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An Analysis of Support for Elementary Engineering Education Offered in the Science Teacher Journal *Science and Children*

Tawnicia Meservy Stocking
Brigham Young University

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A thesis submitted to the faculty of
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Master of Arts

Roni Jo Draper, Chair
Jennifer J. Wimmer
Alessandro A. Rosborough

Department of Teacher Education

Brigham Young University

ABSTRACT

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Tawnicia Meservy Stocking
Department of Teacher Education, BYU
Master of Arts

Teachers use professional journals such as *Science and Children* for ideas to incorporate into their own teaching. As such the purpose of this study was to investigate the support offered for integrating engineering education into science instruction. The research methodology for this was a qualitative content analysis inferring categories based on the information presented. Twenty-three issues of the journal were read, spanning two and a half volume years. The categories that emerged were mentioning, implementing, and integrating. Deeper examples of integration were found to match the mapping and infusion strategies presented by the National Academy of Engineering and National Research Council (NAE & NRC, 2009) in *Standards for K-12 Engineering Education*. The need for consistency in publication of the topic and more explanation on the subject is needed for teachers.

Keywords: content analysis, engineering, integration, science

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Introduction

Statement of Problem

Fields such as aeronautics, architecture, and electrical and mechanical engineering are looking for trained individuals to help with the growth and development of the country (National Research Council [NRC], 2011). These fields need individuals to take the place of current engineers as they retire or move into management. They also need individuals to come in with new ideas who can advance the theory and practice of each field of study. To do this, the country needs to graduate more individuals with engineering degrees. To help encourage students to explore engineering fields, exploration into engineering should begin at a young age (Pearson & Young, 2002). Thus the task of creating interest in the field of engineering logically falls to elementary, middle school, and high school teachers.

Currently there are no national K-12 standards for engineering education in the United States. While there are no standards for engineering education, some material has been included in lessons and classrooms for a number of years. Recently it has surfaced as a curriculum area of importance (National Academy of Engineering and National Research Council [NAE & NRC], 2009). As the importance of this curriculum rises, it elevates a need that teachers have to locate helpful resources to support classroom instruction.

Ironically, in 2010, the National Academy of Engineering (NAE), under the direction of the National Academies Press (NAP), made several arguments against creating national standards for engineering education. "The committee argues *against* the development of standards for K-12 engineering education at this time. Instead we suggest other approaches to increasing the presence and improving the quality of K-12 engineering education in the United

States" (NAE, 2010, p. 19). This may demonstrate to some state governments and teachers that large-scale adjustments of teaching plans to include engineering curriculum are not necessary or recommended. It certainly suggests that other strategies or paths may exist that experts believe would prove more effective.

The NAE goes on to claim that the best way to include engineering is through enhanced science and mathematics curriculum. "As a K-12 school subject, engineering is distinct both in terms of its recent appearance in the curriculum and its natural connections to other, more established subjects, particularly science, mathematics and technology, which already have content standards" (NAE*,* 2010, p. 19). It is evident that inclusion of engineering education into existing science and mathematics curricula and classrooms is occurring incrementally. Contrary to the NAE guidance, individual states are taking action to integrate engineering into their state curricula. Two states, Massachusetts and Minnesota, have developed a series of "learning standards that include engineering at the elementary level" (Cunningham, 2009, p. 4). These states have included engineering into their curriculum in an effort to allow students the chance to see the natural connection between the disciplines.

Teachers are now actively looking to the fields of science, mathematics, and technology for inspiration and ideas for use in their classrooms. A primary resource for teachers to gather ideas for their classrooms are journals published for teachers. Major organizations such as the National Council of Teachers of Mathematics (NCTM) or National Science Teachers Association (NSTA) publish journals to offer suggestions on incorporating engineering content. As mathematics and science are close cousins to engineering, they should share the responsibility of engineering education.

While engineering connects to science and mathematics, connections between science and engineering allow students the chance to turn their knowledge of science into the practical application of engineering. As such, focus was placed on the connections found in science journals. The NSTA publishes four journals that support all grade levels, kindergarten through college. With the NAE supporting engineering as a K-12 subject, the use college level journals can be ruled out. Likewise, in support of Pearson and Young's (2002) viewpoint that exploration into engineering should begin at a young age, we will pare the list down even further to the use of the K-5 journal from the NSTA, titled *Science and Children*.

What resources are being offered to elementary science teachers to support the expansion of engineering education?

Statement of Purpose

Given the focus of engaging students in the connections between science and engineering, and the desire to expose younger students to concepts and designs of engineering, the purpose of this study is to determine what ideas, support, and resources are being offered to elementary teachers who wish to include engineering topics into their curriculum.

Research Question

What is the NSTA teaching journal for grades K-5, *Science and Children*, publishing about engineering education?

Limitations

I will be focusing my attention on the NSTA journal *Science and Children*, which is published to appeal to teachers of grades K-5.

Definition of Terms

While the definition of the word *engineering* varies, for this paper I will be using the definition Wolf (1998) formed (as cited in NAE, 2010). It is defined as “design under constraints” (NAE, 2010, p. 6). Constraints are limitations that are placed on a design. These may include, but are not limited to, available materials, time allotments, or laws of science (NAE, 2010, p. 6).

CHAPTER 2

Review of Literature

In the 1800s engineering education in the United States was promoted as “the application of science to the common purposes of life” (Grayson, 1977, p. 246). By the late 1800s and early 1900s companies were drawing attention to the need for more engineers so automobile and electrical companies could expand and meet consumer demands. This prompted the creation and opening of schools such as Massachusetts Institute of Technology (MIT) and businesses like the Tabulating Machine Company, which became the IBM Corporation (Grayson, 1977).

These developments were a reflection of the growing desires that, “engineering curricula intend to provide a thorough grounding in the principles of science and the methods of engineering” (Grayson, 1977, p. 263). In an effort to support the growing need for engineering, the National Academy of Engineering (NAE) was formed in 1964. The focus was and is to promote the profession of engineering and to provide advice on the subject of engineering (www.nae.edu).

In 2006, a committee was formed through NAE, under the direction of the National Academies Press. Their task was to “determine the scope and nature of efforts to teach engineering to the nation’s elementary and secondary students” (NAE & NRC, 2009, p. vii). In a process that took two years, the committee evaluated existing engineering curriculum, reviewed the literature on engineering education, and studied college-ready students. The committee’s findings state that “evidence shows that engaging elementary…. students in learning engineering ideas and practices is not only possible, but can lead to positive learning outcomes” (NAE & NRC, 2009, p. 149). This again supports the NAE stance that engineering should be promoted in public education.

Included in this chapter is an overview of engineering education, an examination of curriculum integration with focus placed on two ways of incorporating science and engineering, and addressing the challenges facing engineering education in the United States.

Engineering Education

While the scientist may busy herself with discovering patterns in the rock cycle or weather, with studying the physical and chemical make-up of things in nature, and with explaining how natural cycles like reproduction occur, engineers take the information that scientists produce and use it to make informed decisions when designing items for human use. Brophy, Klein, Portsmore, and Rogers (2008) state, “Engineering requires applying content knowledge and cognitive processes to design, analyze, and troubleshoot complex systems in order to meet society’s needs” (p. 371). This suggests the strong linkage between science and engineering.

In an effort to help students develop an understanding of science, the 5E teaching method is often presented as the best practice for science inquiry (Bybee et al., 2006). The 5E method consists of 5 phases of learning: Engagement, exploration, explanation, elaboration, and evaluation. In this approach to teaching science, students are engaged in an activity that helps them explore a specific science concept. These explorations grow either from student-generated questions or by teacher-generated questions. Based on the data collected and analyzed during the exploring phase students try to explain what they observe. From their explanations, students are encouraged to elaborate on what is occurring in the natural world. Elaboration could include comparing their results with results of others, perhaps classmates or experts. The 5E process concludes with an evaluation of the activity, encouraging the students to evaluate their inquiry process. Evaluations could include the students reflecting on their experiences and learning, the way they handled the representation of data or whether or not their conclusions were sound. The process of asking questions helps them solidify their understanding.

The engineering design cycle varies from the 5E model in purpose. 5E is designed to help the students investigate and understand the natural world. The engineering design cycle is designed to help students take the information from science and apply it to solve a human need. Engineering activities are appropriate for science classrooms because they force students to apply their science conceptual knowledge and turn it into procedural knowledge.

The understanding of the natural world is essential in the development of an engineer. Engineers use the concepts of science to present solutions or refinements that solve human needs (Grayson, 1977). To help individuals understand the engineering cycle at a young age, it is essential that the cycle be introduced in elementary school (NAE & NRC, 2009).

Engineering education can be found in elementary schools through their use of the engineering design cycle and observation (Brophy et al., 2008). In the engineering design process students are invited to: Ask a question, imagine possible solutions, plan out designs, to create models and to improve their designs (Cunningham, 2009). Through student engagement with the design process, students are given the chance to learn about a problem, explore possible solutions, and create a design model. From this design, students are then encouraged to test their model and make alterations if necessary.

This process is evident in unit lessons such as “Lighten up: Designing lighting systems,” from the instructional program Engineering is Elementary. Over the course of this unit students design a system that allows light inside of a pyramid. First the question of how to get light inside a pyramid is discussed. The students then explore, create a model, test their design, and make modifications to see if it solves their hypothesis. As the students move through the exercise and address the modifications that will need to be made while in the design cycle, they are seeing how the concepts of science are used to solve a problem.

Curriculum Integration

Students' learning can be greatly enhanced from the integration of engineering and science. Roehrig, Moore, Wang, and Park (2012) state, "Curriculum integration can provide more meaningful learning experiences for students by connecting disciplinary knowledge with personal and real-world experiences" (p. 32). Curriculum integration of science and engineering has been suggested and supported for a number of years. Organizations have published documents such as, Science for all Americans (American Association for the Advancement of Science, 1989), National Science Education Standards (NRC, 1996), and most recently the Next Generation Science Standards (NGSS Lead States, 2013) in support of curriculum integration (Bybee, 2010).

Curriculum integration can take place in several ways. The book by the NAE (2010), *Standards for K-12 Engineering Education*, offers two ways to include the principles of engineering in instruction. These integration strategies are "mapping" and "infusion" (p. 23). Mapping is "drawing attention explicitly to how and where core ideas from one discipline relate to the content of existing standards in another discipline" (NAE, 2010, p. 28). This means making plain the connections between subjects after each specific curriculum point has been outlined. The NAE (2010) continues on to say, "mapping is a retrospective activity to draw attention to connections that may or may not have been understood by the developers of the standards" (p. 28). An example could include teaching a unit on one science concept and then providing an engineering activity that requires that information to solve a human need.

After instruction on the concepts of insulators and conductors, the teacher has students work in groups to create a habitat that would preserve the life of an ice cube shaped like a fish. From this activity, the students have the opportunity to see how insulators and conductors work "in action." This could then lead into a discussion and other activities on how fishermen transport fish to markets or how dismembered fingers and toes are kept cold for reattachment. Activities that follow instruction offer the students a chance to see the science topic can be applied to human needs.

Infusion means "including the learning goals of one discipline – in this case engineering – in the educational standards for another discipline" (NAE, 2010, p. 23). Infusion takes integration one-step further than mapping. It means that from the onset of planning a curriculum, there is intense focus on being able to integrate the secondary subject into the first area.

A classroom example of infusion would be a teacher putting together a lesson where the students must conduct an experiment to see and have proof that energy transferred. In the planning of this lesson, the teacher will plan for the curriculum aspects of science and engineering to be addressed. One such is to include integrating the engineering design cycle in the elaboration phase of the 5E format. A task is presented that requires both curricula to work together. While conducting the experiment, students keep annotated records of their experiments, acknowledging items they could control as well as those which could not be controlled. Once the initial experiment is near conclusion, the students, using their notes make changes to their design and try it again. During the experiment or afterward, the discussion of key aspects of science and engineering are discussed and addressed. Both ways of integration, mapping and infusion, imply that a teacher is concerned with more than just their content curriculum. Teachers can use the strategies of infusion and mapping to help students see the interconnections of the subjects.

Addressing the Challenges

While these integration strategies offer students the chance to be involved with the curriculum, they pose challenges to teachers. One challenge in teaching arises when faced with trying to execute multiple subjects while remaining true to them. Attention should be paid to assure that students participate in scientific inquiry and use knowledge gained to engage in an engineering task. To ensure students move through each stage of the 5E cycle, as well as the engineering design cycle, with the knowledge that will be needed for content comprehension, comes as a culmination of thinking and planning on the part of the teacher.

Another challenge is to find activities or ideas that would connect naturally to science and engineering. These challenges, along with others, present a real problem to teachers who are trying to get started incorporating science and engineering (or any STEM curriculum integration). However, with engineering being a relatively new focus in education, science teachers have a real need for lessons ideas and they will seek to see what professional resources are available.

The NSTA publishes one resource that is available for teachers. They have several professional journal publications with each targeted for specific age ranges. In these journals teachers find ideas on lesson ideas and curriculum. They are a rich source for teachers to gain ideas on curriculum and support. They offer specific lesson examples in science curriculum. Journals, like those put out by NSTA, are continually aware of current and upcoming research-based teaching practices. They strive to have their journal reflect those practices. As teachers strive to include engineering education into science education, they will look to resources that are familiar to them and offer clear and actionable ideas. After the books by the NAE were published in September 2009 with the NRC, and October of 2010, the discussion of engineering education in science classrooms became a priority. In turning to the journals they are familiar with, teachers often pattern their teaching after what is being disseminated. To keep with trends and allowing for transition time with planning, journals such as *Science and Children,* should have started the inclusion of engineering education as early as the 2011-2012 school year issues. Analysis of *Science and Children* starting with this school year would offer the chance to see what resources are available to science teachers who wish to include more engineering concepts.

Research Question

What is the NSTA teacher resource for grades K-5, *Science and Children*, publishing about engineering education?

CHAPTER 3

Methods

Content analysis is one form of qualitative research that involves a specific analysis of data. Holsti (1969) stated that content analysis is a "technique for make inferences by objectively and systematically identifying specified characteristics of messages" (p. 14). Traditionally content analysis focuses on the use of specific words or phrases, or with the use of predetermined categories (Hsieh & Shannon, 2005). From the identification of specific words and phrases and the predetermined categories, statements can be made about the meaning, which can be derived from the work (Ryan & Bernard, 2000).

Given that I am interested in what *Science and Children* is saying regarding the integration of engineering into science curricula, content analysis is effective as it helped me identify what was being said about engineering education in *Science and Children* in two ways. Initially, I started with the predetermined code of integration, and was able to identify articles and columns throughout the journals that supported this topic. A second reason content analysis is effective, is because it allows for the possible meanings (or interpretations) to be uncovered (Bogdan & Biklin, 2007). The goal of conducting a content analysis is to examine a group of texts (or journals) and uncover meaning (Hsieh & Shannon, 2005). This allowed me to analyze the information throughout the journals a second time, to discover types of integration and levels of inclusion of engineering.

Data Sources

Teacher journals like *Science and Children* from NSTA are published to help teachers stay current on what is being written on a particular topic, give ideas on practices, and curriculum or what techniques have worked. Teachers read these journals to glean information in any way they can, as such it is necessary to evaluate all parts of the journal in order to identify any part of the journal that someone might view. Because the call for article submissions begins months in advance of the publishing dates, advertisements or columns featured the engineering aspects faster than the main articles.

An issue of *Science and Children* is comprised of advertisements, columns, and articles, with issues totaling between 80-110 pages. The front cover contains the title and topic of the journal. On pages two and three, the table of contents is found, which outlines the main articles on page two and lists the columns on page three, which are organized under the headings of Teacher Resources and In Every Issue. Then following the page numbers outlined in the table of contents, the journal presents columns and main articles, followed by the remaining columns. Throughout the entire journal the advertisements can be found. Representing a variety of vendors, the advertisements vary in size from 1/8 of a page, to filling an entire page. Images are spread throughout the journal. These images relate to the topic that is discussed around the image, and can be made of clip art, visual representations of models, and pictures submitted from the authors of the main articles.

In conjunction with the studies published in September of 2009 by the NAE and the NRC and October of 2010, by the NAE regarding engineering education, I started my analysis of *Science and Children* journals from the 2011-2012 year, continuing on with 2012-13, 2013-14 (September – December issues). In analyzing 23 issues of the journal, I was able to identify the aspects of engineering education within the journals as an avenue to relay the information to educators.

Data Analysis

Phase 1. Upon beginning my research, I gathered the 23 issues of *Science and Children* from September 2011 through December 2013. Excel spreadsheets were used to organize the volume years and contained all of the aspects of the journals.

Identification information including the volume, issue numbers and the theme of the journal are found at the top. Below the individual journal information are the headers: Page number, item, identifiers, position on page, keywords, authors, description, and summary. All aspects of the journals are then listed in page order, cover to cover. The page column listed the page of the journal upon which the piece could be found. The item column identified what it was (article, advertisement, science 101). The identifier column offered information about the item, such the sponsor of the advertisement. Position on the page was initially intended to describe where the item was found on a page i.e., top right or bottom left. When the design layout became hard to explain briefly, I altered the category to reflect how much of the page the item consumed i.e., whole page, ½ page, ¼ page. The author column listed the author or authors of a piece. The description column gives a short reference to what is being written about (article title, topics, or ad summary). The summary column is a more in-depth summary of what is written or shared. It lists specifics such as the names of the books in the book recommendation section or quotes from the pieces.

In an effort to discern the information visually, color was added. Each line of the spreadsheet was then color coded based on the following divisions: Front cover – Gray, Business pages – Pink, Advertisements – Blue, Articles – Purple, Teacher resources – Green, In Every Issue – Orange.

The categories of Articles, Teacher Resources and In Every Issue derived from the journal itself, being the three categories the table of contents is broken up into. The categories of cover, business pages, and advertisements I labeled as it identified the information found in that section. Several items were initially left white, as they did not fit into any of the initially created categories. Upon closer examination, items left white were identified to be advertisements and changed to blue.

For the 2011-2012 school year the Teacher Resources category contained the following categories: In the News, Teaching Through Trade Books, The Early Years, Formative Assessment Probes, Science 101, Science Shorts, Methods and Strategies, and NSTA Recommends. The 2012-2013 and 2013-2014 volume years contained the same articles in the Teacher resources section.

For the 2011-2012 and 2012-2013 volume years, the In Every Issue category had the following categories: Editor's Note, Guest Editorial, Call for Papers, and Advertisers Index. In September of 2011 there were additional columns of, A Message from the NSTA President and A Message to Our Members. The articles focused on addressing the need for improving science education as well as exploring the *NGSS* deeper. Beginning in September 2012 articles focusing on the *NGSS* were found. Appearing in the 2013-2014 issues, the In Every Issue category has the category of Call for Papers as well as the new category of, Engineering Call for Papers.

Upon compiling the data into spreadsheets, I decided I needed to identify the information that contained STEM or engineering. Writing STEM or engineering in the keywords column identified advertisements, columns or articles that contained the keywords of STEM and engineering. This process allowed a paring down of the information to take place.

Phase 2. When I reviewed all the information that had been labeled with STEM or engineering I found 192 references. The second analysis of these items revealed that all aspects did not contain the same amount of information. Using the information on curriculum integration provided by the NAE (2010) as my basis, I sorted the identified information into those that contained integration and those that did not.

To be placed in the category, *integrating*, I decided the item must have contained the integration of engineering into the science curriculum. Identifying and utilizing the engineering design cycle while engaging in science showed evidence for this. Upon the creation of the Engineering Encounters column there were two columns that met the requirements for this category. Articles that met the requirements appeared sporadically for the first two volume years and then doubled in number for the Fall of 2013. Upon analyzing the articles again, I noted several engaged the students in an engineering activity using science while others included full description of the 5E science cycle and full instruction on the engineering design cycle and took students through several trials of a project. This led me to identifying that there were introduction to integration and full integration examples. Both introduction integration and full integration support the idea from Roehrig et al. (2012) that science and engineering work together to make more meaningful learning experiences.

Phase 3. I completed phase three in two parts: (a) identify the type of curriculum integration presented from the second phase, and (b) categorize the remaining identified STEM or engineering information. In their book, *Standards for K-12 Engineering Education*, the NAE (2010) presented mapping and infusion as ways that integration might be accomplished. Using the definitions provided in the book, I isolated the articles that focused on integrating a third time, by identifying differences in the way authors presented their integration. Articles, which presented their information by outlining all of the science, followed by the engineering, and then making plain the connections between them, represented the mapping method of integration. Other articles engaged in the 5E format, and during each section, had the students engaged in a portion of the engineering design process. Using this method, students engaged in the science and engineering cycles simultaneously in the infusion method of integration.

In the second part of phase three, I reviewed the remaining information that was identified to contain STEM or engineering. Because content analysis allows possible meanings to be inferred (Bogdan & Biklin, 2007), and resulting in the categories imposed on the data based on the literature, I developed the following categories, *mentioning* and *implementing*. I identified the first category, *mentioning*, to state the topic was mentioned with little or no detailed information. Mentions of STEM appeared in advertisements initially because advertisements are more susceptible to short notice changes. Journal topics and articles are planned and called for 6-10 months in advance.

The second category that I sorted data into I labeled *implementing*. To justify assigning an item to this category, I decided the item must have included a STEM format or focused on engineering or the engineering design cycle as a central topic in the article or lesson while leaving out the connections to science. Additionally, inserts or supplement sections, as well as columns, could be included in this category, as long as their purpose is to specifically address the topics of STEM or engineering. Columns and articles labeled as implementing occurred several times in a volume year. Upon analyzing the articles again, I noticed several only gave the students an engineering activity while others included full instruction on the engineering design cycle and took students through several trials of a project. This led me to identifying that there were introduction to implementation and full implementation examples. While varying slightly, both support the NAE and NRC's position that engineering be presented to students in elementary school (NAE & NRC, 2009).

After identifying the categories, a second set of spreadsheets was created. The goal of the additional spreadsheets was to consolidate the information that pertained to my three categories further. In the three new spreadsheets, labeled *mentioning*, *implementing*, and *integrating*, I added all of the items found in the journals matching my criteria for each category in chronological order. This final sort allowed me to see all of the pertinent items in one location, rather than sorting through every issue's notes.

CHAPTER 4

Findings

When I examined 23 issues of a journal spanning two and a half years, I anticipated that engineering education would be specifically covered in the feature articles of the journal. During examination, I discovered that engineering education was initially discussed in conjunction with the STEM acronym rather than isolated as a separate subject. While the STEM acronym appeared throughout all of the journals, once a year an issue was published that highlighted engineering as an individual subject. Upon further inspection of the journals, I found engineering described in the advertisements, columns, and articles, which displayed varying forms of integration. In October of 2013, a new column was formed which highlighted engineering specifically. However, the level and the types of integration found in the journals varied, and were then sorted into one of the following three categories: Mentioning, implementing, and integrating (See Table 1).

While the mentioning of STEM and engineering remained constant throughout the period of time I read, the journal fluctuated between implementation and integration. The 2011-12 year contained mostly mentions of STEM, such as when the NSTA (2012e) advertised for a professional development institute course titled, “Engineering by design: an integrative STEM solution for K-12” (p. 1). 2012-13 there was a mixture of all three categories containing science and engineering. Towards the end of 2013, the journal acknowledged the full shift towards *NGSS* and engineering as a separate entity from STEM (Froschauer, 2013). The 2013-14 year specifically incorporated engineering as a separate topic. Items shared in each category description are exemplars representing the category.

Table 1.

Frequency Levels of Engineering Found in Science and Children

	Fall of 2011			Winter 2012			Fall of 2012			Winter 2013			Fall of 2013		
	Ad	Col	Art	Ad	Col	Art	Ad	Col	Art	Ad	Col	Art	Ad	Col	Art
Mentioning	15	4	1	25	8	1	25	9	1	23	8	3	16	13	4
Implementing	0	0	1	0	1	3	0	0	6	0	2	3	0	1	3
Integrating	0	0	0	0	0	3	0	0	1	0	0	2	0	2	5

Totals	Mentioning	Implementing	Integrating
Advertisements	107	0	0
Columns	42	4	2
Articles	10	16	11

Note. Ad = Advertisements; Col = Columns; Art = Articles.

Mentioning

Mentioning occurred when a word, such as STEM or engineering, was used without more information given in support of the topic. One example was a NSTA advertisement in the September 2011 issue, which announced a NSTA conference on science education featuring STEM strands listing an engineering day (NSTA, 2011b). The word engineering was used without further information, details, or description. Mentioning of STEM or engineering was found in advertisements, columns, and main articles.

Advertisements. Approximately 21 advertisements were found in any given journal issue. This translated to roughly 189 advertisements in a year, and 462 advertisements over the course of the journals I examined. Of these 107 advertisements, roughly one-quarter of all advertisements, mentioned STEM or engineering specifically. An example advertisement introduced “NSTA FREE Web Seminar Series on Scientific and Engineering Practices” (NSTA, 2012f, p. 98) to highlight the eight common practices found between science and engineering in the NGSS.

One general grouping of advertisements in *Science and Children* targeted conferences. Specifically, the advertisements either requested proposals or requested participation in the conference. In September 2011, for example, NSTA invited readers to submit proposals for the STEM Forum and Expo. “Submit a session proposal for our first-ever Forum & Expo: Tools for STEM education” (NSTA, 2011a, p. 5). The advertisement listed the overall objectives NSTA requested in relation to STEM education. These types of proposals appeared for several months each year prior to subsequent forums.

STEM was also mentioned when enticing the reader to attend NSTA conferences, which take place October, November, and December. In each of these advertisements, the locations of the conferences were given with the strands of professional development taking place. During the conferences in October through December of 2011 professional development strands included topics such as, "From the Roots to the Fruits of STEM," "Crafting a college ready and Career STEM workforce for the future," and "STEM connections: Fostering Life, Career, and College readiness" (NSTA, 2011c, p. 13). Similar advertisements continued during 2012-2013, but the focus shifted toward assisting teachers with STEM. Strands such as "Everyday Applications: Putting STEM to Work, Providing Access for All Students to the Science in STEM, and The STEM Puzzle – Putting It Together" were offered for Fall of 2012 (NSTA, 2012b, p. 81).

The National Conference on Science Education was another avenue for advertising. An advertisement for the 2012 conference highlighted a strand entitled, "Merging Inquiry, Creativity, and Innovation Through STEM" (NSTA, 2011d, p. 77). A November 2012 advertisement offered attendees of the 2013 conference a strand titled, "Next Generation Technology: Putting the 'T' in STEM;" the advertisement also stated that "attendees can access: A wide range of Science, Technology, Engineering, and Math (STEM), Next Generation Science Standards (NGSS), and Common Core sessions" (NSTA, 2012d, p. 101).

Another broad grouping of advertisements in *Science and Children* is to promote books published by the NSTA Press. As with the conferences, book advertisements transitioned from STEM – such as *STEM Student Research Handbook* (NSTA, 2012a, p. 9), – to specific mentioning of engineering – such as *Integrating Engineering and Science in Your Classroom* (NSTA, 2012c, p.7). Also of note, when book advertisements offered selections with STEM or engineering, there was only one book out of the five listed. Over time the NSTA offered more selections of related book titles to offer two books on the topics. In the March 2013 journal, NSTA promoted both *Integrating Engineering and Science in Your Classroom* and *Exemplary Science for Building Interest in STEM Careers* (NSTA, 2013b, p. 98).

Companies also contributed advertisements focused on STEM. Initially, their advertisements focused on workshops or professional development. Invent Now offered the Camp Invention program. The advertisement stated, “Be among the thousands of schools that have partnered with Invent Now to provide summer enrichment in science, technology, engineering, and math (STEM) to promote critical-thinking skills essential to success in the 21st century” (Invent Now, 2011, p. 25). The Fisher Science Foundation also offered professional development workshops entitled “S.T.E.M. Explorations for Teachers: Making Real-World Connections.” The foundation explained that the workshops “are designed to present teachers with strategies that will help them incorporate S.T.E.M. learning techniques into their classrooms” (Fisher Science Education, 2011, p. 78). Of interesting note, as the NSTA held more conferences in support of STEM, the private companies advertised for their own conferences less.

Like NSTA, companies also evolved in their word choices. Vernier Software and Technology, for example, advertised in *Science and Children* “for product tours, training videos, and FREE sample demo labs for your classroom” (Vernier Software & Technology, 2011, p. 19). Several months later the same company advertised for the LabQuest 2 Connected Science System, calling it, "the most powerful, connected and versatile data-collection device available for STEM education" (Vernier Software & Technology, 2012, p. 15). Other companies, such as Project Learning Tree (2012) and Ken-A-Vision (2012), also changed the wording of their advertisements to include the key phrase of STEM.

Columns. Columns were a second place that mentioning was found in *Science and Children*. Of approximately 286 columns, 42 mentioned STEM or engineering specifically. I divided the information found in the columns from the divisions found in the journal, with the separations being Teacher Resources and In Every Issue. In Every Issue contained the columns with the editor's note, a call for paper submissions of future issues, and the advertisers index. Occasionally other columns were inserted into this section, like guest editorials or messages from NSTA.

The messages often presented a point or an idea, which later lead to a column that appeared in the Teacher Resource section. An example was a column in the In Every Issue category from the NSTA President, Patricia Simmons in September 2011. Titled "Spirit, Opportunity, and Innovation: Science Education for a Smarter Planet," Simmons outlined the purpose of the coming year of *Science and Children* journals as having a focus on promoting excellence and making improvements for science education. She wrote:

> I strongly encourage you to take advantage of these professional resources to expand your understanding and share them with your colleagues so that they too may extend their learning. Among the other resources that NSTA provides are the Learning Center, e-learning PD, STEM education networks, policy briefings and legislative updates, international connections, and awards and competitions to name a few. (Simmons, 2011, p. 8)

A second article also found in the September 2011 issue introduced *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Here the author, Harold Pratt, explained that the Framework is "a document that represents the more significant and promising step forward in science education since the release of the *National Science*

Education Standards (NSES) and the *Benchmarks for Science Literacy"* (Pratt, 2011, p. 10). Pratt added that the Framework would be used as the foundation for the *Next Generation Science Standards*. "The *Framework* provides an outline and a "frame" for the *Standards'* science content: what is core to learning science and how those ideas are related to the practices needed to engage in scientific inquiry and engineering design, and cross-cutting concepts that bridge both the sciences and engineering" (Pratt, 2011, p. 10). The highlighting of engineering was new to science education:

> The *Framework* brings some new and innovative perspectives to science education. Engineering technology and the applications of science have been added as a fourth discipline to the core ideas of the three major disciplines: physical, life, and Earth and space science. (Pratt, 2011, p. 10)

Pratt further wrote that "one major change in the *Framework* is the introduction of Scientific and Engineering practices, which encompass and expands the (science as) inquiry standards" (Pratt, 2011, p. 10-11). With the change outlined in the two articles, a new column appeared several months later beginning in December of 2011 issue. The columns focused specifically on the *Framework* and later on the *NGSS* were found in the Teacher Resource section. A description of the new column will continue in that section later in this paper.

A second occurrence of a column started in the In Every Issue section and later moved to the Teacher Resource section was found beginning in the Summer 2013 journal. In a column titled, "New Science and Children column call for papers - Engineering in the Elementary Classroom" (NSTA, 2013c, p. 71), the NSTA outlined the components of engineering and called for pieces to be written that "include all of the components necessary for an engineering investigation to be completed and assessed, from design to implementation" (NSTA, 2013c, p.

71). The call for papers then lead to a new column entitled Engineering Encounters that began in the October 2013 issue. The new column will be discussed later in this paper.

The Teacher Resource section contained the columns: In the News, Teaching Through Trade Books, The Early Years, Formative Assessment Probes, Science 101, and NSTA Recommends. Other columns, such as Science Shorts, Methods and Strategies, Natural Resources and Recognizing Excellence, were inserted into this section. Another column in this section, stemmed from the Patricia Simmons article (2011), which represented the goal of informing the reader about the *Framework for K-12 Science Education* and later about the *Next Generation Science Standards.*

The first example of mentioning in this information column appeared in the December 2011 journal. Author Rodger W. Bybee wrote a column titled, "Scientific and Engineering Practices in K-12 Classrooms." Here he outlined the eight science and engineering practices found in the *Framework*. In doing this, Bybee highlighted that engineering overlaps with science and they are complementary.

> The relationship between science and engineering practices is one of complementary. Given the inclusion of engineering in the science standards and an understanding of the difference in aims, the practices complement one another and should be mutually reinforcing in curricula and instruction. (Bybee, 2011, p. 15)

Subsequent articles found in other issues of volume forty-nine outline: "Core Ideas of Engineering and Technology" (Sneider, 2012), "Crosscutting Concepts" (Duschl, 2012), "Engaging Students in Scientific Practices" (Krajcik & Merritt, 2012), and "Engaging Students in the Practices of Explanation and Argumentation" (Reiser, Berland, & Kenyon, 2012). The articles clearly stated the importance and work that is shown in the *Framework*. During volume year fifty, articles such as these continued. Several of the first columns offered a deeper look into the science framework.

Beginning in February 2013 the column shifted focus to address parts of the *NGSS*. These articles broke the *NGSS* into the three parts of science: Life, Physical, and Earth and Space science. Again, author Rodger W. Bybee wrote the initial article in February that outline the purpose of these articles:

> Using the life sciences, this article first reviews essential features of the NRC *Framework for K-12 Science Education* that provided a foundation for the new standards. Second, the article describes the important features of life science standards for elementary, middle, and high school levels. Finally, I discuss several implications of the new standards. (Bybee, 2013, p. 7)

Authors Joe Krajcik (2013) and Michael E. Wysession (2013) addressed these same topics of discussion for Physical science and Earth and Space sciences respectively. In the beginning of volume year fifty-one, there were no articles on the topics of the *Framework* or the *NGSS*.

Other columns found in the Teacher Resource section also mentioned STEM or engineering. The NSTA Recommends column repeatedly mentioned STEM or engineering with book reviews. Book reviews are written by one reviewer from the NSTA reviewer panel. Reviewing *Cool Engineering Activities for Girls* by Heather E. Schwartz, Marilyn Cook (2012) outlined the parts of the book from the 10 engineering activities to the inclusion of the technology aspects. Other books, such as, *Bridges and Tunnels: Investigate Feats of Engineering*, *Integrating Engineering and Science in Your Classroom*, and *STEM Lesson*

Essentials were also reviewed with the particulars outlined and connections to STEM or engineering made.

A unique column appeared in the Summer 2012 issue. “STEM supports a blooming summer” was an additional NSTA recommends page however, all the books listed on the pages were listed under the Science, Technology, Engineering or Mathematics headings which they fall under. Reviewer Juliana Texley briefly addressed the books for each category. For the Engineering and Integration section she reviewed two books: *Everday Engineering* and *Trapped*. *Everyday Engineering* contained articles found in the *Science Scope* NSTA journal. *Trapped* offered the detailed story of how engineering, science, and cooperation worked together to free the Chilean miners (Texley, 2012, p. 67).

“STEM Day in the Park: A Weekend Event” was the title of a Recognizing Excellence column that introduced families to science concepts in an outdoor setting. Here, Kathleen Bledsoe wrote how the STEM day was adapted from activities found at the Dayton Regional STEM center. Students were grouped by ages and participated in activities (Bledsoe, 2012).

The second new column that appeared from a column in the In Every Issue section is the Engineering Encounters column. While calls for this column began in summer of 2013, the column first appeared in the October 2013 issue. The first column written by David Crismond, Laura Gellert, Ryan Cain, and Shequana Wright was titled “Minding Design Missteps.” The authors addressed six errors beginning designers made with an engineering project and offered solutions on how educators have worked with them. They did this to show that, “while design tasks can be used as engaging filler activities, when done well, they can show students how science ideas can be helpful in addressing problems that they face in their daily lives” (Crismond et al., 2013, p. 85). While this column continued, subsequent topics addressed move this column to the Integration section.

Articles. Articles I featured in the mentioning section only give reference to the word of STEM or engineering, while missing the greater details of those topics. Mentioning was less likely to occur in the main articles, because most of the time, the author of the piece moved on to implementing or integrating of STEM or engineering. Of approximately 132 articles, 10 mentioned STEM or engineering specifically. Julie McGough and Lisa Nyberg titled an example of mentioning "Strong STEMs Need Strong Sprouts!" The authors began by writing "Engage young children in asking questions, engineering designs, and constructing knowledge, and see what they can build!" (McGough & Nyberg, 2013, p. 27). The authors made the reference: "*A Framework for K-12 Science Education* describes a vision in which students actively engage in scientific and engineering practices and apply crosscutting concepts to deepen their understanding for the core ideas in these fields (NRC 2012)" (McGough & Nyberg, 2013, p. 27).

In this unit, first graders participated in a study on plants. "In this article, students examine how and why plants work through in-depth investigations based on their questions that go far beyond a first-grade understanding of plants" (McGough & Nyberg, 2013, p. 27). Students started with pumpkins, cutting them open to see what they would find inside. Then students moved onto other plants to see what stems looked like inside. This experiment generated questions inquiring about how plants got food, used sunlight, etc. These questions lead to the creation of a model of a functional plant. Here the students demonstrated how plants worked, lived and grew. The first grade students presented this model in the garden of their school on parent night. While this did not have the engineering design cycle, it did incorporate crosscutting concepts found in *Framework for K-12 Science Education* as far as "questioning, developing models, investigating, constructing explanations, and communicating information of the structure and function and system models" (McGough & Nyberg, 2013, p. 27). While the authors created a vague connection to engineering, there is no other reference to STEM or engineering in the article. The article and authors did not tell us if any explicit connection to STEM were made to the students, or that the students participated in the engineering design. For this reason, this article was identified as fitting into the mentioning category.

"Becoming Science Experi-mentors" by Shelly Lynn Counsell, from October 2011, discussed a professional development program. The article talked about the efforts by "the National Science Foundation project *Ramps and Pathways* (an innovative inquiry-based constructivist science curricula" (Counsell, 2011, p. 52). It talked of the NSF's effort to provide effective professional development to educators. Educators were placed into learning communities and given a chance to move from science learners to science mentors, under the theory that teachers who understand and have experienced the science can then better understand and help students learn. Teachers met over the course of several months and engaged in science inquiry related to ramps and pathways. Meeting overtime, offered the teachers the chance to learn the science, collaborate with peers and engage in productive professional development. The funding for this professional development was provided by the Center for Early Education Science, Technology, Engineering, and Math (CEESTEM; Counsell, 2011).

Most of the article – nearly two and half pages – discussed the format of the professional development, how it was set up, and how to direct the teachers and their learning. One column was dedicated to the topic of what the teachers were actually engaged in doing while participating in this conference. The teachers studied the science behind forces and motion, energy, and Newton's laws. Teachers acted as the students would, and went through the process of building ramps and pathways to achieve goals, make evaluations and changes, and built another. The "teachers use physical science knowledge, concepts, and theory such as Newton's laws to support their hypothesis, interpret the outcomes of their investigations, and eventually guide and inform future ramp structures" (Counsell, 2011, p. 55). Even though the support for the professional development was provided by CEESTEM, labels of the engineering design process were not explicit stated; the activities that the teachers were engaged in outlined the design process. However, I felt that the purpose of this article was to inform us about the professional development and not to outline the STEM and engineering practices.

A third example of mentioning is an article with the subtitle, "An engineering challenge requires students to work together while providing an opportunity for assessing their learning styles" (Gooding & Metz, 2012, p. 26). "Collaborating for communication" authors Julia Gooding and Bill Metz described their activity, which involved creating a statue and hiding it behind a screen. One student looked at the statue and reported back to the group, giving descriptions on how to recreate it. The student who looked may not use their hands so the remaining students in the group must rely on the communication. While this activity allowed for students to make continual alterations based on directions, this one-time activity offered little into the engineering design process (Gooding & Metz, 2012).

Every March, the NSTA publishes an article titled, "Outstanding Science Trade Books for Students K-12." The books that were identified, covered all aspects of science and beyond.

> Our vision of what we call science has broadened. The practices we use to explore the natural world and to create new products now include mathematics and engineering. We also recognize the importance of the arts, history, and human perspectives in these explorations. Science is not just one "way of knowing," but many. (NSTA, 2013a, p. 71)

The book recommendations were formatted in the same fashion. The book title was given, followed by the information about the book, publisher, number of pages, ISBN, price, the grade for which it is intended, and the summary of the book. All of the book reviews were written by a member of the Book Selection Panel and they were identified by their initials at the bottom of the piece followed by a Roman numeral that identifies which National Science Education Standard it represented.

Several books mentioned in the March 2013 issue included the mentioning of STEM or engineering specifically. In the review of *Moonbird: A Year on the Wind With the Great Survivor B95*, Betty Crocker mentioned that the book identified the types of research techniques that were used to study shore birds, then added a short sentence, “Great STEM resource” (Crocker, 2013, p. 76-77). Rebecca Monhardt offers her review of *The Boy Who Harnessed the Wind* by stating, “Creativity, engineering design, and problem solving come together in this true story of how a young man, just 14 years old, built a windmill to provide much needed water for his drought-stricken African village” (Monhardt, 2013, p. 77). The short mentioning that ties these books to STEM and engineering, has offered teachers a quick reference for go-to books on the subjects.

The mentioning of STEM or engineering occurred in advertisements, columns, and articles throughout the journals. Initially engineering appeared in conjunction with STEM. Over time, and following the creation and later use of *A Framework for K-12 Science Education* and the *Next Generation Science Standards*, engineering became a separate subject that was discussed and addressed.

Implementing

Examples of implementation are those I define as teaching engineering content, with detailed information, design cycles, and lesson plans on said curricula, but not in relation to, or with the use of science. The implementing of STEM or engineering is hard to represent in advertisements; as such, I found none. Examples of implementation were found in columns and main articles. Of approximately 286 columns, 4 implemented STEM or engineering specifically.

Columns. The October 2013 issue offered an example of implementation, found in The Early Years column. Writer Peggy Ashbrook connected STEM to inquiry in an activity geared for grades PreK to 2. The author outlined ways to tie STEM into other teaching subjects, with a particular focus on including engineering. She wrote, “Planning to include an engineering process as part of an investigation can help us see how engineering can be an important part of the investigation—not a short activity tacked on to satisfy the ‘E’ in STEM” (Ashbrook, 2013, p. 30). The activity shared by the author contained the objective: “Children will investigate how to carry and transport a heavy object including designing and using a tool” (Ashbrook, 2013, p. 31). Through this activity, children were tasked with moving heavy objects across the room with no hands and no breakage. They were asked to draw one solution, discuss how it will work and then try it. Encouraging the students to redesign helped the students to see the engineering design process.

In the Teaching through Trade Books column titled “The Stealth Profession,” Emily Morgan and Karen Ansberry implemented engineering through the use of trade books: *The Handiest Things in the World* for grades K-2 and *Timeless Thomas: How Thomas Edison Changed Our Lives* for grades 3-5. "This month's lessons give students not only an awareness of the work of engineers but also the opportunity to think like engineers" (Morgan & Ansberry, 2013, p. 16). A 5E format lesson/activity, found on pages 17-18, focused on the use of *The Handiest Things in the World*. The purpose of the lesson was that "students will recognize the difference between designed and natural objects, identify the problems that various objects were designed to solve, and come up with ways to improve upon these designs to make the objects more useful or more fun" (Morgan & Ansberry, 2013, p. 17). Students were shown objects, and while the book was read, the students identified the objects. Then students were given one of the objects in the book to discuss. The author says, “Explain that instead of coming up with completely new inventions, engineers often think of ways to make an old one better” (Morgan & Ansberry, 2013, p. 18). Discussions on the invention of the umbrella and past versions of it took place. Students were tasked with engineering improvements upon the umbrella.

Another Teaching through Trade Books column that demonstrated implementation was “3-2-1 Blast Off” by Christine Anne Royce. She presented two trade books: *Roaring Rockets* for grades K-2 and *The Best Book of Spaceships* for grades 3-5. Pages 19-20 contained a 5E lesson for grades K-3 with the objective: "Students will build balloon rockets in order to manipulate different variables and determine what affects how well the balloon rockets move" (Royce, 2013, p. 19). During this activity the book *Roaring Rockets* was read to the class and a discussion on how the rocket flies was held. Students were shown multiple styles of rockets, with exposure to land rockets, then given a chance to launch land rockets, which are balloons attached to straws on string, across the room. After this, students were given time to engage in designing and engineering a new rocket by making changes to the original land rocket design. What the students changed, and how it worked, was shared with the class. The author connected this activity to Practice Number 8: Obtaining, evaluating and communicating information (Royce, 2013). A 5E lesson for grades 4-6, found on pages 21-22, contained the objective: "Students will construct a rocket and launch it to determine if different amounts of fuel affect the rocket differently" (Royce, 2013, p. 21). Throughout this lesson, students participated in the engineering design cycle by changing the amounts and types of fuel for their rocket. While these columns represent lesson plans and not a completed lesson the idea of implementing engineering is there.

Articles. Of approximately 132 articles, 16 showed implementation of STEM or engineering specifically. As I looked at the main articles, two levels of implementation were seen. The first level I describe as an introduction to implementation. This meant that the author made ties to engineering without providing students a true engineering experience. An example of this was found in “Experiencing Friction in First Grade” by Bill Burton. After several activities, the students tied a rope to a chair and attempted to pull themselves across the floor towards the chair. During this process the students were able to see the amount of friction being shown on the board from a force plate that was attached to the chair. Then the author challenged the students to find a way to reduce the friction. Students redesigned of the experiment included a board placed on top of tennis balls. The students tried the experiment again and were able to see the lower amount of friction displayed on the board (Burton, 2012). In this experiment, the students were able to participate in engineering by changing an aspect and perform the experiment again.

Another example of introduction to implementation was found in “Cooking with the Sun’s Rays.” The writer, Mary Lee Keepler, described a day of summer camp in which students learned about solar ovens and watched cookies being baked. Students were given a pizza box and the ingredients to make smores, and then positioned their box in such a way to catch the sun, to melt the chocolate for the smore (Keepler, 2012). However, the limitation of no explanation of the engineering design process prohibits these experiments from being full implementation.

Full implementation of engineering contains detailed information, design cycles, and lesson plans on engineering. Examples of full implementation in the articles were most often displayed when offering the students a specific design challenge, because they moved past the introduction of engineering to including the full engineering design cycle. Pamela S. Lottero-Perdue, Jennifer Nealy, Christine Roland, and Amy Ryan (2011) offered an example of implementation in the article "Caught on Video." The authors stated, "The engineering instruction is based upon a unit from Engineering is Elementary (EiE) called *A Sticky Situation: Designing Walls…*" (Lottero-Perdue et al., 2011, p. 56). Students were to design and build a wall. Students interacted with all of the materials that they would need to build the wall. Time was spent making notes about walls found in the neighborhood. Students then created possible mortar solutions. During the testing and analysis phase, students built their walls, and tested them using a wrecking ball. All the tests were filmed and recorded for later analysis. Through the entire process the students identified and used the engineering design cycle used by EiE. The outlining of this cycle to the students placed this article at the full implementation level.

A second article that offered an example of full implementation was "Reinventing the Bridge" by Cecilia Owens and Erin Ash Sullivan (2012). The authors used an EiE program titled *Javier Builds a Bridge*. Students were given the challenge of building a bridge to hold 50 pennies and have a car go back and forth four times. Following the first attempt of building a bridge, the students were taught the EiE engineering design cycle. After students had created a second design, a group of four students worked with an adult. They explained the process they had gone through and outlined their current design. After their meeting with an adult, the students reflected on the second attempt and designed a third model (Owens & Sullivan, 2012). With the outlining of the EiE engineering design cycle and the use of it several times this article offered a great example of implementation.

The implementation of engineering was found in twenty columns and articles in the journals. Examples of implementation ranged from an introduction of engineering with the use of an activity to the full explanation and use of the engineering design cycle.

Integrating

The category of integration I defined as an in-depth use of both engineering and science. Explicit instruction on the topic, such as the use of the engineering design cycle, is given with application of the topic into a second subject, such as science, or vice versa. The integration of STEM or engineering has been hard to represent in advertisements; and as such, I found none. Of approximately 286 columns, 2 mentioned STEM or engineering specifically. Examples of integration were found in the columns and main articles.

Columns. Since the monthly column Engineering Encounters began in October 2013, it has offered teachers ideas for integrating engineering. The inaugural column focused on what problems could occur and offered solutions for them. Since then, the column has specifically offered ideas and lessons on what it means to integrate science and engineering.

In the November 2013 column, “Engineer It, Learn It: Science and Engineering Practices in Action,” authors Cathy P. Lachapelle, Kristin Sargianis and Christine M. Cunningham outlined why engineering was included in the *NGSS*. The column then listed the eight practices found in the *NGSS* by presenting them in conjunction with a challenge of designing parachutes. The article described how the class of students engaged in the EiE engineering design cycle and offered several examples that represented each practice. The authors showed their support for the integration of science and engineering with the following statement: “As students gain experience with engineering and science practices, they also become more effective—and creative—problem solvers” (Lachapelle et al., 2013, p. 76).

The December 2013 Engineering Encounters column switched from the explanation of engineering and science integration to an actual classroom example of integration. While the “Catch Me If You Can!” article was written with the subtitle of, “A STEM activity for kindergarteners” was integrated into the curriculum, the science and engineering aspects were highlighted separately. The article offered STEM extensions that had been done with the gingerbread man hunt. Pieces such as adding in the technology of a trap, the engineering of building gingerbread house to try and trap him, and the math of charting to see if the houses caught him (Lott, Wallin, Roghaar, & Price, 2013).

Articles. As I looked at the main articles, I identified two levels of integration: Introduction to integration and full integration. I defined introduction to integration to mean that the author made explicit ties to science and engineering while leaving out portions of one or more of these subjects. Of approximately 132 articles, 11 integrated STEM or engineering specifically. “Landing safely on Mars” by Eileen Merriett and Elizabeth Shifflett offered an example. While the students learned about space and Mars specifically, they also studied the landings of spacecraft on Mars. Students planned a “landing” on Mars and decided on what equipment they would need. "The goal was to have the spacecraft arrive safely at its destination with all of the model equipment intact" (Merriett & Shifflett, 2012, p. 38). While students engaged in the designing of their Mars landing craft, they continued study on the other aspects of space completing personal solar system books. After the completion of the landing crafts, the students were able to witness them ‘land’ on Mars, which was a toss off the building onto the ground below. Then students were able to see how their landing craft faired (Merriett & Shifflett, 2012). I categorized this article under integration because engineering occurred with the science portion clearly addressed. While the connection of engineering and science took place, there was no discussion on the engineering design cycle steps, and no redesign of the students work.

Mapping. Full integration I defined as one where all aspects of engineering and science can be found. According to NAE (2010) there are two ways to demonstrate full integration. The first way is mapping; making plain the connections between subjects after each specific curriculum point has been outlined. I took this to mean that after an initial subject, such as science is covered, then a second subject such as engineering is covered, and then the connections between the subjects are made clear.

Jill Jensen offered an example of mapping in "The Science of Safety." The author specifically wrote that the students came to her, the science specialist, already having learned balance and motion. She engaged them in a unit using the EiE design cycle focusing on creating cars and building ramps. Students began by using basic cars to test the types of ramps they could create. They were given a figurine to place inside the car and again tested their car on the ramp. Students soon noticed that they needed safety belts of some kind. At this point the author introduced the EiE design cycle focusing on how to keep the figurine safe. The students then engaged in completing several models of the car and various ramp heights. Jensen concluded, "The classroom teachers, back in their rooms, reinforced concepts and content throughout the unit" (Jensen, 2012, p. 45). Her statement is a good example of mapping; it completed the two subjects at different time and connected them back together.

A second article that represents mapping is "Shedding Light on Engineering Design" by Brenda M. Capobianco, Chell Nyquist, and Nancy Tyrie. The authors worked together to create a unit that helped students learn about Ultraviolet (UV) light using UV light beads. They looked for ways to incorporate engineering into the curriculum. "Rather than taking an isolated engineering design-based activity and adding it into the curriculum, we took an existing scientific inquiry activity using UV light-detecting beads and purposefully created a series of engineering design-based challenges around the investigation" (Capobianco et al., 2013, p. 59). The authors created several engineering design briefs: "An engineering design brief is a plausible scenario or situation in which students are asked to solve a problem using the engineering design process" (Capobianco et al., 2013, p. 61). Using the information from the science unit on UV light beads, the students were given one of each of the engineering design brief cards and asked to build a prototype to fit the scenario. After multiple attempts through the designs students created models they were comfortable with. As the authors used a previously created science unit and then added an engineering component to it, they offered an example of mapping integration.

Infusion. The second way the NAE (2010) recommended full integration is by infusion. Infusion occurs when from the onset of planning curriculum, intense focus is placed on including the secondary subject into the first area. The method of infusion was more prevalent throughout the journals.

"Save the Boulders Beach Penguins" by Katherine Sheerer and Christine Schnittka demonstrated how one classroom combined the 5E learning cycle of science with the engineering design process. After learning the plight of the penguins on Boulder beach, students were tasked with creating a habitat that would keep the penguin cool and in the student's case retain the most mass in a frozen penguin ice cube. When involved with the explore step of the 5E cycle, students were able to experiment with types of materials. During the elaborate step of 5E, the students were introduced to the engineering design cycle, and participated in making the designs. In the evaluation portion students attempted the experiment of their habitat (Sheerer & Schnittka, 2012). The authors clearly outlined the integration of science and engineering in this article. They also looked forward to the future: “Engineering design will not just be taught as an elective to older students who have an interest in engineering as a career; it will be taught as a habit of mind and a 21st-century skill to all students in every grade at every achievement level” (Sheerer & Schnittka, 2012, p. 54).

A second example of the infusion method of integration was found in the “Buoying Design Skills” article. Angela Bliss, Elizabeth Bell, and Lundie Spence presented a lesson that “incorporated weather, data collection, and buoy construction” (Bliss et al., 2013, p. 50). The students participated in a three-step process to (a) learn about the science content and buoys, (b) building the structure to float and hold supplies, and (c) to install the weather monitoring equipment. Through this process students learned about weather patterns and equipment while they learned about buoyancy and creating things to float. These buoys were placed around the community to gather data. In doing this the students participated in a fully integrated science and engineering lesson while helping the community (Bliss et al., 2013). Also contained was a reference to an article found in December 2012, in which students also built buoys to float and hold weight (Dickerson, Hathcock, Stonier, & Levin, 2012). While the idea was the same, the 2013 article took the idea to another level of integration by including the science aspects of learning about weather and weather-monitoring equipment.

The integrating of engineering was found in thirteen columns and articles in the journals. Engineering became the focus of a newly created column. While an example of an introduction to integration was found, the majority of the eleven articles focused on full integration with the use of the mapping or infusion.

Summary

Engineering began in the journals, as a subject that was incorporated into STEM. Over the course of two and a half years, various levels were covered. It was found in the mentioning of advertisements for conferences and books. It was mentioned in columns and articles that among other things discussed the *Framework for K-12 Science Education* and the *Next Generation Science Standards*. Examples of implementing were found in columns and articles, such as those that asked students to create new designs of an object or fully engaged students in an engineering design task by EiE. Integration was shown in articles three times each year. In the fall of 2013 it became more prevalent by presenting five articles in the space of four months. Mapping and infusion offered two ways of ensuring that integration happened.

CHAPTER 5

Discussion

As a journal published by the National Science Teachers Association, *Science and Children,* by definition should focus on science. Using the 5E process, previously presented as best practice (Bybee et al., 2006), should be a goal of all publications presented by the NSTA. Teachers in turn, should turn their attention to helping students learn science through the inquiry process found in the 5E cycle. This allows for the discovery of science.

Engineering gives place to the practical knowledge of the information found in science. Here individuals take ownership of the information learned during the scientific inquiry, and apply it while addressing the needs of the engineering task. To facilitate deeper understanding, students need to engage in both the 5E of science inquiry and the engineering design cycle. This is supported through the creation of the *NGSS*. The *NGSS* outline age-appropriate science practices for grade-level bands. To this is added, engineering practices to facilitate student understanding of a science concept. While engineering practices can be used to supplement and deepen understanding, teachers must take note that not all science is discovered through engineering, some topics must be learned through discovery.

Integrating engineering into science is not only important to teachers in classrooms, but also to the whole community. Students struggling with textbook learning in classrooms and their parents' care; especially parents of children who display an aptitude for integrated learning. Elementary Educators who read this journal would care because they would know that NSTA and *Science and Children* have a focus to engineering. As such they might be inspired to start small, trying new lessons and finding ways for engineering to become part of their classroom. College professors of Elementary education majors would care because they could use this as a source of information to show their students as a reliable source of information and examples to include engineering. NSTA and *Science and Children* might care because it would indicate the message or focus that they are trying to send.

Upon analyzing the journals, I learned STEM was an important enough concept for the NSTA to place it in the advertisements of the journals for all 23 issues of the journal. Advertisements and conferences quickly incorporated STEM and engineering. In the later issues, advertisements also came from NSTA with invitations to STEM conferences with specific emphasis on engineering. However, not everyone can attend science conferences for information, and therefore turn to the journal. Once STEM and engineering were introduced, as terms readers should be looking for, their natural draw is to look for resources. Engineering became an important topic with *A Framework for K-12 Science Education* and the explanation and release of the *NGSS*. *Science and Children* supported this with additional columns, guest editorials, and book reviews including engineering. With 33 columns and articles mentioning, implementing, and integrating engineering, information was available for teachers to access activities and lessons covering a wide variety of science topics, as well as ways to incorporate engineering. Also within the 33 columns and articles, teachers who are familiar with the engineering design cycle and the integration of science and engineering are found resources available.

While it's true that the NSTA needs time in order for people catch up with new ideas or strategies and try it, before they can write articles that can be included in future journals, the length of time it took for engineering to become a separate focus was considerable. The lack of initial consistency in having columns, and articles that included engineering specifically was frustrating. If a teacher missed an issue, they would miss all connections. Continual consistency, of engineering into columns and articles would be needed.

The mere mentioning of STEM or engineering will not assist in shifting teachers' paradigms. However, it does open conversations about STEM and why engineering is important in science. From conversations, curiosity and interest grow. Teachers with increased interest look for all resources that offer a chance to include engineering into the classrooms. While there have been examples of mentioning, implementing, and integrating, there is no distinguish between the three categories. Teachers who are new to STEM and engineering would need an increase of explanation of what integration of the subjects looks like.

Teachers and educators are talented individuals who have excellent ideas. In many ways, they, like the authors of the articles could expand or build upon ideas that are present with more background information. Little in said in the journals of ways to alter, expand, or deepen an experience between science and engineering. One example of alterations made to a commonly used unit, the gingerbread man hunt, show great possibilities for a teacher to deepen student's understanding and knowledge by small changes (Lott et al., 2013). The inclusion of more expanded examples such as this, allow teachers to see the possibilities of integration.

Movement toward integration was shown with the implementation of engineering into main articles in specific volumes of the journals. Further progress was made with the integration of the engineering encounters column and articles describing integration, in multiple issues. While *Science and Children* identified specific issues as focusing on engineering, there was no way to distinguish which example in the journal offered students a chance to deepen their knowledge.

By offering examples of different types of integration, through mapping or infusion, teachers see multiple ways they can incorporate engineering into their classroom. However, these examples of implementing and integrating engineering into science were sporadic. Teachers familiar to STEM and specifically engineering could quickly grow frustrated at the lack of consistent in-depth information and resources in the journals.

Science and Children need to continue with the engineering counters column as well as smaller examples and including engineering into the main articles, to show a focus toward the integration of engineering into science. If the NSTA were to be more consistent in the publication of engineering, such as the same month(s) every year, or every three months, or at least one main article with the integration every issue, this would allow educators to gain a firm grasp on the concept and be able to start integrating it into their teaching. This would also allow teachers with background knowledge of STEM and engineering a guaranteed place to reference for ideas.

With one quarter of their advertising space and twenty percent of the columns and articles focusing on it, the NSTA clearly made engineering a focus of their journal. They showed a progression from mentioning STEM, to the specific integration of engineering into their journal, *Science and Children*. They started off small, mentioning the buzzword of STEM education through a series of ads for conferences and private companies. Their next step was to include a column that focused on the topics of STEM and engineering specifically. Through the descriptions of the new framework and the NGSS, they discussed the importance of engineering and its integration into science. This was followed with the dedication of one or two volumes of the journal in a year to the discussion and inclusion of engineering and the engineering design process. The journal solidified this with the integration of an additional column focused solely on engineering as well as integration into the monthly-featured articles.

As an elementary teacher who reads this journal, I can see the benefits and ease of including engineering into science lessons. Engineering is an important topic that encourages students to engage in the design cycle while exploring the possible solutions to a problem. While a teacher may seem intimidated by having to include engineering into their curriculum, they should take heart and follow *Science and Children's* model. Start with small connections or implementations and work up to full integration.

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