistent in explicitly defining their use of iSTEM education in their research and to be more concise in selecting keywords that describe their study's contribution to iSTEM education research. This request for further consistency of STEM integration definitions and uses is reiterated and expanded by Moore et al (2020). They suggested that "moving toward a consistent and agreed-upon language and vision for this variation will help facilitate forward progress in research and practice… [and] are important steps… to better define consistent language and ways of thinking about different types of STEM integration (Moore et al., 2020, p. 11).

References

Akaygun, S., & Aslan-Tutak, F. (2016). STEM images revealing stem conceptions of pre-service chemistry and mathematics teachers. *International Journal of Education in Mathematics, Science and Technology*, *4*(1), 56–71. https://doi.org/10.18404/ijemst.44833

Baran, E., Bilici, S. C., Mesutoglu, C., & Ocak, C. (2016). Moving STEM beyond schools: Students' perceptions about an out-of-school STEM education program. *International Journal of Education in Mathematics, Science and Technology*, *4*(1), 9–19. https://doi.org/10.18404/ijemst.71338

Barrett, B. S., Moran, A. L., & Woods, J. E. (2014). Meteorology meets engineering: An interdisciplinary STEM module for middle and early secondary school students. *International Journal of STEM Education*, *1*(1), 1–7. https://doi.org/10.1186/2196-7822-1-6

Becker, K., & Park, K. (2011). Effects of integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A preliminary meta-analysis. *Journal of STEM Education*: *Innovations and Research*, *12*(5/6), 23–37.

Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. National Science Teachers Association.

Bybee, R. W. (2018). *STEM education*: *Now more than ever*. National Science Teachers Association.

Celebi, N. (2019). Teachers and ICT's in secondary education: The Turkish case. *International Journal of Technology in Education and Science*, *3*(1), 19–28.

Cherrstrom, C. A., Robbins, S. E., & Bixby, J. (2016). 10 years of *Adult Learning*. *Adult Learning*, *28*(1), 3–11.

Creswell, J. W. (2007). *Qualitative inquiry & research design*: *Choosing among five approaches* (2nd ed.). SAGE.

Elo, S., & Kyngäs, H. (2007). The qualitative content analysis process. *Journal of Advanced Nursing*, *62*(1), 107–115. https://doi.org/10.1111/j.1365-2648.2007.04569.x

English, L. D., & King, D. T. (2015). STEM learning through engineering design: Fourth-grade students' investigations in aerospace. *International Journal of STEM Education*, *2*(1), 1–18.

Griese, B., Lehmann, M., & Roesken-Winter, B. (2015). Refining questionnaire-based assessment of STEM students' learning strategies. *International Journal of STEM Education*, *2*(1), 1–12.

Grbich, C. (2013). *Qualitative data analysis: An introduction.* SAGE.

Hsieh, H. F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research*, *15*, 1277–1288. https://doi.org/10.1177/1049732305276687

Johnson, C. C., Peters-Burton, E. E., & Moore, T. J. (Eds.). (2016). *STEM road map: A framework for integrated STEM education*. Routledge.

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*, *1*(11), 1–11. https://doi.org/10.1186/s40594-016-0046-z

Li, Y., Wang, K., Xiao, Y., & Freud, J. E. (2020). Research and trends in STEM education: a systematic review of journal publications. *International Journal of STEM Education*, *7*(11), 1–16.

Moore, T. J., Johnston, A. C., & Glancy, A. W. (2020). STEM integration: A synthesis of conceptual frameworks and definitions. In C. C. Johnson, M. J. Mohr-Schroeder, T. J. Moore, & L. D. English (Eds.), *Handbook of Research on STEM Education* (pp. 3–16). Routledge

Nadelson, L. S., & Seifert, A. L. (2017). Integrated STEM defined: Contexts, challenges, and the future. *The*

Journal of Educational Research, *110*(3), 221–223. https://doi.org/10.1080/00220671.2017.1289775

National Commission on Excellence in Education. (1983). A nation at risk: The imperative for educational reform. *The Elementary School Journal*, *84*(2), 113–130. https://doi.org/10.1086/461348

National Research Council. (2014). *STEM integration in K–12 education: Status, prospects, and an agenda for research.* The National Academies Press. https://doi.org/10.17226/18612

Ntemngwa, C., & Oliver, J. S. (2018). The Implementation of Integrated Science Technology, Engineering and Mathematics (STEM) Instruction using Robotics in the Middle School Science Classroom. *International Journal of Education in Mathematics, Science and Technology*, *6*(1), 12–40.

Sanders, Mark. (2008, December/January). STEM, STEM education, STEMmania. *The Technology Teacher*, *68*(4), 20–26. http://hdl.handle.net/10919/51616

Slavit, D., Nelson, T. H., & Lesseig, K. (2016). The teachers' role in developing, opening, and nurturing an inclusive STEM-focused school. *International Journal of STEM Education*, *3*(1), 1–17.

Tanenbaum, C. (2016). *STEM 2026*: *A vision for innovation in STEM education* (TD/TNC 127.520). Office of Innovation and Improvement, US Department of Education. http://hdl.voced.edu.au/10707/422006

Wyss, V. L., Heulskamp, D., & Siebert, C. J. (2012). *Increasing middle school student interest in STEM careers with videos of scientists* (EJ997137). ERIC. https://files.eric.ed.gov/fulltext/EJ997137.pdf

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Appendix

Code #	Code	References
1	iSM	kaygun & Aslan-Tutak, 2016)
2	iSTEM	none, K. A., & Hanuscin, D. (2018). An exploratory cross-sectional survey study of elementary teachers' conceptions and methods of STEM integration. *Journal of Research in STEM Education*, *4*(2), 159–178. https://doi.org/10.51355/jstem.2018.43
3	iSTEM	deniz, M., & Bilican, K. (2018). The impact of engagement in STEM activities on primary pre-service teachers' conceptualization of STEM and knowledge of STEM pedagogy. *Journal of Research in STEM Education*, *4*(2), 213–234. https://doi.org/10.51355/jstem.2018.46
4	iSTEM	ker, C. K., & Galanti, T. M. (2017). Integrating STEM in elementary classrooms using model-eliciting activities: Responsive professional development for mathematics coaches and teachers. *International Journal of STEM Education*, *4*(1), 1–15. https://doi.org/10.1186/s40594-017-0066-3
5	iSTEM	aran et al., 2016)
6	iSE	arrett et al., 2014)
7	iST	elik, T., & Yarden, A. (2016). Promoting the asking of research questions in a high-school biotechnology inquiry-oriented program. *International Journal of STEM Education*, *3*(1), 1–13. https://doi.org/10.1186/s40594-016-0048-x
8	iSTE**A**M (**A**rt)	sh, S. B., Cook, K. L., Ronau, R. N., Rakes, C. R., Mohr-Schroeder, M. J., & Saderholm, J. (2016). A highly structured collaborative STEAM program: Enacting a professional development framework. *Journal of Research in STEM Education*, *2*(2), 106–125. https://doi.org/10.51355/jstem.2016.25
9	iSTEM**M** (**M**edicine)	anady, M. A., Moore, D., Votruba-Drzal, E., Greenwald, E., Stites, R., & Schunn, C. D. (2017). How personal, behavioral, and environmental factors predict working in STEMM vs. Non-STEMM middle-skill careers. *International Journal of STEM Education*, *4*(1), 1–16. https://doi.org/10.1186/s40594-017-0079-y
10	iSE	vlazoglu, B., & Stuessy, C. L. (2017). Identifying and verifying earthquake engineering concepts to create a knowledge base in STEM education: A modified Delphi study. *International Journal of Education in Mathematics, Science and Technology*, *5*(1), 40–52. https://doi.org/10.18404/ijemst.60674
11	iSTEM	ittum, J. R., Jones, B. D., Akalin, S., & Schram, Á, B. (2017). The effects of an afterschool STEM program on students' motivation and engagement. *International Journal of STEM Education*, *4*(1), 1–16. https://doi.org/10.1186/s40594-017-0065-4
12	iSTEM	rlu, M.A., & Aydin, E. (2016). Evaluation of learning gains through integrated STEM projects. *International Journal of Education in Mathematics, Science and Technology*, *4*(1), 20–29. https://doi.org/10.18404/ijemst.35021
13	iSTEM	re, E. A., Ellis, J. A., & Roehrig, G. H. (2018). Understanding science teachers' implementations of integrated STEM curricular units through a phenomenological

		multiple case study. *International Journal of STEM Education*, *5*(1), 1–19. https://doi.org/10.1186/s40594-018-0101-z
14	iSM	ərdorp, A., Bakker, A., van Maanen, J. A, & Eijkelhof, H. M. (2014). Meaningful statistics in professional practices as a bridge between mathematics and science: An evaluation of a design research project. *International Journal of STEM Education*, *1*(1), 1–15. https://doi.org/10.1186/s40594-014-0009-1
15	iSTEM	ıglish & King, 2015)
16	iSTEM	łogan, N., & Stuessy, C. L. (2015). Modeling successful STEM high schools in the United States: An ecology framework. *International Journal of Education in Mathematics, Science and Technology*, *3*(1), 77–92. https://ijemst.org/index.php/ijemst/article/view/54
17	iSTEM	apa, A. T., & Tank, K. M. (2017). Supporting integrated STEM in the elementary classroom: A professional development approach centered on an engineering design challenge. *International Journal of STEM Education*, *4*(1), 1–16. https://doi.org/10.1186/s40594-017-0058-3
18	iSTEM	ꞑua, J. L., Bargagliotti, A., Phillips, J. A., Herreiner, D., & DaSilva, L. (2018). Antecedents, processes, and outcomes of an interdisciplinary, conference/collaboration: A comparative study of three interdisciplinary working groups. *Journal of Research in STEM Education*, *4*(1), 101–116. https://doi.org/10.51355/jstem.2018.38
19	iSE	ldstein, M. H., Omar, S. A., Purzer, S., & Adams R.S. (2018). Comparing two approaches to engineering design in the 7th grade science classroom. *International Journal of Education in Mathematics, Science and Technology*, *6*(4), 381–397. https://doi.org/10.18404/ijemst.440340
20	iSE	fer, S. I., Schumacher, R., & Rubin, H. (2017). The test of basic Mechanics Conceptual Understanding (bMCU): Using Rasch analysis to develop and evaluate an efficient multiple choice test on Newton’s mechanics. *International Journal of STEM Education*, *4*(1), 1–20. https://doi.org/10.1186/s40594-017-0080-5
21	iSTEM	lmlund, T. D., Lesseig, K., & Slavit, D. (2018). Making sense of “STEM education” in K-12 contexts. *International Journal of STEM Education*, *5*(1), 1–18. https://doi.org/10.1186/s40594-018-0127-2
22	iEM	ıopio, P. J., & Wesonga, R. (2017). Polytechnic engineering mathematics: Assessing its relevance to the productivity of industries in Uganda. *International Journal of STEM Education*, *4*(1), 1–10. https://doi.org/10.1186/s40594-017-0078-z
23	iSTEM	Force, M., Noble, E., King, H., Century, J., Blackwell, C., Holt, S., Ibrahim, A., & Loo, S. (2016). The eight essential elements of inclusive STEM high schools. *International Journal of STEM Education*, *3*(1), 1–11. https://doi.org/10.1186/s40594-016-0054-z
24	iSTEM	nberg, T., & Trzynadlowski, N. (2015). How STEM academy teachers conceptualize and implement STEM education. *Journal of Research in STEM Education*. *1*(1), 45–58. https://doi.org/10.51355/jstem.2015.8

25	iSTE**M** (**M**edicine)	dwig, P. M., Nagel, J. K., & Lewis, E. J. (2017). Student learning outcomes from a pilot medical innovations course with nursing engineering, and biology undergraduate students. *International Journal of STEM Education*, *4*(1), 1–14. https://doi.org/10.1186/s40594-017-0095-y
26	iSTEM	nch, S. J., Spillane, N., House, A., Peters-Burton, E., Behrend, T., Ross, K. M., & Han, E.M. (2017). A policy-relevant instrumental case study of an inclusive STEM-focused high school: Manor New Tech High. *International Journal of Education in Mathematics, Science and Technology*, *5*(1), 1–20. https://www.ijemst.net/index.php/ijemst/article/view/104/105
27	iSEM	this, C. A., Siverling, E. A., Moore, T. J., Douglas, K. A., & Guzey, S. S. (2018). Supporting engineering design ideas with science and mathematics: A case study of middle school life science students. *International Journal of Education in Mathematics, Science and Technology*, *6*(4), 424–442. https://doi.org/10.18404/ijemst.440343
28	iSTEM	yes, R., Rittschof, K., Gallant, B., & Martin, C. (2017). Real STEM: An interdisciplinary STEM program. *Journal of Research in STEM Education*, *3*(1/2), 1–16. Retrieved from https://doi.org/10.51355/jstem.2017.26
29	iSTEM	Fadden, J. R., & Roehrig, G. H. (2017). Exploring teacher design team endeavors while creating an elementary-focused STEM-integrated curriculum. *International Journal of STEM Education*, *4*(1), 1–22. https://doi.org/10.1186/s40594-017-0084-1
30	iSM	hmetlioglu, D., & Ozdem, Y. (2014). Connectivity Theory at work: The referrals between science and mathematics in a science unit. *International Journal of Education in Mathematics, Science and Technology*, *2*(1), 36–48. https://www.ijemst.net/index.php/ijemst/article/view/10/10
31	iSTEM	gdi, M. E., Leammukda, F., & Roehrig, G. (2018). Developing identities of STEM teachers at emerging STEM schools. *International Journal of STEM Education*, *5*(1), 1–13. https://doi.org/10.1186/s40594-018-0136-1
32	iSTEM	emngwa & Oliver, 2018)
33	iSTEM	ers-Burton, E. E., & Johnson, T. (2018). Cross-case analysis of engineering education experiences in inclusive STEM-focused high schools in the United States. *International Journal of Education in Mathematics, Science and Technology*, *6*(4), 320–342. https://doi.org/10.18404/ijemst.440335
34	iSTEM	ers-Burton, E. E., House, A., Han, E., & Lynch, S. (2018). Curriculum and instruction at exemplar inclusive STEM high schools. *Journal of Research in STEM Education*, *4*(2), 193–212. https://doi.org/10.51355/jstem.2018.45
35	iSE	zer, Ş., Goldstein, M. H., Adams, R. S., Xie, C., & Nourian, S. (2015). An exploratory study of informed engineering design behaviors associated with scientific explanations. *International Journal of STEM Education*, *2*(1), 1–12. https://doi.org/10.1186/s40594-015-0019-7
36	iSTEM	ng-Whalen. E., Dare, E., Roehrig, G., Titu P., & Crotty, E. (2018). From conception to

		curricula: The role of science, technology, engineering, and mathematics in integrated STEM units. *International Journal of Education in Mathematics, Science, and Technology*, *6*(4), 343–362. https://doi.org/10.18404/ijemst.440338
37	iSTEM	berts, T., Jackson, C., Mohr-Schroeder, M. J., Bush, S. B., Maiorca, C., Cavalcanti, M., Schroeder, D. C., Delaney, A., Putnam, L., & Cremeans, C. (2018). Students' perceptions of STEM learning after participating in a summer informal learning experience. *International Journal of STEM Education*, *5*(1), 1–14. https://doi.org/10.1186/s40594-018-0133-4
38	iSTEM	ıwab, D. B., Cole, L. W., Desai, K. M., Hemann, J., Hummels, K. R., & Maltese, A. V. (2018). A summer STEM outreach program run by graduate students: Successes, challenges, and recommendations for implementation. *Journal of Research in STEM Education*, *4*(2), 117–129. https://doi.org/10.51355/jstem.2018.40
39	iSTEM	ɜrnoff, D. J., Sinha, S., Bressler, D. M., & Ginsburg, L. (2017). Assessing teacher education and professional development needs for the implementation of integrated approaches to STEM education. *International Journal of STEM Education*, *4*(1), 1–16. https://doi.org/10.1186/s40594-017-0068-1
40	iSTEM	avit et al., 2016)
41	iSTEM	ngkulluksn, V. W., Matewos, A. M., Sinatra, G. M., & Marsh, J. A. (2018). Motivational factors in makerspaces: a mixed methods study of elementary school students' situational interest, self-efficacy, and achievement emotions. *International Journal of STEM Education*, *5*(1), 1–19. https://doi.org/10.1186/s40594-018-0129-0

Notes. Abbreviated references are listed in the final reference list.