ELECTRONIC JOURNAL FOR RESEARCH
IN SCIENCE & MATHEMATICS EDUCATION
VOL. 29, NO. 1, 1-15

STEM Curricula, Practices, Policies, and Implications in the Middle Grades: A Review

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ABSTRACT

STEM education has become an economic factor in the United States, developing countries and in other established economies such as Europe and Australia. There is, however, a lack of consensus on how STEM curricula are enacted across K-12 learning environments in general and with particular interest in the middle grades - the phase of schooling that includes grades five to nine. We conducted a comprehensive review of empirical studies, related to STEM curriculum in formal middle school classrooms. Specifically, our review was guided by the question: How is STEM conceptualized and implemented in middle grades instruction? With a focus on curriculum containing two or more of the four disciplinary combinations, 93 empirical studies were selected for review. Each article was read and snippets from the studies related to the research question were documented. These snippets became codes, and during focused and repeated readings and discussions, patterns emerged from which themes were generated. Some of the emerging themes were the STEM curricular landscape and the positioning of science in the STEM curriculum. Our findings revealed inconsistencies around the practices of STEM as a discipline within the middle grades and the nature of integration across the disciplines. While science was treated as a core discipline, in most cases there was no clear identification of competencies across the disciplinary combinations. Leveraging reasonable connections in ways to initiate and improve the development of STEM literacy was limited. Our review signals the need for evidence-based practices and an established consensus around STEM curricula in middle schools.

Keywords: STEM education; STEM in the middle grades; STEM literacy; secondary curriculum; middle school curriculum; student STEM learning

Introduction

Over the past two decades, the STEM acronym has been afforded much prominence in the political, economic, and educational spheres in both developed and developing countries. The morphing of science, technology, engineering, and mathematics into this acronym signaled a move away from their treatment as singular disciplines and toward a more comprehensive approach to developing a range of literacies. This was promising! The acronym was coined by the National Science Foundation-NSF (2010) in response to concerns in the United States (U.S.) related to maintaining the pipeline of professionals to fill STEM jobs and careers, impacting the economic needs for national security and personal needs to become productive knowledgeable citizens prepared with 21st-century workforce skills (Brophy et al., 2008; Brown et al., 2011; Kennedy & Odell, 2014; Zollman, 2012).

This notion of a 21st century workforce became a rallying point around the world and with implications for the reconceptualization of the nature of schooling and science teaching and learning.

The need to improve teaching and learning in STEM education quickly became an economic factor in developing countries and in long established economies such as Europe, Australia. and the U.S. Thus internationally, STEM caught the attention of educators, researchers, and policymakers as a framework for fostering scientific literacy in schools (Brown et al., 2011; Bybee, 2010) and more importantly the development of literacy across all four disciplines

STEM Literacy

STEM education, however, does not simply mean achieving literacy in the four disciplines (Toulmin & Groome, 2007; Zollman, 2012) nor mapping the numerous overlapping interdisciplinary skills, concepts, and processes. STEM literacy within a knowledge-based economy, as reported in the National Governor's Association Building a Science, Technology, Engineering, and Math Agenda (2007) is the promise to adapt and accept changes guided by the prominence of technology. According to Bybee (2010), STEM literacy includes conceptual understanding and procedural skills and abilities for individuals to address STEM-related personal, social, and global issues. These outcomes, advocates assert, can enhance motivation for learning and improve student interest, achievement, and persistence (National Research Council, 2014). STEM learning has therefore been given much credence in education as a vehicle to engage learners in real-world experiences. In the process, such learning experiences have the potential to enhance the skills, creativity, and disposition of learners toward alleviating the concerns first brought to the fore by the NSF.

Middle grades can be considered the transition stage of schooling where learners make choices that will impact their educational trajectory influencing the path to their career choices (Nugent et al., 2015; Ogle et al., 2017). Researchers posit that STEM education in middle schools provides viable opportunities for students to begin to connect learning to the real world outside the school (Barak & Asad, 2012). However, there is a lack of understanding and visibility of how STEM in general is enacted, particularly in the middle grades where it remains vague and poorly understood. This lack of visibility and the importance of schooling in the middle grades has heightened the need to better understand the state of STEM education within this phase of student learning. Of concern is the ways STEM education is conceptualized and enacted within the middle grades. We therefore reviewed the literature and examined the design, implementation practices, and effectiveness of STEM-focused curriculum in middle schools. Specifically, our review sought to answer the following question: How is STEM conceptualized and implemented in middle grades instruction?

Methods

To respond to our research question, we conducted a comprehensive search of global, empirical studies, related to STEM curriculum and its implementation in formal middle school classrooms. Our purpose was to better understand how STEM education is conceptualized and enacted in the middle grades and to identify areas for further research. We defined middle schools as the phase of schooling that includes grades five to nine. We also intentionally set out to review studies of curriculum containing two or more of the four disciplinary combinations. We began our research by exploring international research bases such as EBSCO host, Academic Search Premier, APA PsychInfo, Education Source, ERIC, Professional Development Collection and Google Scholar. In establishing our parameters, we limited our search to empirical research published in the years between 2010 and 2021 and excluded practitioner articles, book chapters, and dissertations. Our search terms included STEM, STEM in the middle grades, STEM literacy, secondary curriculum, middle school curriculum, and student STEM learning. In the initial search of the databases, we amassed 171 potential studies. In the preliminary review, studies were eliminated based on their titles. For example, titles containing elementary and post-secondary education or preservice teachers were removed, leaving 110 articles. The abstracts were then read independently by both researchers and together we determined the extent to which each of the studies met our established criteria. The authors shared and discussed the articles that were included and excluded and settled on a total of 93 potential studies for review. These studies were downloaded as pdf documents and saved using the author's last name, year of publication, and the first four words in the title.

In the next phase of the review process, each article was read, and annotated bibliographies were developed. As the annotated bibliographies were being developed, 17 articles were further deselected because questions arose around the research participants and or the nature of the research approach. For example, Asghar et al. (2012) and Burrows et al. (2021) were deselected because of their focus on teachers' professional development. Further organization of the studies occurred, in addition to the alphabetical arrangement of the surname of the first author, columns were added that documented selected snippets from the studies related to the research questions. These snippets became codes, and during focused and repeated readings and discussions, we were able to discern emerging patterns and themes across the 93 studies that satisfied the selection criteria. Some of the emerging themes were STEM curricular landscape, the positioning of science in the STEM curriculum, and the outcomes for formal STEM curricular implementations.

Research Synthesis

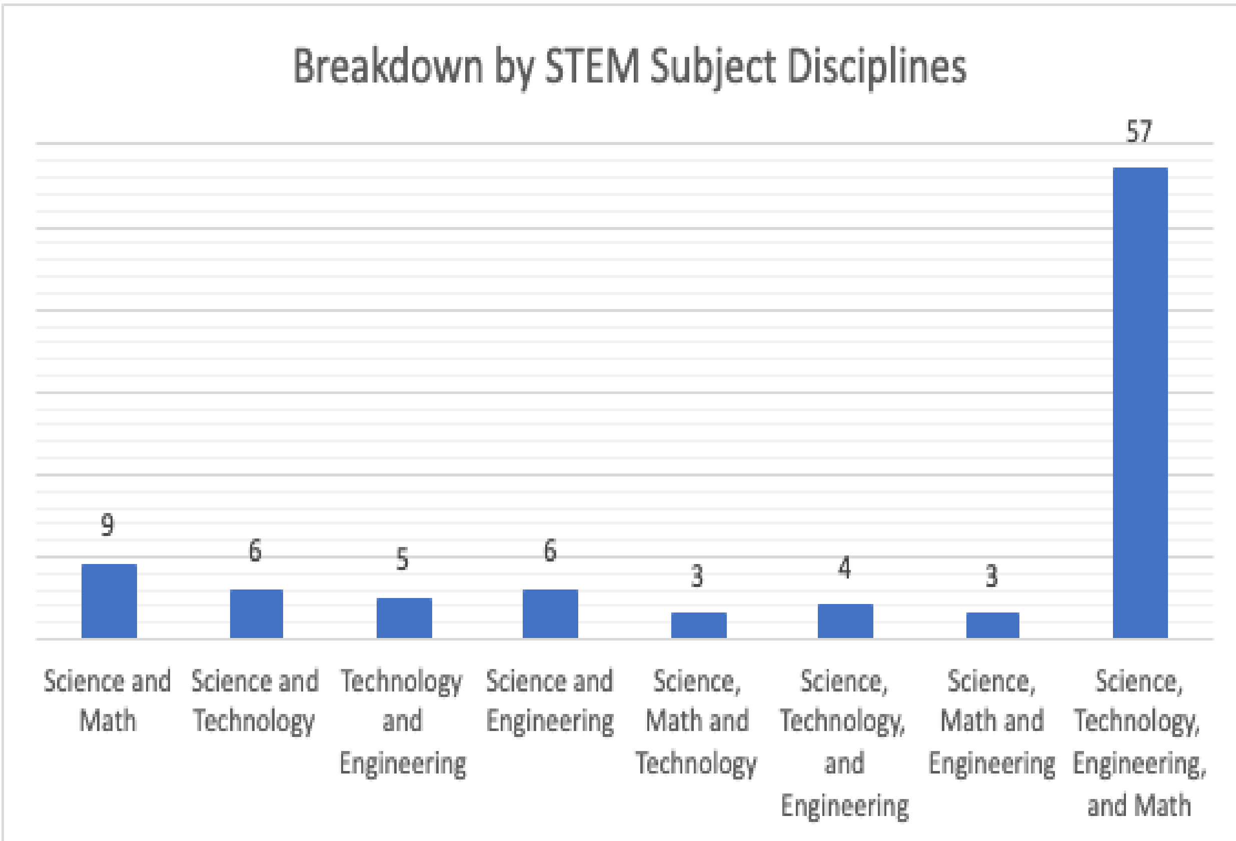
STEM Curricula Landscape

Our review of the body of literature on STEM curricula in the middle schools reveals many inconsistencies in the description of the common attributes and their implementation across the four combined disciplines within the STEM acronym. These inconsistencies impacted the discipline combinations within the landscape of STEM teaching in the middle grades and the determination of the hallmarks of the disciplines when combined. The exploration of how STEM is implemented, and the occurrences of the combination of disciplines provides an understanding of the status of middle grade STEM curricula development, practices, policies, and implementation. Ninety-three research studies implementing two or more STEM disciplines satisfied the criteria and became the data set for the review. A total of 69 studies were based within the U.S. and spanned the mid-west, northeast, southern, southeast, intermountain, western, and coastal plains regions. Additionally, the remaining 24 articles were international research studies from China, Turkey, Thailand, Switzerland, Malaysia, United Kingdom, Israel, Australia, Korea, and Cambodia. Figure 1 provides a graphical representation of the selected articles to show the distribution in the number of STEM discipline combinations. Interestingly, the full combination of the four disciplines, science, technology, engineering, and mathematics was by far the most prevalent curriculum.

The purpose of the review was to better understand how STEM education is conceptualized and enacted in the middle grades. Our research highlighted the similarities and differences in the conceptualization and enactment of STEM in the middle grades on an international level. Figure 1 shows the variation that exists among the combinations of the disciplines and the conceptualization of STEM. Our findings further reveal the selection and combination of disciplines was not necessarily a function of the learning needs of the immediate students or participants. Rather, the enacted programs and the research were short-term and directly tied to funding from a range of agencies with interest in both education in general and STEM. For example, research conducted by Karahan and colleagues (2015), which explored students' attitudes towards science and technology digital media in a middle grades' science classroom sought to motivate and engage, which improved their learning of science content and participation in class discussions. In another project, the researchers expressed how providing lesson activities to teachers influenced students' critical thinking, collaboration, and communication skills in finding solutions to real-world problems (Quigley et al., 2016).

Figure 1

Breakdown by STEM Subject Disciplines



Science, Technology, Engineering, and Mathematics (STEM)

Educators posit that effective STEM education has the potential to enrich K-12 curriculum and instruction (Guzy et al., 2014). The nature of STEM education and the implementation practices requires students to be engaged in curricular activities that connect to real-world experiences. We recognized that there were many variations in the approaches to implementing STEM instructional activities. Some researchers highlighted problem-based and project-based learning (Caprano et al., 2016; Han & Carpenter, 2014; Prettyman et al., 2012; Tsinajinie et al., 2021), including robotics (Barak & Assal, 2018; Juliaet al., 2017; Kucuk & Sisman, 2020; Ntemngwa et al., 2019, Zhong & Wang, 2021). Project Lead the Way, a STEM curriculum (Stohmann et al., 2011; Stohmann et al., 2012), included the use of technology to approach solving real-world problems. Other researchers incorporated the arts in the instructional activities, thus forging its importance and establishing STEAM as a value to integration (Quigley et al., 2016; Quigley et al., 2017; Hunter-Doniger & Sydow, 2016. In exploring the viability of STEAM, Hunter-Doniger & Sydow, (2016) compared performances on standardized tests and posited that incorporating the arts proved beneficial to student learning and in supporting the goals of STEM learning.

Gardner and colleague (2018) used an approach that required high student engagement during the enactment of a STEM module. Throughout the project, students were engaged in critical reflections and continuous sharing of their learning within small groups. The researchers reported that when students navigate a STEM-focused curriculum, they learn specific STEM disciplinary content knowledge and develop critical thinking skills. In one study, however, Genareo et al. (2016) focused on the development and study of a partnership between the local university and a middle school. These researchers examined how the partnership could influence students' STEM interest and confidence and concluded that students did not gain interest and in fact lost confidence in STEM.

Science, Technology, and Engineering

Students were engaged in several innovative experiences in Science, Technology, and Engineering (STE) curriculum, as researchers examined the use of creative tools in learning. A key feature of the combination of the disciplines STE was the use of interactive design tools to engage students in simulations (Mosqueda et al., 2011) and virtual field trips (Bowen et al., 2015; Potkonjak, et al., 2016). In one learning experience described as a short-term intervention, Nugent et al. (2010) implemented a virtual robotic summer camp with the goal of increasing student interests in technology. The program required students to analyze scenarios that depicted robotics, global positioning systems, and geographic information systems engaging in problem-solving activities requiring teamwork. The students were not only engaged with and learning the technology tools, but were also expected to evaluate their learning during the process. The researchers reported success and posited that the high student engagement resulted in the development of positive attitudes towards STEM.

Science, Technology, and Mathematics

Data analysis revealed that enacting Science, Technology, and Mathematics (STM) curriculum lacked commonality across the disciplines, as researchers were heavily focused on creating learning environments that would stimulate interests in the discipline. The number of articles found for this section was sparse but revealed the hidden gem of how STM positively impacted both teachers' and students' experiences, supporting student interest in pursuing related careers. To positively impact student interest in STEM careers, Ashchbacher et al. (2014) evaluated participants' curriculum and concluded that the discipline combination did not address STM related careers. The researchers evaluated students' beliefs and skills with the focus of seeking to understand students' potential career aspirations. In another example, Berlin & White, (2012) used a pre-service teacher preparation course for beginning teachers who were certified to teach the subject areas of STM to evaluate how STM influence attitudes and perceptions. The research revealed that incorporating the three disciplines complemented instruction, allowing the development of concepts and skills.

Science, Engineering, and Mathematics

Only three research articles focused on Science, Engineering, and Math (SEM). See Table 1 for this information and other details about the review of the literature. Smith et al. (2013) provided hands-on approaches using science and mathematics to solve real-world engineering problems. Students designed and evaluated the rate of change and slope of a staircase. Also, students could identify and navigate how to use math to solve real-world engineering problems (Smith et al., 2013). The integration of SEM enhanced the learning environment by providing avenues for teachers to increase their knowledge and skills in the related disciplinary content areas.

Table 1

Review of Literature Key Features of STEM Disciplines

Discipline Combinations	Methods Used	Common feature(s) within discipline	Different feature(s) within discipline	Contributing Authors
STEM	quantitative/ qualitative	Curriculum focused/used to enhance instruction/student engagement/surveys used to quantify student attitudes and career choices	Curriculum design (i.e. problem-based learning, project-based learning, robotics, agriculture, astronomy)	Barak & Assal, 2018; Cooper & Heaverlo, 2013; Gardner & Tillotson, 2018; Hava & Ünlü., 2021; Wyss et al., 2013
SEM	practitioner/ quantitative/ qualitative	Use of workshops/PD's	Methods approach	Foutz et al., 2011; Harwell et al., 2015; Smith et al., 2013;
STM	practitioner/ quantitative/ qualitative	Career focus/student attitude/student engagement	Pre-service teachers (certified to teach STM)	Aschbacher et al., 2014; Berlin & White, 2012; Clark et al., 2018
STE	practitioner/ quantitative/ qualitative	Virtual laboratories/virtual simulation/student engagement	Methods approach	Bowen et al.,2015; Mosqueda et al.,2011; Nugent et. al., 2010; Potkonjak et.al., 2016;
ST	quantitative/ qualitative	Technology serves as support role/common methods approach/ student engagement/ implications were based on improving programs or existing curriculum	N/A	Adedokun et al., 2015; Basu et al., 2016; Becker & Bishop, 2016; Karahan et. al., 2015; Macbeth et al.,2021; Mosley et al.,2016
TE	quantitative/ qualitative	Technology and engineering used as a support for engaging students	Tool used is different (i.e., curriculum, robotics game, coding, in-person factory visits)	Bartholomew et al., 2018; Hughes et al., 2021; Leonard et al., 2016; McCulloch et al., 2012; Smit et al., 2021
SM	political advocacy/ practitioner/ quantitative/ qualitative	Focused on improving STEM/influential in the field	Tool used is different (i.eg., survey, EOG exam, graduate course)	Blotnicky et al., 2018; Eng & Szmodis, 2016; Hansen & Gonzalez., 2014; Lee et al., 2013; McHugh et al., 2017; Paff Ogle et al., 2017; Selmer et al., 2014; Shaughnessy, 2013; Stump et al., 2016
SE	practitioner/ quantitative/ qualitative	Workshop/PD used to implement curriculum/real-world connection	Method for collecting data (i.e., observation, survey, interview, book creation)	Abbot, 2016; Allen, 2013; Ardito et al., 2014; Christensen & Knezek, 2018; Egbue et al., 2015; Guzy et al., 2016; Lie et al., 2019; Moore et al., 2016; Stansell et al., 2015; Thananuwong, 2015

Note: Not all STEM articles recorded

Harwell et al., (2015) designed an engineering-based learning experience for teachers to understand STEM standards with a focus on SEM. Students were evaluated after the implementation of the engineering-based curriculum. Each discipline was assessed separately, pre- and post- unit implementation. These researchers found evidence that supports that psychometrically sound instruments sensitive to STEM-oriented curriculum offer school districts a suitable tool for gauging the impact of an engineering design-based approach to teacher professional development and curricular design on students' understanding of STEM concepts. In another example, Foutz et al., (2011) provided a workshop experience that supported teachers as they developed SEM lesson plans. According to Foutz et al. (2011), an agriculture engineering lesson implementation lends itself to not only integrating science, but also mathematics both horizontally and vertically across curriculum. In addition, the integration was beneficial to students as they worked on finding solutions to real-world problems.

Science and Technology

The articles that focused on the integration of Science and Technology (ST) reflected the well-documented historical role where technology served to enhance science teaching and learning. The expressed focus of all six articles was the development and understanding of how student perspective, engagement, and learning were enhanced during the enactment of the curriculum that included ST (Adedokun et al., 2015; Basu et al.., 2016; Becker & Bishop., 2016; Karahan et al., 2015; Macbeth et al., 2021; Mosley et al., 2016). Adedokun et al. (2015) studied the use of virtual field trips to elicit students' perspective of science and evaluated and determined how students' attitudes and motivation towards science changed while participating in this research study. Adedokun et al. (2015) found that the "moderating effect of program type on student's perception of a scientist offers insights into a potential factor related to differential program effect" (p. 98). While Adedokun et al.'s (2015) research advances knowledge of virtual field trips on students' perceptions of a scientists it also makes available tools to effectively evaluate observations of students in science and technology-related activities.

In another exploration of the use of technology, Becker & Bishop., (2016) used the social media platform, Twitter, where student participants interacted with their peers, engaged in discussions related to science, and connected their science learning to their own lives. The use of this digital platform allowed students to explore science from distant geographical locations. This digital platform allowed both teachers and students to interact with science phenomena and collected evidence from various locations. Becker & Bishop (2016) affirmed that social media was a unique set of technological tools to aid the effective implementation and support of student science learning. Overall, these studies show that 21^{st} century educational technology, and the related digital platforms, have the potential to aid science learning by engaging students and connecting them to their real-world activities.

Science and Engineering

Articles that focused on Science and Engineering (SE) contributions to STEM instruction appeared in three categories: curriculum enhancements, focused workshops, and professional development. The SE articles also incorporated a real-world connection to STEM learning. Articles related to curriculum enhancements fostered student support by implementing valuable resources that encourage student engagement (Ardito et al., 2014; Christensen & Knezek, 2018; Egbue et al., 2015; Guzy et al., 2016; Moore et al., 2016; Stansell et al.,2015; Thananuwong et al.,2015). Some of the researchers focused on the creation of professional development to aid and prepare teachers to promote SE curriculum that centered real-world connections within STEM-related learning. Eight of the nine research articles included the strategy of problem-based learning activities with direct applications to the real world (Ardito et al.., 2014; Christensen & Knezek, 2018; Egbue et al., 2015; Guzy et al.., 2016; Moore et al., 2016; Stansell et al.,2015; Thananuwong et al.,2015). Lie et al. (2019), however, evaluated SE curriculum through teacher professional development by focusing on diverse students. One important conclusion that emerged from the approach of using problem-based activities was that SE related concepts can be effectively integrated in a curriculum that includes real-world activities.

Science and Mathematics

History confirms that when Science and Mathematics (SM) are integrated, learners are likely to gain meaningful knowledge and skills from each of the two subjects (Pringle et al., 2020). Eng et al (2016) examined how the quality of female student education was enhanced through incorporating SM measures to positively influence student-led instruction and teacher effectiveness. They posited that confidence and perceptions of STEM can enhance the learning experience of SM learners. In another example, Selmer et al. (2014) incorporated real-world examples by having participants complete a farmer's market and school gardening project centered on a project-based learning approach. In these activities, participants manipulated a three-phase project where phase one, known as the "before phase" (p. 21-22) elicited background knowledge of what students knew about gardening. Phase two, the "during phase" (p. 22-23), implemented guided facilitation, where students answered formulated questions about their potential experience at a farmers' market and gardening in general, prior to collecting classroom data based on the generated questions. The final phase, known as the "after phase" (p. 24-25) analyzed and interpreted the data collected from participants real-world experiences. The researchers found that the importance of "the inclusion of standards and instructional ideas for learning science content in this article heeds the recommendation in the NGSS to not teach science practices in isolation from science content" (Selmer et al., 2014, p. 29). The authors also imply that "statistical literacy"(Selmer et al., 2014, p. 29), integrated science, and mathematics can be facilitated in ways to provide learners with authentic learning exposure addressing real-world concerns.

Technology and Engineering

Technology and Engineering (TE) have been given much credence for supporting student engagement and in accomplishing the goals of each of two disciplines within curriculum implementation. Researchers examining the integration of TE focused on courses supported with an open-ended design problem (Bartholemew et al., 2010; McColluch et al., 2012), robotics (Leonard et al., 2016), factory visits (Smit et al., 2021), and coding camps (Hughes et al., 2021). This exposure to the various implementation tools supported student interests in navigating their mindset to incorporate innovative and authentic resources within their daily learning. Leonard et al. (2016) conducted a study that allowed students the opportunity to use "LEGO EV3" robotics software that allowed participants the ability to manipulate a robot. In contrast, Smit et al. (2021) engaged participants with an experience beyond technology allowing them to visit a chainsaw, filter technology, and spring factories to explore and determine if their career interest was influenced.

Research shows how integrating TE has the effect of increasing student engagement (Leonard et al., 2016; McCulloch et al., 2012). However, there are inconsistencies with the level of knowledge and skills that students learn from these digital interactions (Pringle et al., 2020). These authors contended that specific learning goals and tailored learning experiences should be at the forefront when developing and seeking to enact a cohesive and consistent STEM curriculum (Pringle et al., 2020).

Examining STEM Disciplines

Separating and reviewing the existing combinations of disciplines within STEM reveals one of the main issues of addressing STEM learning in middle school. As noted, our analysis reveals the variability that exists within the combinations of the STEM disciplines. Furthermore, there were no expressed rationale for combining the disciplines. We are therefore left to question the criteria used by the researchers and educators in determining the extent to which the discipline combinations satisfy the goals of STEM as indicated in both political and educational policy documents. While the tools used for implementation also varied based on funding and the researchers' agenda, one key observation in the research studies of this review was the position of science in STEM and the role it plays when included in the various disciplinary combinations.

Role of Science in STEM

Throughout the review, the positioning of science within curricular involving STEM was notable. All related work afforded much prominence to science content knowledge and skills and practices in the enactment of school curricula. For example, Christensen & Knezek, (2018), in the integration of SE used hands-on and real-world experiences to promote a positive influence and deepen students' knowledge of climate change. In another study, Hite & White (2019) implemented a project-based learning activity that revealed the impact of humans on sea turtles and marine environments. While their efforts were to develop a deeper understanding of how the environment is impacted by humans, a close reading reveals the extent to which the science content knowledge of sea turtles and marine education became dominant in the students' learning. Stansell et al. (2015) provided students with an opportunity to navigate real-world experiences through an engineering lens. The activity included a book titled "Engineers Needed Help-Tamika Save the Farm" with the main character navigating students through solving various real-world problems. Our analysis revealed that science as the core discipline was considered the gateway for implementing various STEM-related tools to enhance and engage student learning of STEM disciplines.

However, when incorporating science within a discipline combination, for example in SM, Hansen & Gonzalez, (2014) expressed how project-based learning in science enhanced learners' achievement in SM based in STEM instructional principles grounded in student performances. In addition, Egbue et al. (2015) proposed that when incorporating real-world energy related activities, an environment that builds sustainable and alternative resources are promoted. Regardless, science has shown to be the core for implementing STEM effectively in formal K-12 learning environments.

Notably and amongst the discipline combinations, science was not included in one, TE. In this work, students were engaged with robotics, coding, and in-person visits to relevant sites. In these project activities, students participated in real-world experiences as they developed skills related to careers in the areas of TE. Some of these skills were adaptive comparative judgment, open-ended evaluation, innovative game design, and coding. These researchers concluded that these sorts of skills engaged learners through creative and authentic experiences. It is these kinds of experiences that proponents of STEM have lauded in the thrust to enact STEM curricula in the middle grades.

Complexity of Establishing a Research Agenda in STEM

From a historical perspective, science is a well-established discipline in school curriculum. Reforms in science have often emerged in response to the nation's socio and political issues (Pringle et al., 2020). In the U.S. the recent reform in science education as documented in "A Framework for K-12 Science Education" (National Research Council, 2012) includes a definite call for integration of engineering practices in the three- dimensional approach to science learning. In addition to crosscutting concepts and core ideas, the framework document includes a call for specific opportunities to develop SE practices.

For STEM learning to maintain a desirable position in supporting the development of literacy among middle grades, it is critical for consistency across the conceptualization of the STEM disciplines. While research indicates that STEM education has had a positive impact on student learning, engagement, and motivation within STEM disciplines (Pringle et al., 2020), our review reveals that a research agenda that seeks to establish a formidable framework for implementation of STEM is warranted. Such work would not only provide a vision of effective STEM education in middle school but would provide a cohesive guide to inform curricular and classroom practices. Looking forward, a consensus around what constitutes STEM integration or STEM as a discipline is warranted. We believe such consensus would foster effective implementation of STEM within the middle grades, creating the framework for further learning and developing STEM literacy.

Conclusion

As a method, this systematic literature review allowed us to "map out areas of uncertainty and identify the lack of relevant research" and areas where innovative studies are needed (Petticrew & Roberts, 2006, p. 2). Our review of the literature also responds to calls for a greater understanding of STEM, as implemented in middle schools, with the goal of offering direction to best practices. STEM researchers regardless of the discipline combination showed much interest in student engagement and interest in the subjects. However, the range of possibilities in the combination of the disciplines does not provide a roadmap for consistency that can lead toward the full realization, and the impact of, STEM in the middle grades. As discussed, STEM is embraced by policymakers and educators because of the potential to develop literacy across all four disciplines – STEM literacy. Such combinations were not fully realized as indicated in the variability that exists.

Integration of the four disciplines should result in students making connections across the subject areas. However, not many projects facilitated such within their program and among the students. That is, from our review there was much evidence introducing practices and skills around core science ideas. However, there was little evidence to support and leverage reasonable connections across the subject areas in ways to improve student learning of the core content knowledge and skills related to each of the disciplines. Clearly, inconsistencies abound around STEM as a discipline and how each contributes to the identification of core knowledge and skills. The lack of agreement continues to plague its development and curricular enactment in middle schools. This review has heightened the awareness and the need for STEM education to arrive at a consensus that clearly articulates the importance of a core learning set of experiences. Such importance would be integrated and include core ideas, crosscutting concepts and practices, and skills from each of the disciplines – and could lead to defining STEM beyond its acronym.

The authors received no financial support for the research, authorship, and/or publication of this manuscript

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