International Journal of Education Humanities and Social Science

ISSN: 2582-0745
Vol. 3, No. 04; 2020

ANALYZING K-5TH GRADE INTEGRATED STEM CURRICULUM IMPLEMENTED SINCE 2010

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ABSTRACT
Science, Technology, Engineering, and Mathematics (STEM) education has received increased interest in the past decade. Integrated STEM education can provide students with relevant and meaningful experiences that develop STEM knowledge and 21st century competencies. The world is increasingly becoming more reliant on STEM knowledge which makes quality integrated STEM education imperative for students. One of the main concerns that has been raised in regards to integrated STEM education is the need for further curriculum development where the STEM disciplines are integrated in a meaningful way. At the elementary education level there is great potential for this to occur. The purpose of this article is to describe and analyze kindergarten to fifth grade integrated STEM education curriculum that has been implemented since 2010. This will provide perspective on the curriculum that has been implemented and what STEM subjects have been integrated in this curriculum. Implications for further work with integrated STEM education curriculum at the elementary education level are discussed.

Keywords: Curriculum; Elementary Education; Integrated STEM

1. INTRODUCTION

In a rapidly changing world, it is imperative that we educate well-rounded global citizens who are problem solvers with 21st century competencies to conquer new challenges. Integrated Science, Technology, Engineering, and Mathematics (STEM) education is a vital way to help prepare students for their current and future lives. Integrated STEM education involves hands-on learning that is done through relevant open-ended problems that develop teamwork and communication skills (Carlson & Sullivan, 2004). It can motivate students learning in mathematics and science (Wendell & Rogers, 2013) and can lead students to be interested in STEM careers (Capobianco, Yu, & French, 2015). Integrating subjects also makes learning more connected and relevant (Furner & Kumar, 2007).

Students need early exposure to integrated STEM education to build a strong foundation in STEM concepts and competencies. Because of this there has been great interest in integrated STEM education at the elementary level (Lottero-Perdue, Lovelidge, & Bowling, 2010; Stohlmann, Maiorca, & DeVaul, 2017). Though elementary teachers new to integrated STEM education may be apprehensive at first and unsure how it can be implemented well (Tuttle,

ISSN: 2582-0745
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Stanley, & Bieniek, 2016). This highlights the importance of well-designed curricular resources for integrated STEM education.

The purpose of this paper is to describe and analyze integrated STEM curriculum that has been implemented with elementary students (ages 5-11) since 2010. Moore & Smith (2014) note that "curricula that integrate STEM are rare for K-12 spaces, and of those that do, even fewer are research based and have meaningful mathematics and science. Funding to back new and research-based STEM integration curricular innovations is needed and should be targeted" (p.7). Well-designed and tested integrated STEM integration curriculum can help teachers' implementation that can lead to meaningful integration of concepts (Stohlmann, Roehrig, & Moore, 2014).

This article will provide insights on real-world contexts of integrated STEM curriculum as well as what STEM concepts have been integrated. It will serve to provide an update of what integrated STEM curriculum has been developed in the past decade. In particular, I focus on articles from teacher practitioner journals in my analysis. Prior reviews connected to integrated STEM curriculum have rarely included teacher practitioner journals. In order to get a more complete idea of what integrated STEM curriculum has been developed and implemented in classrooms, this work is needed. This can help to guide future research and implementation of integrated STEM education. One of the recommended research questions to pursue from the National Academies Press (NAP) report, *STEM integration in K-12 education: Status, prospects, and an agenda for research*, is directly related to this article. "What synergistic STEM concepts and practices are learned better through integrated STEM education approaches than via disciplinary-focused approaches, and what students and teacher supports are needed to accomplish this learning?" (NAP, 2014, p. 146). Having a clearer picture of what STEM concepts have been integrated is useful knowledge to guide future work. I now provide my theoretical framework for integrated STEM education and then summarize prior reviews on integrated STEM education.

Integrated STEM Education Theoretical Framework

The goal of integrated STEM education is to be "a holistic approach that links the disciplines so the learning becomes connected, focused, meaningful, and relevant to learners" (Smith &Karr-Kidwell, 2000, p. 22). Further, integrated STEM education is an approach that builds on natural connections between STEM subjects for the purpose of (a) furthering student understanding of each discipline by building on students' prior knowledge; (b) broadening student understanding of each discipline through exposure to socially relevant STEM contexts; and (c) making STEM disciplines and careers more accessible and intriguing for students (Wang, Moore, Roehrig, & Park, 2011). In general, integrated STEM education is an effort to combine at least two of the four disciplines of science, technology, engineering, and mathematics into a class, unit, or lesson that is based on connections between the subjects and relevant contexts (Moore et al., 2014).

There are five main tenets for assessing or developing integrated STEM curriculum (Stohlmann, Moore, & Cramer, 2013). First, the context should be motivating, meaningful, and engaging for students (Brophy, Klein, Portsmore, & Rogers, 2008). Second, there must be mathematics and/or science content as the main objectives of the curriculum (Mehalik, Doppelt, & Schunn, 2008; Stohlmann, Moore, McClelland, & Roehrig, 2011). Third, the problems students work on should be open-ended with the teacher employing student-centered pedagogies including teacher as a facilitator and cooperative learning (Stinson et al., 2009). Fourth, the curriculum should allow students to learn from failure and/or have the opportunity to redesign as they develop teamwork and communication skills (Dym et al., 2005). Finally, the curriculum should enable students to become more technology savvy through the use of technology or design of technology through the engineering design process (Morrison, 2006). In terms of technology, I use the broad definition of technology. It does not only refer to electronic devices but to every object, system, or process that has been designed or modified to be useful to some person or a group of people.

Prior Reviews of Integrated STEM Education Curriculum

There have been several reviews done in the past to describe integrated STEM education curriculum. Berlin (1989) noted that during the 1970s and 1980s several attempts were made to develop curriculum programs that integrated science and mathematics education (e.g., USMES-Unified Science and Mathematics for the Elementary School; SOCKEMS – South Central Kansas Elementary Math-Science Project; MINNEMAST– Minnesota Mathematics and Science Teaching Project; and AIMS – Activities to Integrate Mathematics and Science). Little research was done on these programs. The research that was done did not find any significant difference in achievement of students compared to a control group.

Pang and Good (2000) reviewed studies integrating mathematics and science in the 1990s and concluded that the dominant approach at this time was science content receiving the main focus with mathematics in a supporting role. The researchers also noted that there is a need for evaluating the effectiveness of integrated approaches. Berlin and Lee (2005) conducted an analysis that surveyed the nature and number of documents related to integrated science and mathematics education published from 1901 to 2001. A total of 850 documents were included in the analysis with a large amount of the publications (389) in the 1990s. It was noted that science and mathematics integration was seen most in the elementary school grades compared to middle and high school.

Becker and Park (2011) looked at studies from 1989 to 2009 on integrated STEM education that included empirical data to calculate effect sizes. Twenty-eight studies were identified and it was found that integrating STEM subjects had a positive effect on students' achievement. Only quantitative studies that measured students' achievement were included in this meta-analysis. There was limited research on the effects of integrative approaches among STEM subjects on students' mathematics achievement though.

Taking a focus on engineering as the essential feature of integrated STEM, Diaz and Cox (2012) reviewed the literature on P–12 engineering education between 2001 and 2011. Fifty publications were identified and thirty-four of the studies used the rationale of improving mathematics and science achievement through engineering education interventions. The vast

ISSN: 2582-0745
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majority of the studies looked at teacher professional development or outreach activities with students done outside of the regular school setting. It was suggested that more work needs to look at integrated STEM education implemented during the regular school day.

Another article that described how integrated STEM education could be advanced in elementary education noted two curriculum programs that showed promise to be beneficial to students that had a focus on engineering education. One of the curriculum programs was Engineering is Elementary (EiE) which was developed through a National Science Foundation grant at the Boston Museum of Science (BMS). The program includes 20 stand-alone modules that are paired with 20 major science concepts taught in the elementary grades. Each unit includes assessments for students to judge the quality of both the original design and the improved design. The second program was a collaboration between the Tufts University Center for Engineering Educational Outreach (CEEO) and the LEGO® company. The LEGO® Engineering project strives to provide tools and resources to educators based on LEGO® Education products, most notably the Mindstorms line. This has led to the ROBOLAB software for LEGO® Mindstorms, used by over ten million students around the world in 15 languages (Brophy et al., 2008). The number of elementary teachers using the LEGO® engineering project and/or EiE in elementary classrooms has increased. Further research has also been conducted on these programs to improve the curriculum and demonstrate effectiveness (Boston Museum of Science, 2020a; Yanyan, et al., 2016).

A systematic analysis of STEM education publications in thirty-six journals from 2000 to 2018 showed tremendous growth in scholarship in the field of STEM education internationally; especially in the past ten years. The review looked at the number of articles published, authorship nationality, and research topic. Curriculum development continues to be an important topic of research to support teachers to implement integrated STEM education well. Authors from the United States of America, Australia, Canada, and countries in Asia are very active in the field (Li, Wang, Xiao, & Froyd, 2020).

In my work, I reviewed empirical studies done on integrated steM education done at the K-12th grade level from 2008 to 2018. Integrated steM education has an explicit focus on mathematics in integration. At the elementary level there were five studies identified that showed mostly positive results along with the importance of well-structured curriculum. The results of the studies in the review provided support for the benefits of an integrated STEM education approach and further research in this area. I proposed three main ways in which to focus future research: mathematical modeling, engineering design challenges, and open-ended or game-based mathematics integrated with technology (Stohlmann, 2018).

The findings and conclusions of the prior research support that further research work is needed with integrated STEM education at the elementary grades level in the regular school setting. Recently, positive results have been found in integrating STEM subjects including the development of mathematical understanding, increased mathematical achievement, engagement, and interest in STEM fields (Stohlmann, 2018). It is known that integrated STEM education research work is increasing (Li et al., 2020) but more needs to be known about the STEM topics that are being integrated (Stohlmann, 2018). Also, a better idea of what integrated STEM curriculum is being implemented during the regular school day is needed (Diaz & Cox, 2014). This article will provide further insights into the curriculum that has been developed and implemented in the past decade. This article can be a useful resource for teachers as they seek to integrate STEM education in their classrooms. It can also aid researchers and teachers who do work in integrated STEM education curriculum development by analyzing what STEM curriculum is available and what STEM content has been integrated. This can guide further work by knowing what STEM content topics show promise for integration and what topics may need further curriculum development.

2. METHOD

The articles analyzed and described in this paper were identified by a close examination of two elementary education journals: Science and Children and Teaching Children Mathematics. Both of these journals are published by leading organizations in mathematics and science education. Science and Children is published by the National Science Teaching Association (NSTA). NSTA is the largest organization in the world committed to promoting excellence and innovation in science teaching and learning (NSTA, 2020). Teaching Children Mathematics is published by the National Council of Teachers of Mathematics (NCTM). NCTM is the world's largest mathematics education organization with the goal to advocate for high-quality mathematics teaching and learning for every student (NCTM, 2020). Both of these journals publish articles on classroom-tested integrated STEM education curriculum. Often in reviews of integrated STEM education these journals are not included due to being more practitioner-based. Analyzing articles in these two journals will provide a more accurate picture of the integrated STEM curriculum that has been developed and implemented in the regular school setting. In addition, many of these articles are authored by teachers and researchers collaborating together in the classroom. This is beneficial as the curriculum developed and tested is analyzed by an instructional and research-based lens.

Every article published in these two journals between 2010 to March 2020 was analyzed to determine if the implementation of kindergarten-5th grade (ages 5-11) integrated STEM education curriculum was the focus of the article. At least two of the four disciplines of STEM had to be integrated through a relevant context. Every article was read through until it could be determined if the article included integrated STEM education curriculum. Eighty-five articles were identified that included integrated STEM education curriculum. Twenty-one of the articles were NCTM articles and sixty-four of the articles were NSTA articles. Each article was then summarized with the following information: grade level of students, description of integrated STEM education curriculum, time or number of lessons to implement the curriculum, what STEM disciplines were integrated, and what STEM content was focused on. As noted at the end of my description of my theoretical framework, technology was viewed in a broad sense in that it is anything humanmade that is used to solve a problem. Many of the integrated STEM curriculum activities included materials that students would use in their designs such as measurement tools and consumables like cardboard, aluminum foil, cloth, tape, and construction paper. In summarizing the technology, any materials used for design in the open-ended activities are summarized as "design materials." If there was technology programs, robotics, or 3D printers

ISSN: 2582-0745
Vol. 3, No. 04; 2020

used in the curriculum this was specifically noted. The articles were then categorized by grade band (K-2nd and 3rd-5th) as well as which STEM disciplines were integrated.

3. RESULTS

The results are organized by describing the kindergarten to second grade curriculum first and then the third to fifth grade curriculum. Each grade band is broken down by which of the four disciplines of STEM were integrated in the curriculum. If the time for each lesson is not noted, it was approximately 50 minutes. Some of the lessons were implemented outside of the regular school setting in after school, summer, or weekend programs. These implementations are noted as informal education. The implementation time listed for each unit or lesson includes any time described for activities to develop mathematics and/or science concepts to be used in the open-ended integrated STEM parts of the units. Overall, there were twenty-four articles at the K-2nd grade level and sixty-one at the 3rd-5th grade level.

K-2nd Integrated STEM curriculum

SE

There was one unit that integrated science and engineering. This was a four week unit with second graders centered around designing healthy ice pops. Students worked to create a new flavor of ice pop that was tasty and healthy. Students also worked on marketing and selling the ice pops. Science was incorporated through a focus on nutrition and engineering was included through the design process (Bubnick, Enneking, & Egbers, 2016).

SEM

There was one article that described a set of lessons that integrated science, engineering, and mathematics. The activities lasted three lessons and were implemented with first graders. The context of the lessons was on recycling and protecting the environment. The students worked on methods to categorize and represent a collection of objects. They also determined a method to predict the number of items of litter collected each day based on data from previous days. The science content involved recycling. The mathematics included was data analysis and engineering was included through the design process (English, 2013). In these types of activities engineering design is incorporated as students express, test, and revise their ways of thinking (English, 2009).

STE

There were ten articles where science, technology, and engineering was integrated (Table 1). The science content included animals, sound, force, structure and properties of matter, and types of interactions. The structure and properties of matter often related to testing materials that could be used in a design or looking at how objects can be combined or built to serve a purpose. All of the articles involved the integration of design materials used with the engineering design process. Two of the activities included robotics. Kindergarten students worked to design a fenced in area to keep a Hexbug nano mini robot from getting out (Lottero-Perdue, Grabia, & Sandifer, 2017). First grader students used a KIBO-18 robotics set from KinderLab Robotics to design an alarm for a cookie jar (Lott, Urbanek-Carney, & Mitchell, 2019). One article also described that students learned more about the work of mechanical and environmental engineers through solar oven and windmill design challenges (McCullar, 2015).

Table 1

Description of K-2nd grade STE curriculum

Grade level (Time to implement)	**Integrated STEM curriculum description**	**Science**
K (Five lessons) (Tank, Pettis, Moore, & Fehr, 2013)	Design a hamster habitat and trail with basic needs of food, water, and shelter met.	Animals and habitats
K (Three lessons) (Lottero-Perdue et al., 2016)	Design a package to protect an egg when dropped.	Properties of materials
K (Four lessons) (Douglass, 2016)	Design a structure to organize toys.	Structure and properties of matter
K (One lesson) (Lottero-Perdue, Grabia, & Sandifer, 2017)	Design a fenced in area to keep a robot from getting out.	Force and motion Types of interactions
K (Two lessons) (Parks & Oslick, 2018)	Design a chair to support each character in Goldilocks and the three bears. The chair also needed to be earthquake resistant.	Types of interactions
1st (Two weeks) (Lott, Urbanek-Carney, & Mitchell, 2019)	Design an alarm for a cookie jar.	Sound
1st and 2nd (Five lessons) Informal learning (McCullar, 2015)	Design a solar oven. Design a windmill. Both challenges were adapted from Engineering is Elementary units (BMS, 2020b)	Structure and properties of matter
2nd (One lesson) (Marrero, Gunning, & Buonamano, 2016)	Design a roof for a dog house to withstand rain.	Properties of materials
2nd (Two weeks)	Design a trunk for an elephant that does	Animals and

ISSN: 2582-0745
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(Hefty, 2014)	not have one.	characteristics
2nd (Three to four lessons) (Brown et al., 2014)	Design a water filter	Structure and properties of matter

TEM

There were seven articles where the integrated STEM education curriculum allowed for the integration of technology, engineering, and mathematics (Table 2). All of the articles involved the integration of design materials used with the engineering design process. The Sketch Up 3D modeling program and a 3D printer were used as kindergarten and first grade students designed new playground equipment (Wendt & Wendt, 2015). First and third grade students designed a mathematics app using TinyTap (www.tinytap.it) to help kindergarten students at their school (Schaen et al., 2016). The mathematics integrated mainly included shapes, mathematical operations, measurement, and data analysis. These were common topics when mathematics was integrated across the K-5th grade articles.

Table 2

Description of K-2nd grade TEM curriculum

Grade level (Time to implement)	Integrated STEM curriculum description	Mathematics
K (Four weeks) (Hefty, 2016)	Design a chair for a Goldilocks doll that stays balanced with different forces acting on it.	Properties of shapes
K (One lesson) (Appelgate & Beecher, 2018)	Design playdough that is a bright color, moldable, and does not stick to hands.	Counting Addition
K and 1st (Five lessons) (Wendt & Wendt, 2015)	Design new playground equipment.	Shapes Measurement
1st (One lesson) (Kurz, 2013)	Using Geoblocks, design and build a structure that has at least one line of symmetry.	Symmetry
1st and 3rd (Five lessons) (Schaen, Hayden, & Zydney, 2016)	Design an app on mathematics concepts for kindergarten students. The app needs to include vocabulary and sample problems.	Representing and comparing whole numbers Describing shapes

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2nd (Two weeks) (Delaney & Jurgenson, 2019)	Design a bridge to hold at least 21 small toy elephants.	Operations Measurement Data analysis
2nd (One lesson) (Orona, Carter, & Kindall, 2017)	Create a cutout of a giant's head given a handprint of the giant.	Measurement

STEM

In the final category for the K-2nd grade level band there were five articles where all four disciplines of STEM were integrated (Table 3). All of the articles involved the integration of design materials used with the engineering design process. The mathematics used in the curriculum was used to analyze the designs or to ensure that the designs were at or under budget. The design challenges used in these curriculum were not used as a formative or pre-assessment. The design challenges were used as a way for students to apply mathematics and science concepts.

Table 3

Description of K-2nd grade STEM curriculum

Grade level (Time to implement)	Integrated STEM curriculum description	Science	Mathematics
K (Six lessons) (Lott, Wallin, Roghaar, & Price, 2013)	Design a trap for the gingerbread man.	Properties of materials Forces and motion	Bar graphs
1st (Two weeks) (Bautista & Peters, 2010)	Design a house that is cost effective and strong enough to survive strong winds, heavy rains, and earthquakes.	Properties of materials	Bar graphs Budget
1st (Unknown length) (Tuttle, Stanley, & Bieniek, 2016)	Design a car to travel the farthest when going down a ramp.	Structure and properties of matter	Measurement

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2nd (Two lessons) (Parks, 2020)	Design a car to travel and stop in a specified zone on a track.	Force Structure and properties of matter	Measurement
2nd (Five lessons) Informal learning (Masters et al., 2019)	Design a house to withstand wind and water erosion.	Structure and properties of matter Erosion	Budget

3rd-5th Integrated STEM Curriculum

SE

There was one activity that integrated science and engineering. A class of fifth graders worked to design healthy smoothies over three lessons. The science concept was nutrition and the engineering design process was also used (Molinar, Gomez, &Molinar, 2012). This curriculum and a number of others included in this paper was implemented with the 5E learning cycle model (Engage, Explore, Explain, Elaborate, and Evaluate)(Bybee, 1997).

STM

There were three activities that integrated science, technology, and mathematics. In the first activity the goal was for students to design a diet and exercise routine for someone who wants to lose weight. Fifth and sixth graders worked on this problem over two lessons. The science content was nutrition and exercise. The technology integration was done through an eating and exercise simulation program (University of Colorado, 2016). The mathematics involved was operations (Yanik & Memis, 2016).

A class of fourth graders worked on a six week project where each group selected a topic related to sustainability. The groups had to create a mathematical representation depicting their chosen topic, meaningfully describe a current trend in their topic, and make predictions for future events based on the trend. The science content was on sustainability and the mathematics was on data collection, data analysis, and operations. Students used the Internet for background research and data collection (Sibley & Kurz, 2014).

Fifth graders at a school developed a method to determine when ice on a river nearby the school would break. This method was developed based on data from prior years including ice thickness, dates when the ice broke, and temperature. Students worked on this for one lesson. Science was incorporated through weather and mathematics involved data analysis. Students used measurement devices and the Internet for data from prior years (Daml, 2017).

TEM

There were three articles where the integrated STEM curriculum involved technology, engineering, and mathematics. In a Saturday STEM program 3rd to 5th grade students designed a soda can crusher. The program lasted 13 hours over five days. The engineering design process was incorporated and technology involved the available materials for the design. Students used the mathematics of data collection, data analysis, and measurement (Deniz, Kaya, &Yesilyurt, 2018). Another activity with third to fifth grade students also used the same mathematical concepts along with the engineering design process. The activity lasted one lesson and occurred in a regular school setting. In this challenge, the goal was to design an air cannon to shoot a cotton ball as far as possible (Enderson, 2015). The final curricular unit in this section lasted ten lessons and was implemented with fifth and sixth grade students. Students designed a children's recreation room that would be soundproof, include facilities that children like, and have a cost that would not exceed $7,000. Students used the engineering design process along with the mathematics of measurement, conversions, and keeping a budget. The technology to design the recreation room was the Planner 5D design app (Lee, 2015).

STE

There were sixteen articles where the curriculum used integrated science, technology, and engineering (Table 4). Five of the articles involved multiple grades of students and in two of the articles, students participated in the activities in informal education. There were a variety of science concepts integrated including systems, the water cycle, energy, force and motion, and structure and properties of matter. All of the articles involved the integration of design materials used with the engineering design process. Two of the articles also incorporated video recordings. One involved the whole class watching and discussing selected video recordings of students' design work (Lottero-Perdue et al., 2011). In the other article, video recordings were used to assess students as they demonstrated science knowledge as newscasters (Sterling, 2010). The Scratch coding program was used with 4th grade students to design a musical instrument (Maguire et al., 2016). The Tinkercad program with a 3D printer was used by 3rd to 5th grade students to design a boat (Mendez et al., 2019). Three implementations used EiE curriculum and had students learn about mechanical engineering (Lottero-Perdue et al., 2010), materials engineering (Lottero-Perdue et al., 2011), and green engineering (Hegedus & Carlone, 2015).

Table 4

Description of 3rd-5th grade STE curriculum

Grade level (Time to implement)	**Integrated STEM curriculum description**	**Science**
3rd (Eight to ten hours) (Lottero-Perdue, Lovelidge, & Bowling, 2010)	Design windmill blades for a windmill to lift the most washers in a cup. EiE unit: Catching the Wind (BMS, 2020b).	Position, force, motion, and energy

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3rd (unknown length) (Holt-Taylor, 2017)	Design a hand bee pollinator.	Plants and animals
3rd-4th (One class) (Erk et al., 2015)	Design a sound reducing wall for the middle of a shoebox.	Sound
3rd-5th (One lesson) (Crismond, Soobyiah, & Cain, 2013).	Design a spinning paper helicopter toy that goes in a straight path and stays in the air the longest.	Force and gravity
3rd-5th (One lesson) (Royce, 2014)	Design a boat to float filled with the most marbles.	Density Structure and properties of matter
3rd-5th (Four weeks) Informal learning (Mendez, Baird, & Patino, 2019)	Design a boat to float filled with the most pennies	Structure and properties of matter
4th (Eight to ten hours) Lottero-Perdue, Nealy, Roland, & Ryan, 2011).	Design a model rock-and-mortar wall to keep a hungry rabbit away from a classroom garden EiE unit: A sticky situation: Designing walls (BMS, 2020b).	Properties of rocks and minerals
4th (Seven lessons) (Tank, Moore, & Strnat, 2015)	Design a water collection device for families on Popa island in Panama.	System and systems models Water
4th (Four lessons) (Flannagan & Sawyer, 2015)	Design a car that moves with a breath of air.	Force and motion
4th (Unknown length) (Ehlers & Coughlin, 2015)	Design a water filter.	Water and water cycle
4th (Twelve lessons) (Maguire, Kang, Hogan, & McCarthy, 2016)	Design a robot that makes doodles on paper. Design a bookmark booklight. Design a musical instrument.	Energy Electricity and circuits
4th-6th (5 lessons) (Sterling, 2010)	Design a building to withstand wind, rain, and debris from a hurricane.	Weather

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5th (Five lessons) (Capobianco, Nyquist, Tyrie, 2013)	Design a device that can monitor the amount of sun that children are getting.	Light
5th (Eight to ten hours) (Hegedus & Carlone, 2015)	Design a well-insulated solar oven with the least environmental impact. EiE Unit: Now you're cooking: Designing solar ovens (BMS, 2020b).	Energy
5th (Seven lessons) (Barth, Bahr, & Shumway, 2017)	Design a water chamber that uses the water cycle to produce safe water.	Water cycle Structure and properties of matter
5th (Unknown length) Informal learning (Kilpatrick et al., 2018)	Design a water filter.	Water and natural resources

STEM

The final category for the 3rd-5th grade band involved the integration of all four disciplines of STEM. This category had the most articles with thirty-six. Because of the large number of articles, three summary tables will be used with a table for those articles that involved 3rd graders as the youngest students, those with 4th graders as the youngest students, and then fifth graders.

There were eleven articles where all four disciplines of STEM were integrated with 3rd grade students as the youngest learners (Table 5). Heat transfer was the science focus in three of the articles. Force and motion and properties of materials continued to be popular science concepts. All of the articles involved the integration of design materials used with the engineering design process. LEGO® WeDo 2.0 robots were used by third to fifth graders to design a solution to get people across a river (Edelen, 2019). The Tinkercad program and a 3D printer were used by third to fifth grade students to design a boat (Chesky & Wells, 2017). The mathematical content included new concepts not used in prior articles including mean, decimals, angles, proportional reasoning, and area.

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Table 5

Description of STEM curriculum that involved 3rd graders

Grade level (Time to implement)	Integrated STEM curriculum description	Science	Mathematics
3rd (Three lessons) (Sheerer & Schnittka, 2012)	Design a dwelling for an ice cube penguin to keep it from melting.	Heat and temperature	Measurement
3rd (Three lessons) (Hawkins & Rogers, 2014)	Design straw rockets to go the farthest distance.	Force and motion	Measurement Mean
3rd (Unknown length) (Monson & Besser, 2015)	Design a machine to crush milk cartons.	Recycling Properties of matter	Graphs
3rd (Eight to ten hours) (Lottero-Perdue & Bollinger, 2018)	Design a method to clean up a simulated oil spill. EiE unit: A slick solution: Cleaning an oil spill (BMS, 2020)	Biodiversity and humans	Budget
3rd (Four lessons) (Houghton, Soto, & Appelgate, 2018)	Design a cup for coffee that minimizes the decrease in temperature after 15 minutes.	Heat transfer	Decimal subtraction
3rd-5th (Ten lessons) (Wendell, 2012)	Design a model house that stays warm, is strong, stable, quiet on the inside, and waterproof.	Properties of materials Sound Heat transfer	Measurement
3rd and 5th (Six lessons) (Lottero-Perdue, Luigi, & Goetzinger, 2015)	Design blades for a wind turbine to maximize power output.	Force and motion Energy	Measurement Data collection and analysis Angles
3rd-5th (Five lessons) Informal education (Rehmat & Owens, 2016)	Design a satellite that is under 10 grams in mass, fits in an oatmeal canister, and can withstand a 1 meter drop.	Structure and properties of matter	Measurement

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3rd-5th (Three lessons) (Edelen, Bush, & Nickels, 2019)	Design a solution to get people across a river.	Impact of erosion	Proportional reasoning Operations Measurement
3rd-5th (Three lessons) (Jurkiewicz, Kirn, & Crowther, 2019)	Design a water wheel that can lift the most weight.	Energy and energy transfer	Measurement Budget
3rd-5th (Unknown length) (Chesky & Wells, 2017)	Design a boat that floats holding the most pennies.	Buoyancy	Measurement Area

There were twelve articles that involved fourth graders as the youngest learners that integrated all four disciplines of STEM (Table 6). There were a variety of contexts for the curriculum including designing a roller coaster (Cook et al., 2017), determining what a dinosaur looked like based on a skull (Hunter et al., 2017), and designing a prosthetic hand for a student using the Tinkercad program and a 3D printer (Bush et al., 2016; Cook et al., 2015). Science concepts used were mainly force and plants and animals. All of the articles involved the integration of design materials used with the engineering design process. A mathematical data analysis program, Tinkerplots, was used in a study that involved fourth and fifth grade students designing a boat (Lee, 2014). Fourth grade students learned about aerospace engineering in designing paper airplanes (English et al., 2014) and about biomimicry in designing a water catching and storage device (Farmer et al., 2015). New mathematical content in the articles in this section included velocity, volume, measurement conversions, and median and mode.

Table 6

Description of STEM curriculum that involved 4th graders

Grade level (Time to implement)	**Integrated STEM curriculum description**	**Science**	**Mathematics**
4th (Five lessons) (Wilcox, Roberts, & Wilcox, 2010)	Design a gravity-powered car to go the farthest distance.	Force and motion	Measurement
4th (Three lessons) (Lee, Kier, & Phillips, 2016)	Design a structure to withstand water and wind from a hurricane.	Natural hazards	Measurement
4th (Unknown length) (Cook, Bush, & Cox, 2017)	Design a roller coaster that is safe, fun, and affordable.	Energy	Measurement Velocity Budget

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4th *(Six weeks)* (Cook, Bush, & Cox, 2015) (Bush, Cox, & Cook, 2016)	Design a prosthetic hand for a student without a hand.	Structure and function	Measurement Budget
4th *(Three lessons)* (Lottero-Perdue, Haines, & Baranowski, 2020)	Design a habitat for terrapins while reducing erosion.	Earths materials and systems Erosion	Budget
4th *(Two lessons)* (Hefty, 2015a)	Design a rubber band powered vehicle to go the farthest distance.	Force	Measurement Speed Operations
4th *(Several weeks)* (Farmer, Tank, & Moore, 2015)	Design a water catching and storage system.	Plants and animals	Measurement Volume Operations
4th *(Three lessons)* (English et al., 2014)	Design a paper airplane to stay in the air as long as possible.	Force	Measurement
4th *(One lesson)* (Hunter et al., 2017)	Determine what an entire dinosaur looked like based on a skull.	Fossils	Measurement Conversions Operations Proportional thinking
4th-5th *(Four lessons)* (Purzer, Duncan-Wiles, & Strobel, 2013)	Design a way to protect an egg when dropped.	Air resistance Force	Budget
4th-5th *(Four 90 minute lessons)* (Dalvi & Wendell, 2015)	Design a system to water plants where there is no easy water access.	Plants	Measurement
4th-5th *(Unknown length)* (Lee, 2014)	Design a boat that floats holding the most pennies	Buoyancy	Measurement Area Measures of central tendency Data collection and analysis

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There were thirteen articles where fifth graders participated in curriculum that implemented all four disciplines of STEM (Table 7). A variety of relevant contexts were included in the curriculum including designing a car that moves from a chemical reaction (Smith & Meyer, 2017), designing butterfly wings to have the most lift (Macalalag, 2018), and designing a coat to keep a giant warm (Kaiser et al., 2018; Owen et al., 2018). Force and motion was the most common science content. All of the articles involved the integration of design materials used with the engineering design process. Fifth grade students used the Tinkercad program and a 3D printer to design a car (Wright et al., 2018). Fifth grade students learned about civil engineers in a bridge design challenge (Hefty, 2015b) and aerospace engineers in designing a plane (Gerlach, 2010). Incorporating measurement and a budget were the most common uses of mathematics.

Table 7

Description of 5th grade STEM curriculum

Grade level (Time to implement)	Integrated STEM curriculum description	Science	Mathematics
5th (Unknown length) (Gerlach, 2010)	Design a plane to glide the farthest distance in a straight line.	Force and motion	Measurement
5th (Three lessons) (Dickerson et al., 2012)	Design a PVC-pipe buoy that will float holding the most golf balls.	Force and motion Properties of matter	Measurement
5th grade (One lesson) Informal education (Owens & Sullivan, 2012)	Design a strong, stable, and cost effective bridge.	Forces and interactions	Measurement Budget
5th (Ten lessons) (Dare et al., 2014)	Design a foam toy rocket that is safe, inexpensive, and has a predictable behavior.	Force and motion	Measurement
5th (Three lessons) (Parks, 2014)	Design a cost effective water filter.	Ecosystems and climate	Budget
5th (One lesson) (Llewellyn et al., 2016)	Design the tallest structure that has a marshmallow at the top. The structure should also be earthquake resistant.	Natural hazards	Shapes Angles Measurement

5th (Unknown length) (Smith & Meyer, 2017)	Design a car that moves at least one meter by chemical reaction.	Chemical reactions Structure and properties of matter	Measurement Data collection and analysis
5th (Two 90 minute lessons) (Bautista, 2017)	Design a paper airplane to fly the furthest distance.	Force and motion	Measurement
5th (Four 90 minute lessons) Informal education (Macalalag, Johnson, & Johnson, 2018)	Design butterfly wings that have the most lift.	Force and motion	Angles Grams to Newtons conversion
5th (Nine lessons) (Kaiser et al., 2018) (Owen et al., 2018)	Design a coat to keep a giant warm.	Thermal conductivity Structure and properties of matter	Measurement Proportional reasoning
5th (Ten weeks) (Wright et al., 2018)	Design a cost-effective propeller driven car to go a maximum distance and a maximum average speed.	Force and motion	Measurement Mean Budget
5th (Five lessons) (Katchmark et al., 2020)	Design a paper airplane to fly the farthest distance.	Force	Measurement Data collection and analysis
5th (Eighteen lessons) (Hefty, 2015b)	Design a bridge taking into account cost, weather, strength, span, and appearance.	Force	Measurement Budget

4. DISCUSSION

The purpose of this paper was to describe and analyze integrated STEM curriculum that has been implemented with elementary students (Ages 5-11). This was done by identifying articles published since 2010 in the Science and Children journal published by NSTA and the Teaching Children Mathematics journal published by NCTM. My definition of integrated STEM education is that it is an effort to combine at least two of the four disciplines of science, technology, engineering, and mathematics into a class, unit, or lesson that is based on connections between the subjects, relevant contexts, and open-ended problems (Moore et al., 2014). There are other main tenets as well including that mathematics and/or science content are the main objectives of the curriculum, student-centered pedagogies are used, and students have the opportunity to learn from failure (Stohlmann et al., 2013).

Overall, there were eighty-five articles identified with twenty-one of the articles in the NCTM journal and sixty-four of the articles in the NSTA journal. Past research has noted that science is often integrated more in integrated STEM education than mathematics (Becker & Park, 2011; Pang & Good, 2000). While more articles appeared in the science education journal, a total of fifty-five of the articles integrated mathematics. This was encouraging to see and shows progress towards including mathematics more in integrated STEM education. The large number of articles published across both journals in the last decade shows the continued growth of integrated STEM education.

There were a variety of contexts for the curriculum that reflect the diversity of ways in which STEM knowledge is used in the world. Designing an object for motion or an object to hold weight were frequent contexts. Overall, there were twenty-four articles at the K-2nd grade level and sixty-one at the 3rd-5th grade level. To ensure contexts are relevant and meaningful for students, continued work can be done on identifying culturally relevant contexts where there are natural connections between STEM subjects.

There were a variety of STEM concepts that were integrated into the curriculum. Table 8 has a summary of the STEM connections organized by the K-2nd grade band level and the 3rd-5th grade band level. Force and motion was a popular science topic. This has been noted in past research as a frequently covered topic (Guzey et al., 2014). There were other popular science topics though in this review including structure and properties of matter, energy, natural hazards/weather, and heat transfer.

Almost all of the curriculum included the engineering design process. There were also a few instances of students learning more about specific fields of engineering. This is an important implication for integrated STEM education. In the United States and countries around the world engineering design standards have not been fully adopted (Carr, Bennett, & Strobel, 2012). Engineering design is an integral part of integrated STEM education to ensure that natural connections can be made between subjects. To ensure a diverse well prepared STEM workforce engineering education should become a required part of K-12 education.

The technology included materials used in the designs as well a few instances of robotics, 3D printers, and 3D modeling. Future work can look at ways of incorporating more coding and programming into integrated STEM curriculum. There is a movement for students in the elementary grades to have experiences with computer science concepts (Computer Science Teachers Association, 2018). Current technologies for programming are becoming more user-friendly, which can make it more likely for teachers to feel comfortable integrating programming. Exposing students to this work is essential as applications software developers is the largest STEM occupation (Fayer et al., 2017). There is a need for more qualified workers in this area.

Data collection and analysis, measurement, and including a budget were the most often ways that mathematics was included. Prior research has noted that measurement and data analysis are frequent math topics for STEM integration (Guzey et al, 2014). There were a number of other mathematical topics included which shows progress in mathematics integration. The mathematics was often integrated though as an application of knowledge and not to develop mathematical knowledge. Internationally, mathematical modeling is an important research area (Stohlmann et al., 2016). Generally, mathematical modeling is connected with engineering education as students, express, test, and revise their ideas (English, 2009). Mathematical modeling is an excellent way for students to experience STEM education and develop their mathematical knowledge and thinking. A focus on mathematical modeling provides more opportunities to integrate ratios and proportional thinking, operations, measurement, and statistics (Stohlmann & Albarracin, 2016).

In order to meaningfully include other mathematical topics I have suggested further work on game-based mathematics integrated with technology as well (Stohlmann, 2018). The Polygraph games by the Desmos company are promising examples of open-ended game-based learning integrated with technology. In these games sixteen cards are shown. Each game focuses on a different mathematical topic. For example, in Polygraph: Shape Bucket, sixteen shapes are shown (Desmos, 2020). One student selects a shape. The other student asks yes or no questions to determine which shape is picked. After playing the game several times, students discuss what are quality questions to ask and strategies for asking the least amount of questions. Students interact through the technology and are also allowed to see the questions asked by other students in the class. Through this process students express, test, and revise their ideas. Game-based learning has great potential to engage students and integrate technology well to benefit mathematics learning.

Almost half of the articles included curriculum where all four disciplines of STEM were integrated. There were five at the K-2nd level and thirty-six at the 3rd-5th grade level. Meaningful STEM integration can lead to students having increased interest in mathematics and science as well as improved science and mathematical understanding. Integrated STEM education curriculum can provide teachers opportunities to meet standards from multiple disciplines which can save time and make learning more meaningful (Huff, 2016). It is important that integration of STEM concepts is done when there are natural connections between subjects, so that the integration is not forced (Stohlmann et al., 2017).

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Table 8

Summary of K-5th integrated STEM content integrations

K-2nd		3rd-5th	
Science		**Science**	
-Structure and properties of matter (10) -Force and motion(3) -Types of interactions (2) -Animal characteristics and habitats (2)	-Erosion -Nutrition -Recycling -Sound	-Force and motion (17) -Structure and properties of matter (11) -Energy (7) -Natural hazards/weather (7) -Heat transfer (4) -Water and water cycle (3) -Plants and animals (3) -Nutrition (2) -Sound (2) -Buoyancy (2)	-Systems (2) -Sustainability (2) -Light -Density -Fossils -Types of interactions -Biodiversity and humans -Chemical reaction -Structure and function
Technology		**Technology**	
-Design materials (22) -Robotics (2) -3D modeling program	-3D printer -App creator website	-Design materials (56) -3D modeling or coding program (5) -3D printer (4) -Video recordings (2)	-Simulation program -Data analysis program -Robotics -Design program
Engineering		**Engineering**	
-Design process (24) -Environmental	-Mechanical engineering	-Design process (56) -Aerospace engineering (2)	-Biomimicry -Civil engineering

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engineering		-Mechanical engineering -Materials engineering	-Green engineering
Mathematics		**Mathematics**	
-Data collection and analysis (3) -Measurement (3) -Shapes (3) -Budget (2) -Operations (2)	-Counting -Symmetry -Representing and comparing whole numbers	-Measurement (32) -Budget (11) -Data collection and analysis (9) -Operations (8) -Proportional reasoning (3) -Measures of central tendency(3)	-Angles (3) -Conversions (3) -Area (2) -Velocity (2) -Volume -Shapes

Integrated STEM education can develop elementary students' curiosity, creativity, critical thinking, perseverance, teamwork, communication, and innovation capabilities (Hefty, 2014). Students can apply mathematics and science in meaningful and engaging contexts. The problem solving in these types of activities are similar to real life in that there is more than one possible solution. Students start with a problem and then plan, create, and test while learning from their failures and successes (Burton, 2014). The many benefits of integrated STEM education make it vital for continued curriculum development. The results of this article demonstrate that work in this area is increasing and moving in the right direction. It also provides support for the benefits of an integrated STEM education approach and continued research in this area.

REFERENCES

Appelgate, M., & Beecher, C. (2018). Messiness and math. *Teaching Children Mathematics, 24*(4), 264-267.

Barth, K., Bahr, D., & Shumway, S. (2017). Generating clean water. *Science and Children, 55*(4), 32-38.

Bautista, J. (2017). The paper airplane challenge. *Science and Children, 55*(2), 82-87.

Bautista, N., & Peters, K. (2010). First-grade engineers. *Science and Children, 47*(7), 38-42.

Boston Museum of Science (2020a). "Internal articles and publications." Retrieved from https://www.eie.org/articles-publications

Boston Museum of Science (2020b). "Engineering is elementary curriculum units." Retrieved from https://www.eie.org/eie-curriculum/curriculum-units

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classroom. *Journal of Engineering Education, 97*(3), 369-387.

Brown, S., Newman, C., Dearing-Smith, K., & Smith, S. (2014). Can a student really do what engineers do? *Science and Children, 51*(9), 79-85.

Bubnick, L., Enneking, K., & Egbers (2016). Designing healthy ice pops. *Science and Children, 54*(1), 70-75.

Burton, B. (2014). The tightrope challenge. *Science and Children, 52*(1), 80-85.

Bush, S., Cox, R., & Cook, K. (2016). A critical focus on the M in STEAM. *Teaching Children Mathematics, 23*(2), 110-114.

Bybee, R. (1997). *Achieving scientific literacy: From purposes to practices.* Portsmouth, NH: Heinemann.

Capobianco, B., Nyquist, C., & Tyrie, N. (2013). Shedding light on engineering design. *Science and Children, 50*(5), 58-64.

Capobianco, B., Yu, J., & French, B.(2015). Effects of engineering design based science on elementary school science students' engineering identity development across gender and grade. *Research in Science Education, 45*(2),275-292.

Carlson, L., & Sullivan, J. (2004). Exploiting design to inspire interest in engineering across the K-16 engineering curriculum. *International Journal of Engineering Education, 20*(3), 372-380.

Carr, R., Bennett, L., & Strobel, J. (2012). Engineering in the K-12 STEM standards of the 50 U.S. states: An analysis of presence and extent. *Journal of Engineering Education, 101*(3), 1-26.

Chesky, N., & Wells, L. (2017). Keep your boat afloat. *Teaching Children Mathematics, 24*(1), 56-59.

Computer Science Teachers Association (2018). State of computer science education. Retrieved from https://code.org/files/2018_state_of_cs.pdf

Cook, K., Bush, S., & Cox, R. (2017). From STEM to STEAM. *Science and Children, 54*(6), 86-93.

Cook, K., Bush, S., & Cox, R. (2015). Creating a prosthetic hand. *Science and Children, 53*(4), 80-86.

Crismond, D., Soobyiah, M., & Cain, R. (2013). Taking engineering design out for a spin. *Science and Children, 50*(5), 52-57.

Dalvi, T., & Wendell, K. (2015). Community-based engineering. *Science and Children, 53*(1), 67-73.

Daml, M. (2017). Using community events to enliven STEM education. *Teaching Children Mathematics, 23*(6), 376-379.

Dare., E., Childs, G., Cannaday, A., & Roehrig, G. (2014). Blasting off with engineering. *Science and Children, 52*(3), 60-64.

Delaney, A., & Jurgenson, K. (2019). Building bridges. *Science and Children, 57*(1), 82-88.

Deniz, H., Kaya, E., & Yesilyurt, E. (2018). The soda can crusher challenge. *Science and Children, 56*(2), 74-78.

Desmos. (2020). "Polygraph: Shape bucket." Retrieved from https://teacher.desmos.com/polygraph/custom/560aa8d09e65da561507a466

Diaz, N., & Cox, M. (2012). An overview of the literature: Research in P-12 engineering education. *Advances in Engineering Education, 3*(2), 1-37.

Dickerson, D., Hathcock, S., Stonier, F., & Levin, D. (2012). The great build-a-buoy challenge. *Science and Children, 50*(4), 62-66.

Douglass, H. (2016). No, David! But yes, design! *Science and Children, 53*(9), 69-75.

Dym, C., Agogino, A., Eris, O., Frey, D., & Leifer, L. (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education, 94*(1), 103-120.

Edelen, D., Bush, S., & Nickels, M. (2019). Crossing the amazon by lego. *Science and Children, 56*(6), 30-36.

Ehlers, B., & Coughlin, J. (2015). Think it, design it, build it, test it, refine it. *Science and Children, 52*(6), 59-65.

Enderson, M. (2015). Ready, aim, fire your cannons! *Teaching Children Mathematics, 21*(8), 502-506.

English, L. (2013). Surviving an avalanche of data. *Teaching Children Mathematics, 19*(6), 364-372.

English, L. (2009). Promoting interdisciplinarity through mathematical modeling. *ZDM-International Journal on Mathematics Education, 41*(2), 161-181.

English, L., King, D., Hudson, P., & Dawes, L. (2014). The aerospace engineering challenge. *Teaching Children Mathematics, 21*(2), 122-126.

Erk, K., Lumkes, J., Shambach, J., Braile, L., Brickler, A., & Matthys, A. (2015). Designing a sound reducing wall. *Science and Children, 53*(1), 52-59.

Farmer, S., Tank, K., & Moore, T. (2015). Using STEM to reinforce measurement skills. *Teaching Children Mathematics, 22*(3), 196-199.

Fayer, S., Lacey, A., & Watson, A. (2017). *BLS spotlight on statistics: STEM occupations-past, present, and future*. Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics.

Flannagan, J., & Sawyer, M. (2015). SCAMPERing into engineering! *Science and Children, 53*(1), 34-43.

Furner, J., & Kumar, D. (2007). The mathematics and science integration argument: A stand for teacher education. *Eurasia Journal of Mathematics, Science &Technology, 3*(3), 185–189.

Gerlach, J. (2010). Elementary design challenges. *Science and Children, 47*(7), 43-47.

Guzey, S., Tank, K., Wang, H., Roehrig, G., & Moore, T. (2014). A high-quality professional development for teachers of grades 3-6 for implementing engineering into classrooms. *School Science and Mathematics,* 114(3), 139-149.

Hawkins, S., & Rogers, M. (2014). Three, two, one…blast off! *Science and Children, 52*(1), 53-59.

Hefty, L. (2016). Goldilocks an engineer? *Teaching Children Mathematics, 22*(6), 375-378.

Hefty, L. (2015a). STEM gives meaning to mathematics. *Teaching Children Mathematics, 21*(7), 422-429.

Hefty, L. (2015b). Investigating bridge design. *Teaching Children Mathematics, 22*(4), 255-260.

Hefty, L. (2014). Elephant trunks and dolphin tails. *Science and Children, 52*(4), 56-61.

Hegedus, T., & Carlone, H. (2015). You and your students as green engineers. *Science and Children, 52*(9), 74-81.

Holt-Taylor, L. (2017). What's the buzz on bees? *Science and Children, 55*(4),82-88.

Houghton, J., Soto, M., & Appelgate, M. (2018). Insulating and conducting heat energy using STEM. *Teaching Children Mathematics, 25*(1), 60-62.

Huff, K. (2016). Addressing three common myths about the next generation science standards. *Science and Children,* 53(5), 30–33.

Hunter, K., Cox, R., Bush, S., Cook, K., &Jamner, J. (2017). Unearthing the mathematics. *Teaching Children Mathematics, 23*(7), 438-441.

Jurkiewicz, M., Kirn, A., Crowther, D. (2019). A water wheel challenge! *Science and Children, 56*(6), 46-51.

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Kaiser, L., Owen, K., Cook, K., & Bush, S. (2018). The giant problem. *Science and Children, 55*(8), 71-75.

Katchmark, L., McCabe, E., Matthews, K., &Koomen, M. (2020). In flight with paper airplanes. *Science and Children, 57*(6), 42-47.

Kilpatrick, J., Marcum-Dietrich, N., Wallace, J., & Staudt, C. (2018). Engineering a model of the earth as a water filter. *Science and Children, 56*(3), 73-77.

Kurz, T. (2013). Setting up symmetrical structures. *Teaching Children Mathematics, 20*(2), 116-119.

Lee, M. (2015). Designing a children's recreation room. *Teaching Children Mathematics, 22*(2), 110-114.

Lee, M. (2014). Tinkering with buoyancy. *Teaching Children Mathematics, 20*(9), 574-578.

Lee, T., Kier, M., & Phillips, K. (2016). Storm warning. *Science and Children, 54*(2), 30-35.

Li, Y., Wang, K., Xiao, & Froyd, (2020). Research and trends in STEM education: A systematic review of journal publications. *International Journal of STEM Education, 7*(11), 1-16.

Llewellyn, D., Pray, S., DeRose, R., & Ottman, W. (2016). Building a spaghetti structure. *Science and Children, 54*(2), 70-75.

Lott, K., Urbanek-Carney, S., & Mitchell, A. (2019). Cookie jar alarms. *Science and Children, 57*(3), 66-71.

Lott, K., Wallin, M., Roghaar, D., & Price, T. (2013). Catch me if you can! *Science and Children, 51*(4), 65-69.

Lottero-Perdue, P., & Bollinger, L. (2018). Testing oil spill cleanup methods ethically. *Science and Children, 56*(2), 60-67.

Lottero-Perdue, P., Bowditch, M., Kagan, M., Robinson-Cheek, L., Webb, T., Meller, M., & Nosek, T. (2016). An engineering design process for early childhood. *Science and Children, 54*(3), 70-77.

Lottero-Perdue, P., Grabia, K., & Sandifer, C. (2017). Oh no Henrietta got out! *Science and Children, 55*(4), 46-53.

Lottero-Perdue, P., Haines, S., Baranowski, A., & Kenny, P. (2020). Designing a model shoreline. *Science and Children, 57*(7), 40-45.

Lottero-Perdue, P., Lovelidge, S., & Bowling, E. (2010). Engineering for all. *Science and Children, 47*(7), 24-27.

Lottero-Perdue, P., Luigi, A., & Goetzinger, T. (2015). Blade structure and wind turbine function. *Science and Children, 52*(7), 45-55.

Lottero-Perdue, P., Nealy, J., Roland, C., & Ryan, A. (2011). Caught on video! *Science and Children, 49*(4), 56-60.

Macalalag, A., Johnson, B., Johnson, J. (2018). STEM-ify Me: It's Elementary! Designing Butterfly Wings. *Science and Children, 55*(9), 76-82.

Maguire, C., Kang, E., Hogan, T., & McCarthy, M. (2016). Robots, bookmarks, and guitars, oh my! *Science and Children, 54*(4), 70-75.

Marrero, M., Gunning, A., & Buonamano, C. (2016). A house for chase the dog. *Science and Children, 53*(5),76-83.

Masters, H., Hilgendorf, C., Stundahl, L., Gresl, M., & Jentsch, A. (2019). Help batman build a safe and stable house. *Science and Children, 56*(5), 78-83.

McCullar, H. (2015). Am I *really* teaching engineering to elementary students? *Science and Children, 52*(7), 80-84.

Mehalik, M., Doppelt, Y., & Schunn, C. (2008). Middle-school science through design-based learning versus scripted inquiry: Better overall science concept learning and equity gap reduction. *Journal of Engineering Education, 97*(1), 71-85.

Mendez, J., Baird, K., & Patino, G. (2019). Sinking and floating 2.0. *Science and Children, 56*(9), 66-71.

Molinar, A., Gomez, C., & Molinar, R. (2012). From soda to smoothies. *Science and Children, 50*(1), 74-76.

Monson, D., & Besser, D. (2015). Smashing milk cartons. *Science and Children, 52*(9), 38-43.

Moore, T., & Smith, K. (2014). Advancing the state of the art of STEM integration. *Journal of STEM Education, 15*(1), 5-9.

Moore, T.J., Stohlmann, M., Wang, H.-H., Tank, K.M., Glancy, A., & Roehrig, G.H. (2014). Implementation and integration of engineering in K-12 STEM education. In S. Purzer, J. Strobel, & M. Cardella (Eds.), *Engineering in Pre-College Settings: Research into Practice.* (pp.35-60). West Lafayette, IN: Purdue Press.

Morrison, J. (2006). *Attributes of STEM education. TIES STEM education monograph series.* Baltimore, MD: TIES.

National Academies Press. (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*. (M. Honey, G. Pearson, & H. Schweingruber, Eds.). Washington, DC: National Research Council.

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Vol. 3, No. 04; 2020

National Council of Teachers of Mathematics. (2020). "About NCTM." Retrieved from https://www.nctm.org/About/

National Science Teaching Association. (2020). "About NSTA." Retrieved from https://www.nsta.org/about/overview.aspx

Orona, C., Carter, V., & Kindall, H. (2017). Understanding standard units of measure. *Teaching Children Mathematics, 23*(8), 500-503.

Owen, K., Kaiser, L., Bush, S., & Cook, K., (2018). A STEAM investigation: Making giant strides. *Teaching Children Mathematics, 25*(2), 122-125.

Owens, C., & Sullivan, E. (2012). Reinventing the…bridge. *Science and Children, 49*(6), 58-61.

Parks, M. (2020). The roadster challenge. *Science and Children, 57*(7), 22-27.

Parks, M. (2014). Modeling water filtration. *Science and Children, 52*(2), 42-47.

Parks, M., & Oslick, M. (2018). Goldilocks and the engineers. *Science and Children, 55*(6), 66-72.

Purzer, S., Duncan-Wiles, D., & Strobel, J. (2013). Teaching fourth and fifth graders about engineering optimization and trade-offs. *Science and Children, 50*(5), 34-39.

Rehmat, A., & Owens, M. (2016). The cat in the hat builds satellites. *Science and Children, 53*(7), 81-86.

Royce, C. (2014). Will it sink or will it float? *Science and Children, 51*(9), 18-23.

Schaen, R., Hayden, G., Zydney, J. (2016). Now we have an app for that. *Teaching Children Mathematics, 22*(8), 506-509.

Sheerer, K., & Schnittka, C. (2012). Save the boulders beach penguins. *Science and Children, 49*(7), 50-55.

Sibley, A., Kurz, T. (2014). Celebrating earth day with sustainability. *Teaching Children Mathematics, 20*(8), 516-519.

Smith, J., & Karr-Kidwell, P. (2000). *The interdisciplinary curriculum: A literary review and a manual for administrators and teachers.* Retrieved from http://eric.ed.gov/?id=ED443172.

Smith, W., & Meyer, J. (2017). Chemical reaction vehicles. *Science and Children, 55*(3), 71-78.

Sterling, D. (2010). Hurricane proof this! *Science and Children, 47*(7), 48-51.

Stinson, K., Harkness, S., Meyer, H., & Stallworth, J. (2009). Mathematics and science integration: models and characterizations. *School Science and Mathematics, 109*(3), 153–161.

Stohlmann, M. (2018). A vision for future work to focus on the "m" in integrated STEM. *School Science and Mathematics, 118*(7), 310-319.

Stohlmann, M., Maiorca, C., & DeVaul, L. (2017). Elementary teachers' engineering design activities from a state without engineering standards. *Science Educator, 26*(1), 48-59.

Stohlmann, M., DeVaul, L., Allen, C., Adkins, A., Ito, T., Lockett, D., & Wong, N. (2016). What is known about secondary grades mathematical modeling-a review. *Journal of Mathematics Research, 8*(5), 12-28.

Stohlmann, M. & Albarracin, L. (2016). What is known about elementary grades mathematical modelling. *Education Research International, 2016*, 1-9.

Stohlmann, M., Roehrig, G.H., & Moore, T.J. (2014). The need for STEM teacher education development. In S. Green (Ed.), *STEM Education: Training 21st Century Teachers.* (pp.17-32). Hauppauge, NY: Nova Science Publishers.

Stohlmann, M., Moore, T., & Cramer, K. (2013). Preservice elementary teachers' mathematical content knowledge from an integrated STEM modeling activity. *Journal of Mathematical Modelling and Application, 1*(8), 18-31.

Stohlmann, M., Moore, T., McClelland, J., & Roehrig, G. (2011). Year-long impressions of a middle school STEM integration program. *Middle School Journal, 43*(1), 32-40.

Tank, K., Moore, T., & Strnat, M. (2015). Nature as inspiration. *Science and Children,* 53(2), 72-78.

Tank, K., Pettis, C., Moore, T., & Fehr, A. (2013). Hamsters, picture books, and engineering design. *Science and Children, 50*(9), 59-63.

Tuttle, N., Stanley, W., & Bieniek, T. (2016). Engineering motion. *Science and Children, 53*(5), 46-53.

University of Colorado (2016). "Eating and Exercise." PhET Interactive Simulation. Retrieved from http://phet.colorado.edu/en/simulation/eating-and-exercise

Wang, H., Moore, T., Roehrig, G., & Park, M. (2011). STEM integration: The impact of professional development on teacher perception and practice. *Journal of Pre-College Engineering Education Research, 1*(2), 1-13.

Wendell, K. (2012). Just right: Students design a model house and learn about the properties of materials. *Science and Children, 50*(4), 46-53.

Wendell, K. B., & Rogers, C. B. (2013). Engineering design-based science, science content performance, and science attitudes in elementary school. *Journal of Engineering Education, 102*(4), 513–540.

ISSN: 2582-0745
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Wendt, S., & Wendt, J. (2015). Printing the playground. *Science and Children, 52*(5), 43-47.

Wilcox, D.R., Roberts, S., & Wilcox, D. (2010). Gravity racers. *Science and Children, 47*(7),19-23.

Wright, L., Shaw, D., Gaidos, K., Lyman, G., & Sorey, T. (2018). 3D pit stop printing. *Science and Children, 55*(7), 55-63.

Yanik, B., Memis, Y. (2016). What is your body mass index? *Teaching Children Mathematics, 22*(7), 442-446.

Yanyan, L., Zhinan, H., Menglu, J., Ting-Wen, C. (2016). The effect on pupils' science performance and problem-solving ability through Lego: An engineering design-based modeling approach. *Educational Technology & Society, 19*(3), 143-156.