Where is the L in STEM? One Teacher's Integration Experiences with Literacy, Science, and Engineering

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The undersigned, appointed by the dean of the Graduate School,

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A candidate for the degree of

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And hereby certify that, in their opinion, it is worthy of acceptance.

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Chapter One: Introduction

Research Problem and Rationale

During the 2010-2011 school year, my principal at Bowling Elementary was approached by the Assistant Superintendent of Elementary Education regarding improved student performance. In response the principal, Mr. Hall, met with our staff members of Bowling to decide what their interests and ideas were regarding changes. Two classroom teachers who had participated in a technology integration program suggested that the focus for the school should be on technology. After Mr. Hall met with the Assistant Superintendent of Elementary Education to share the technology focus suggestion, they decided to expand the focus to include the areas of mathematics, science, and engineering (STEM.) As a Title I school with approximately 90% students of minority and 90% students receiving free and reduced price lunch, the decision to focus on STEM was made to increase enrollment and improve achievement for all students in our building.

As part of the transition, I was asked to assume the role of science, technology, engineering, and mathematics (STEM) instructional coach. While there were no defined expectations or job description, I knew I would work collaboratively with our teachers to help them make this transition. My new role taught me more about STEM and allowed me more opportunities to research this concept. There were several models and some research on STEM education at the middle and high school levels but little at the elementary level. This curriculum focus was going to be a challenge for us and we were going to have to figure it out as we proceeded.

In January of 2011, the school hosted a World Cafe event where administration, staff, parents, and community members were invited to discuss the new focus. Comments and questions were collected from all participants and compiled into a list to help provide input for the transition. Some of the comments regarding curriculum at Bowling included "adding things with scientific backing (i.e. nonfiction in reading), integrating all day long units integrating multiple academic areas, and using collaborative/inquiry lessons." These curriculum comments focused on an integrated curriculum that connects multiple content areas together (see Appendix I for additional information).

As the 2010-2011 school year continued, the administration held several other staff and community meetings to make decisions and to receive input on how to best transition to a STEM school. Conversations from these meetings centered on defining STEM and deciding what it would look like at Bowling Elementary. For example, minutes from the February 11, 2011, meeting described the central ideas from the staff around STEM to including incorporating career talk into curriculum lessons and teaching through inquiry and problem solving (See Appendix J). A small group of staff members including classroom teachers, support staff, and the principal even traveled to a model STEM school in Minnesota to see what type of curricular and instructional changes the school implemented when they became a STEM school.

Over the last two school years, the school has slowly continued its transition. It has adopted the "Engineering is Elementary" curriculum developed by the Boston Museum of Science (2013) to bring more engineering aspects into the curriculum. The school has also made several purchases to increase the amount of technology available to teachers and students. Each staff member has a school-purchased iPad to help integrate technology into the classroom. A set of thirty iPads and thirty laptops are available to teachers to use in their classrooms. Several of these purchases came from grants and donations given to the building as a result of its STEM focus. These changes were outlined in one of the school's brochures (see Appendix K).

The second year in the STEM transition was focused on curriculum and instruction. In a document presented to teachers at back-to-school meetings, the principal outlined some of the expectations for the school year such as teachers were to attend a minimum of one professional development session each month and all grade levels taught a minimum of two engineering units over the course of the year. Through conversations with the principal, we decided that as the STEM specialist I would collaborate frequently with the grade level teams to help revise curriculum, in addition to team-teaching science and engineering lessons (see Appendix L). Bowling Elementary also partnered with a local university to write a grant to provide more effective instructional strategies through the implementation of the 5E instructional model. This instructional model developed by the Biological Sciences Curriculum Study (BSCS) is designed around constructivism and the belief that students should be encouraged to construct their own knowledge. After receiving the grant, teachers were asked to think about the current design of their science lessons and how they could be modified to fit the 5E model. During the school year, the university partner instructor met with teachers and helped them modify lessons that allow more inquiry and discovery as opposed to a more traditional lecture experience. Once teachers had taught a lesson using the 5E model, they were asked to share their results at monthly faculty meetings. This helped teachers share their experiences and get feedback from their peers regarding changes in practice. Based on my conversations with teachers and the principal, the hope is to continue to learn about implementing these practices in future years.

As we transitioned to focus on STEM education, we attended a school board meeting to discuss this change. Many community and board members were uncertain why our school was selected for this transition. There was also some hesitation about what this type of change would mean for our curriculum. I attended the meeting along with several other staff members to show our support of the change and our dedication to making this transition happen for our students. We were unwavering in our belief that our students deserve this type of change and should not be written off simply because of their past academic performance. At one point during the board meeting, one of the members looked over at the group of teachers and asked if this change meant we would no longer be teaching our students to read and write. She thought the focus on science, technology, engineering, and mathematics meant there would be no time for literacy. That question had never even crossed my mind: I understood how critical literacy skills were to understanding the world around us. The board member's question was pivotal for my research and I began to develop the topic for my dissertation.

I left that board meeting asking myself not whether we would teach reading, but how the STEM focus would change how we taught reading and writing. In other words, it was more of HOW are we going to teach literacy as opposed to WHAT would we teach. The more I explored these questions, the more excited I was to study this for my dissertation. I realized that in spending a year as a STEM instructional coach, I had been in classrooms listening and watching how teachers were teaching reading, writing, science, and engineering. So, after four years of pondering my dissertation topic, the decision was made. I would spend the next year researching the impact of STEM education on integration and literacy instruction.

Theoretical Underpinnings

Inquiry in education has been around for many years but has been pushed aside by the focus on testing and the requirements of No Child Left Behind. While some classroom teachers have moved to a more traditional and direct method of instruction, others still emphasize the important impact an inquiry curriculum has on student learning. The National Research Council (1996) defined inquiry within the context of the national science education standards. According to the NRC,

> Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (p. 23)

This definition of inquiry highlights the importance of students being active participants in their own learning by asking questions, gathering data, and developing conclusions based on evidence. The use of inquiry methods is beginning to return to classrooms with the creation of the Common Core State Standards, the Next Generation Science Standards, and a push for STEM education. STEM education challenges teachers to use inquiry to help students see connections among content areas and emphasizes students being in control of their own learning.

The current research on impacts of STEM education on student learning is limited. Several studies focused on secondary students and the integration of two or more content areas (Kelley, Brenner, & Pieper, 2010; Redmond et al., 2011; Merrill, 2001). Each of these studies examined the effects of using an integrated curriculum on student learning. All three studies found the use of an integrated program did result in an increase in student learning, but Merrill (2001) indicated the need for more research in this area to provide more support for this type of curriculum.

The amount of research is even more limited when looking for studies that incorporated literacy and STEM education in elementary classrooms. While some studies have attempted to address integration of literacy and other content areas (Larkin-Hein, 2001; Guzzetti & Bang, 2010), the focus has still remained on secondary students. The literature on integrating literacy and content areas in the primary grades is limited, but current studies have provided some insights for this area. Research studies in the areas of content area literacy, talk and oral language, and pictorial representations have all added to the literature on literacy integration.

Content area literacy is another important area to consider when looking at an integrated STEM curriculum. Content area literacy involves the use of reading and writing to learn about other areas such as science and engineering. Reading and writing about these content areas helps students develop a deeper understanding (McKenna & Robinson, 1990). Effective content area instruction includes comprehension strategy instruction, as well as implementing specific instructional strategies geared towards reading and writing about other content areas. Some research has supported the use of nonfiction texts (Kraemer, McCabe, & Sinatra, 2012; Heisey & Kucan, 2010) and science notebooks (Fulwiler, 2011; McMillan & Wilhelm, 2007) as ways to get students reading and writing about science.

Research on use of talk and oral language in classrooms adds to the understanding of effective instructional strategies in STEM education. One way that language skills can be developed in classrooms is through opportunities for students to talk about what they are learning. Many researchers have focused their work on studying the impact of talk on learning (Chapin, O'Connor, & Anderson, 2009; Barnes, 2008). In each of these instances, talk was the central component to helping students make sense of the content. Opportunities for "exploratory talk" as described by Barnes (2008) provided students with oral language experiences where they shared ideas and constructed new understandings.

Finally, another research area that helped to inform this study focused on semiotics and the use of pictorial representations. While Charles Sanders Peirce (1958) and Ferdinand de Saussure (1983) are traditionally known as two of the founders of semiotics (the study of symbols used to communicate meaning), other researchers have expanded on this area of study. Science notebooks are often incorporated into classrooms and students are required to draw scientific sketches or drawings. When students take knowledge from one sign system (ex. facts learned from a text) and transfer that to another sign system (ex. sketch in their science notebook), they are developing a more complex understanding of that concept. Research in this area supports this belief that transferring from one sign system to another requires a deeper understanding of the content (McCormick, 2011).

While the documentation of literacy instructional strategies and content area reading and writing is plentiful, the research on implementing these in the context of STEM education is not. More research needs to focus on the impact of teaching and applying literacy strategies within the context of science and engineering at the elementary level.

Purpose of the Study

This study was designed to gain a better understanding of how literacy is taught within the context of STEM education (more specifically science and engineering) in a primary classroom through integration. I have worked with many elementary teachers who think integration provides a way to teach students skills in context. These teachers suggest teaching skills within the context of other areas allows students to make more connections and helps them learn to apply the skills in multiple areas. STEM education is also becoming more of a trend in education with support from the White House. It will be important for teachers to begin to look at ways to pull more science and engineering instruction into an already busy instructional plan.

This study describes how one primary classroom teacher integrated literacy practices and strategies into her science and engineering instructional blocks. Findings from this study provide insights into teacher questioning, inquiry, teacher reflection, and how the view of reading and writing moved from strategies to practices of scientist and engineers. This information is valuable to someone who is just beginning to consider integration of these areas. In addition, participation in this study allowed the participating teacher a way to share her experiences, frustrations, and successes with a wider audience. As she explained, it provided a sense of validation that she was in fact closer to "seamless integration" than she thought she was.

Finally, the purpose of this study was to provide a deeper insight into how students respond to instructional strategies that incorporate integration. Findings from this study describe how students often use sketches and drawings to communicate literacy skills during science and engineering time. These young first and second grade students often relied on oral language and pictures to communicate meaning to themselves and others. This information is important to consider when looking at primary students who are just learning to communicate through written language.

The Research Questions

The research questions and related sub-questions that guided this study are:

RQ1: How does a first/second grade teacher integrate literacy strategies and practices within the context of science and engineering units?

Sub Q1: How does she use reading and writing instructional practices as tools to teach science and engineering?

Sub Q2: What are her successes?

Sub Q3: What are her tensions?

Sub Q4: How does she change over the course of the study?

RQ2: How do the students incorporate literacy into their science and engineering work?

Sub Q1: How do the students apply literacy in their science/engineering conversations and discussions?

Sub Q2: How are the students using pictorial representations to communicate meaning?

Methodological Procedures

To answer the research questions, I conducted a study using a case study design. I selected one primary classroom teacher from a local STEM school to be the main participant. Prior to collecting the data, I obtained consent and assent from the school district, IRB, school principal, participating teachers, parents of students in the participant's classroom, and the students themselves.

Once permission was obtained, I collected data for a total of three months (October through December). During these three months, I met weekly with the participating teacher to plan observations for the week. Each week, I observed a total of three lessons during science/engineering and/or literacy time (reading and writing). Each lesson was videotaped and each conversation was recorded with a digital recorder. Then, at the end of each week, we would meet again for a follow-up interview. I showed photographs of student work and/or video segments from one of the lessons for the week. This process is similar to that of video stimulated recall as described by Lyle (2003). The goal of these interviews was to gain a deeper understanding of her planning, reflection, and reaction to the lessons. The participant teacher also wrote in a digital journal on a weekly basis to reflect on different lessons and the process of integration.

I also collected student work samples from their science notebooks. I made photocopies of six student notebooks every two weeks. When copying the notebooks, I selected every entry from the past two weeks for each of the six students. I also took pictures of any projects or student work during the observations that would not be available to photocopy at a later date. In addition to these student work samples, I informally interviewed two students each week that I observed. These interviews occurred during the observations and focused on the activity and related thought processes of the students.

Limitations

As with any research study, this study has necessary limitations. First, and as a result of the use of a case study design, I only collected data from one classroom teacher. The goal of a case study was to provide enough detail and description to provide the reader with a better understanding of the case. For this reason, the findings from this study are not meant be generalized and applied to all classrooms. Secondly, my role as a participant observer significantly influenced the design and findings for this study. I had a relationship with all participants prior to the start of the study. As such, I influenced some of the decisions and instructional practices of the participants. I provided professional development sessions and collaboration meetings for all involved. Each of these instances impacted the decisions made on a daily basis in the classroom. Finally, when conducting research in classrooms, it is often hard to separate the various factors that impact instruction and achievement. It is impossible to say whether the experiences this teacher had were a direct result of her reflection, planning, and instruction or if they were results due to the group of students. Perhaps both factors played a role in the findings for this study.

Organization of the Study

This study is broken down into a total of five chapters. Chapter one provides a brief introduction and overview of the research. Here I provided insight into the rationale and purpose of the study. I also briefly described the research methodology used to design the study and collect data. Chapter two is a review of the literature relating to this study. In this chapter, I focused on the following areas: STEM education, instructional practices across the disciplines, oral language and talk, semiotics and pictorial representations, and teacher change. Chapter three describes the research methodology including research questions, data collection procedures, and methods of analysis. In chapter four I offered both the study findings and a discussion of the themes that emerged from the data. The concluding chapter, chapter five, provides conclusions, interpretations of the findings and themes, and suggestions for future research.

Chapter Two: Review of Literature

STEM Education

Overview

Recently, a move towards the implementation of STEM (Science, Technology, Engineering, and Mathematics) education focused on helping teachers better prepare students to enter these important fields. When this movement first came about, it was referred to as SMET (Science, mathematics, engineering, and technology). However, program developers did not feel the acronym promoted a positive image so it was changed to what we now know as STEM. As this movement has become more popular, it has increased the need to develop a general understanding of what it means. Sanders (2009) differentiated between STEM and STEM education. He explained, "Most, even those in education, say 'STEM' when they should be saying 'STEM education,' overlooking that STEM without education is a reference to the fields in which scientists, engineers, and mathematicians toil. Science, mathematics, and technology *teachers* are STEM *educators* working in STEM *education*" (p. 20). In his mind, it is more than just a focus on these fields; it is a new focus for education.

So what exactly does STEM education mean? While there is not a clear definition, some individuals have attempted to describe its characteristics. Lantz (2009) explained, "STEM education offers students one of the best opportunities to make sense of the world holistically, rather than in bits and pieces. STEM education removes the traditional barriers erected between the four disciplines, by integrating them into one cohesive teaching and learning paradigm" (p. 1). For Lantz, the key components of this approach are the integration of content areas and the application to real-world experiences. STEM education takes the skills learned across content areas and integrates them. In other words, it has an “interdisciplinary approach” to education and instruction.

As with any educational movement, it is important to consider the impact STEM education has on teaching and learning. Since it is a relatively new area, little research has looked at the empirical evidence to support the use of this interdisciplinary approach to education. Becker and Park (2011) highlighted this gap in research in their meta-analysis of integrative approaches among STEM subjects. Their focus was to provide an overview and better understanding of the impact of an integrated approach to teaching and learning. For this meta-analysis, the researchers found twenty-eight studies that compared integrative approaches an student achievement and met their three research study criteria: 1) studied integrative efforts of STEM education between 1989 and 2009, 2) were searchable in the selected databases using preselected terms, and 3) examined students’ achievement with quantitative findings (Becker & Park, 2011, p 25-26).

Results from this meta-analysis found a total of thirty-three achievement effect sizes in the twenty-eight studies. Of those thirty-three effect sizes, eleven studies had a statistically significant effect size over 0.8. In all of the studies, only seven of the effect sizes fell below 0, which would indicate the traditional approach was more effective than the integrative approach on student achievement. They also compared effect sizes across grade levels, types of integration, and student achievement in STEM content areas. The effect sizes for each of their research questions can be found in the Appendix A. Becker and Park explained, “Looking at students’ achievement through integrative approaches, the findings revealed that students’ achievement on the integrated concepts of STEM literacy showed large effect sizes" (Becker & Park, 2011, p. 31). In other words, the students who were taught content using an integrative approach had higher achievement in the STEM subject areas. While this study does show some support for a more integrative approach to education, such as STEM, the findings are limited because the number of studies devoted to this topic is small.

Integration of Curriculum

Just as Lantz (2009) explained, STEM education involves the integration of content areas. However, integration is not a new concept in education and continues to be found in a range of research and literature. In some classrooms, integration involves the connection between two or more content areas. For example, teachers might accomplish this type of integration by making connections between science and math. For the purpose of this paper, this type of integration will be referred to as basic integration. In other classrooms the teacher views integration more through the idea of teaching through inquiry. Harste (2001) described the various processes of an inquiry-based curriculum as seen in Figure 1. According to Harste (2001), "A good inquiry-

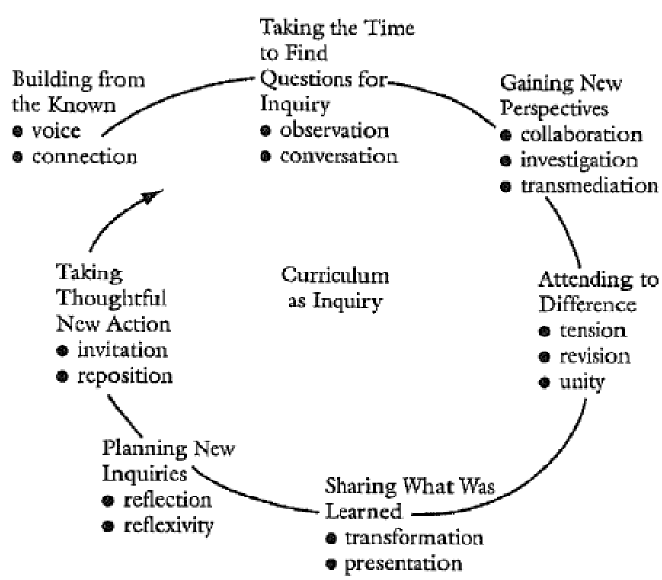


Figure 1 Harste (2001) Curriculum as Inquiry Processes

based curriculum focuses on learning how to learn" (p. 7). In other words, a classroom teacher who teaches integration through inquiry focuses on the process of learning and not on the content areas themselves. Again, for the purpose of this paper, this type of inquiry will be referred to as seamless integration/inquiry.

Since the integration of content areas is a key component of STEM education, the development of this type of curriculum has been the focus of recent studies. Satchwell and Loepp (2002) outlined an integrated mathematics, science, and technology curriculum developed for seventh grade students. This type of study used the idea of basic integration because the focus was on integrating specific content areas and not seamless integration/inquiry. The developers worked to build a framework that connected the practices of all three areas mathematics, science, and technology. Once this framework was developed, the committee moved on to developing the curriculum by identifying themes that were shared across the three disciplines. From these shared themes came a learning cycle that included open-ended, hands-on activities (Satchwell & Loepp, 2002, p. 46).

The overall goal of the learning cycles was to allow students to construct their own learning by exploring concepts in a structured environment. Each learning cycle included four phases: exploring the idea, getting the idea, applying the idea, and expanding the idea. The initial phase, exploring the idea, was developed to introduce students to the concept through hands-on activities. During this phase, common misconceptions were identified, predictions were made, and ideas were recorded in various ways. During the getting the idea phase, the teacher was responsible for guiding the investigation through discussions, reflective questioning, and identifying any misconceptions. Once a common consensus was made about the concept, students were allowed to explore some of their own questions with the goal of expanding what they had learned in the previous phases by applying it in new ways. Finally, during the expanding the idea phase, students were given opportunities to expand on what they had learned by applying the concept in another context.

The Biological Sciences Curriculum Study (BSCS) developed a similar instructional model around the idea that students learn best when they are engaged and involved in the learning process. The model was designed around constructivism and the belief that students should be given opportunities to construct their own knowledge. The five E's in this model were engage, explore, explain, extend, and evaluate (Bybee et al., 2006, p. 8-10). Table 1 outlines the central idea behind each stage.

Stage Name	Description
Engage	The purpose for the ENGAGE stage is to pique student interest and get them personally involved in the lesson, while pre-assessing prior understanding.
Explore	The purpose for the EXPLORE stage is to get students involved in the topic; providing them with a chance to build their own understanding.
Explain	The purpose for the EXPLAIN stage is to provide students with an opportunity to communicate what they have learned so far and figure out what it means.
Extend	The purpose for the EXTEND stage is to allow students to use their new knowledge and continue to explore its implications.
Evaluate	The purpose for the EVALUATION stage is for both students and teachers to determine how much learning and understanding has taken place.

Table 1 NASA (2012) 5E Instructional Model

The overall purpose of this instructional model was to provide students with opportunities to explore various concepts while teaching them to collaborate with others and to construct their own understanding. For this reason, this same process could be used to learn content through inquiry and collaboration in other content areas.

In contrast to the studies that focused on STEM education, a majority of the research has looked at one or more of the STEM content areas: science, technology, engineering, and/or mathematics. Redmond et al. (2011) designed a research study with the intention of improving sixth and seventh grade students' learning by incorporating science and mathematics with engineering by using project-based activities. This integration study evaluated the use of *Get a Grip* engineering curriculum and after-school mentoring to improve students' attitudes and academic performance. The researchers used two quantitative surveys (Middle School Mathematics Attitude Survey and Middle School Science Attitude Survey) to collect data on the students' attitudes, beliefs, and knowledge about science and mathematics. They also conducted interviews with classroom teachers about their experiences with the *Get a Grip* curriculum.

Results from this study demonstrated a positive impact of the engineering curriculum on four areas: 1) confidence in science and mathematics, 2) effort toward mathematics and science, 3) awareness of engineering, and 4) interest in engineering as a potential career path (Redmond et al., 2011, p. 406). This study also found students who participated in the program for two years had an increased confidence in the area of mathematics. These results suggest the integration of engineering, science, mathematics, and problem-based learning has a positive impact on middle level student beliefs and learning.

Another study by Merrill (2001) examined the impact of an integrated curriculum on a group of high school students. In this study, the researchers examined the cognitive learning effect of an integrated technology, mathematics, and science curriculum; the perceived connections between the content areas by students; and the long-term impact on retention for the students. To accomplish this task, the study followed a modified quasi-experimental nonequivalent control group design to help answer their research questions (Merrill, 2001, p. 47). High school students were randomly assigned to either an experimental group or control group course. Over the course of two weeks, the experimental groups were taught using an integrated curriculum while the control group was taught the same skills, only through more traditional “workbook exercises.” Results from this study found that although both the control and experimental groups did make academic gains, the experimental group did not show significantly higher gains compared to the control group. The finding indicated that while this type of instructional model does increase student learning, the impact on testing is not necessarily significantly greater than that of the more traditional method of instruction. This study also used more basic integration by focusing on integrating a select few content areas. The researchers suggested that more research needs be done to investigate this topic on a more longitudinal basis.

With the push towards curriculum integration and STEM education, it is becoming clear more research needs to be done in these areas. Current research has identified success in the use of these models but has not indicated the degree to which it impacts student learning (Merrill, 2001; Redmond et al., 2011). Findings from research on integration have also identified the common struggles that come with this type of instruction and teaching. One of these struggles is the impact of teachers’ perceptions and of their willingness or not to change (Satchwell & Loepp, 2002; Merrill, 2001). Satchwell and Loepp (2002) explained:

> Teacher attitudes had a significant influence on the implementation of the IMaST curriculum. In some cases an administrator and perhaps one teacher was enthusiastic about integrated learning, while the other teachers resisted change. This situation had the potential to cause positive professional growth, but also resulted in a negative attitude on the part of some of the teachers. The collective attitude of the teachers had a direct impact on student learning. (p. 50)

With an integrated curriculum, many teachers are pushed to teach content areas they might not feel comfortable teaching previously. For this reason, some teachers might be more hesitant to adopt this form of instruction. Additionally, the significant time commitment needed to successfully plan and deliver this type of curriculum often influences whether or not it is successful.

Adding Literacy to STEM Education

A large amount of the research on STEM education and integrated curriculum has focused on the integration of two or more of the content areas in middle school or higher (Satchwell & Loepp, 2002; Redmond et al., 2011; Kelley, Brenner, & Pieper, 2010). There are a small number of studies that focus on integrated curriculum including literacy (Larkin-Hein, 2001; Guzzetti and Bang, 2010). This number gets even smaller when looking at integration of literacy in the elementary schools (Van Meeteren and Escalada, 2010; Connor et al., 2010;). A brief look at these studies is below.

A study conducted at American University evaluated the effectiveness of using writing as a tool to understand science. Larkin-Hein (2001) explained, “A traditional science classroom may present potential barriers that could inhibit learning for some students. The active process of writing can provide one mechanism through which these barriers to learn could be reduced and possibly even removed" (p. 26). For this study, researchers selected a general education course to study because these students are often overlooked as not needing to master the science content. However, the researchers argued that these students need to be taught these skills because they are important members of our society. The overall goal was to help students use writing as a way of understanding the science content they were learning. While the study did not produce any quantitative data, feedback received through the oral presentations and interviews provided valuable qualitative data. The information from these data sources supported the belief that the use of writing allowed these college students to gain a deeper understanding the science content.

Guzzetti and Bang (2010) also studied the impact of integrating literacy instruction with science content for secondary students. In this mixed-methods study, the researchers analyzed the impact of the instructional approach on female students' interest and achievement in science. During the study, the teachers implemented a three-week integrated literacy-science unit. This integrated unit focused on forensics and included a wide range of literacy activities including journal writing, reading-related texts and mysteries, analyzing handwriting samples, and small group discussion. The results demonstrated statistically significant differences between the control group and experimental group regarding student achievement on pre- and post-tests. In other words, students who participated in the experimental group, receiving instruction through the integrated forensic unit of study, performed higher on the post-test. These results provided support for the STEM practice of integration and of teaching skills in the context of other content areas for secondary students.

Focusing on elementary students, Van Meeteren and Escalada (2010) described their experiences in the classroom with literacy and science centers. They explained that there is a clear connection between science and literacy instruction because the areas require similar cognitive functions (Van Meeteren & Escalada, 2010, p. 77). While this article did not describe a typical research study, it did provide insight and added to the literature on the integration of science and literacy. The authors described the importance of bringing in science concepts to their literacy centers. By incorporating a hands-on science station during guided reading stations, the students were asking questions and developing inquiry skills (Van Meeteren & Escalada, 2010, p. 74). These stations allowed the students to build on their reading and writing skills while also strengthened their vocabulary and the background knowledge necessary to be successful as scientists. The students manipulated the objects and tested theories they developed through the hands-on experiments. They also asked questions and challenged each other's ideas by talking with peers. The strategies shared in this article provided more support to the notion that STEM education requires integration of literacy and other content areas.

Similar to Van Meeteren and Escalada, Connor et al. (2010) conducted a research study in a second-grade classroom to look at how students can develop science content knowledge while also developing their literacy skills. To accomplish this task, the teachers and collaborating researchers developed a five-lesson unit with each lesson lasting between three and six days. The Individualizing Student Instruction Science (ISI-Science) curriculum was designed using the 5-E Learning Cycle, which involved inquiry-based activities and discussions. During the lessons, the teacher differentiated instruction through the use of leveled text, scaffolding, and assignment modification. Students were evaluated on taught content and additional science content using pre- and post-test assessments. The assessments were composed of both multiple choice and constructed response questions.

To assess the impact of this curriculum, the researchers compared pre-and post-test scores on both target skills and non-target skills. Paired sample *t*-tests indicated "an average increase of 30% in the number of science content questions answered correctly following the ISI-Science intervention" (Connor et al., 2010, p. 480). Results also indicated the improvement was a direct result of the instruction because student scores on non-target skills did not improve on the post-test. Finally, even students who started the unit of study with lower reading and science skills made positive gains in their post-test scores. This study provided important insights into how curriculum integration impacted the learning of primary students. However, its limited timeframe for data collection again illustrates the need for more research on the impact STEM education and integrated curriculum have on primary students.

Some of the previous studies (Connor et al., 2010; Van Meeteren & Escalada, 2010) discussed research conducted in primary elementary classrooms where literacy was integrated with science. Their findings indicated positive academic outcomes for students when the teacher connects reading and writing to what they learned in science. However, this data is limited when looking at primary students and should be an area of focus for future researchers, because the learning that takes place at this level serves as the foundation for later learning. Many primary classrooms focus mostly on reading, writing, and mathematics, with science occurring occasionally. Additional research could change this practice by identifying the positive impact integration of these areas has on student learning.

Instructional practices across the disciplines

Comprehension and strategy instruction

The National Reading Panel (2000) identified comprehension as one of the key concepts in the area of literacy. By identifying the importance of comprehension, this report supports the idea that creating meaning out of what is being read is the overall goal of reading. We read for a wide range of purposes, all with comprehension as the central idea. However, the process one goes through to understand what is being read is not a simple one. For this reason, it is important to understand the complex nature of comprehension instruction.

Rosenblatt (1994) wrote about the "transactional" view of the reading process. This perspective on reading and comprehension was built around the belief that readers create their own meaning through purposeful and active reading. According to Rosenblatt's transactional view of reading, "The 'meaning' does not reside ready-made 'in' the text or 'in' the reader but happens or comes into being during the transaction between reader and text" (p. 7). Readers bring their own experiences and background knowledge, which helps to comprehend the text. While the central ideas a reader takes away from the piece might be the same, each reader creates a unique understanding of the text and comprehends it in a slightly different manner than someone else.

Armbruster, Lehr, and Osborn (2001) supported the belief reading is a complex process and involves many components. They argued that proficient readers are both purposeful and active when reading. They explained, “Using their experiences and knowledge of the world, their knowledge of vocabulary and language structure, and their knowledge of reading strategies (or plans), good readers make sense of the text and know how to get the most out of it” (p. 41). According to Armbruster, Lehr, and Osborn, teachers should provide students instruction on specific comprehension strategies. This instruction helps students learn how to monitor their own comprehension when reading by identifying when something does not make sense. When this happens, readers then implement additional comprehension strategies to understand what is being read.

Some of the literature on reading comprehension focused on specific comprehension strategies. Miller (2002), Dorn and Soffos (2005), and Keene and Zimmerman (2007) all believed that comprehension is best taught directly and practiced regularly. While Miller concentrated on young readers and identified six specific comprehension strategies, Dorn and Soffos focused on the important role language plays in comprehension. Keene and Zimmerman (2007) identified the importance of teaching students meta-cognitive strategies and the thought process that occurs during reading. All of these researchers believed that comprehension instruction needs to be modeled and students need to have a wide range of opportunities to practice their comprehension skills using both fiction and nonfiction texts.

In contrast to the research supporting strategy-based instruction, McKeown, Beck, and Blake (2009) found different results in their study to determine the most effective method for teaching reading comprehension. During this two-year study of fifth grade students, comprehension instruction was taught using three different methods: content approach, strategies approach, and a control group. The content approach requires students to think about the text through meaning-based questions. In contrast, the strategies approach focused on the mental processes and strategies used to comprehend a text (p. 223). The control group worked on comprehension through predetermined questions found in the basal reader. Results indicated the students who were taught using the content approach performed better on the narrative recall and expository learning probes (p. 242). It seemed that students who were taught to think about the text using meaning-based questions developed a better understanding than those taught only using comprehension strategies.

While a large majority of research focuses on comprehension of narrative texts, Hammond and Nessel (2011) provided insight into understanding comprehension by focusing on the importance of using informational texts. According to them, informational texts engage students as they search for answers and knowledge about a particular topic (p. 57). More background knowledge and critical thinking is involved to comprehend informational texts. For this reason, it is important to provide opportunities to learn comprehension strategies for informational texts and have opportunities to practice these strategies frequently. These skills become increasingly important as students begin to get into more difficult texts often found in content area reading.

Fetters, Ortlieb, and Cheek (2011) conducted a study to better understand the use of expository science text in elementary classrooms. They looked at the similarities and differences in the teachers' instruction of expository reading strategies with second through fifth grade students. After the ten-week data collection and analysis, the researchers found the six teachers used both higher and lower level questions during group discussions. This frequent use of questioning strategies allowed their students to get engaged in the conversations around the science topic. These teachers also encouraged students to summarize what they had been learning on a frequent basis. The successes found in this study are important to consider when looking at the impact of strategy instruction with expository texts during science time. These researchers believed more research should be conducted that focuses on these areas.

A study by Lutz, Guthrie, and Davis (2006) looked at the impact of an integrated science and reading curriculum on students' comprehension, text complexity, and teacher scaffolding. Three fourth grade classrooms were selected for this study, with one receiving traditional reading instruction while the other two were taught using an integrated reading-science curriculum. In the integrated classrooms, strategy and comprehension instruction was taught in the context of understanding plant and animal survival through the incorporation of fiction and nonfiction titles. The researchers found that the students in the classrooms that received the integrated instruction demonstrated growth in reading comprehension and strategy use (Lutz, Guthrie, & Davis, 2006, p. 13). The text complexity in the integrated classes was also higher compared to the classroom that taught through a more traditional approach. This result indicated the classrooms with integrated reading and science instruction allowed students to become engaged in what they were learning through the implementation of complex literacy tasks.

It is clear from the research and literature that comprehension is a key component to becoming a proficient reader. It is important for readers to be able to monitor their own understanding and identify when meaning gets lost. As many would agree, teaching comprehension strategies seems to be an effective way to help readers improve their comprehension skills (Miller, 2002; Keene & Zimmerman, 2007). For educators, comprehension instruction is vital to the success of our students. Keene and Zimmerman (2007) explained, “When immersed in compelling text and equipped with comprehension strategies, children will reach further, probe deeper, and understand complex material from the earliest ages” (p. 11).

Content Area Literacy

Through studies and experience, educators have begun to understand how different content areas require students to read and comprehend texts differently. William S. Gray (1919) was one of the first individuals to discuss the idea of reading and writing in content areas. Results from a study with high school teachers indicated that different content area departments valued different uses of reading. As a result, Gray suggested that students should be trained in ways to comprehend content area texts (Gray, 1919, p. 158). As a result of research in this area, the connection between content area knowledge and reading instruction has become more clear. They have to occur together for the students to be able to apply reading strategies to new learning.

McKenna and Robinson (1990) talked about reading and writing as tools for understanding other content areas. They defined content literacy as “the ability to use reading and writing for the acquisition of new content in a given discipline” (p. 184). From their perspective, content literacy is the means in which an individual learns the content in other areas of the curriculum. In other words, students learn and come to understand science concepts through reading and writing about them. Content knowledge and content literacy are complementary and one cannot happen without the support of the other, according to McKenna and Robinson.

When students use reading and writing in content areas, they are reading and writing to learn new ideas and content. Similar to McKenna and Robinson, Jacobs (2002) believed content area literacy uses reading and writing as tools to understand other information. She spoke of two processes (reading to learn and writing to learn) as meaning-making processes (p. 61). In other words, students engage in these literacy activities with the purpose of creating new meaning about the content. In these instances, students have moved past learning the basics of how to read and write to use these skills as tools to help them learn other content.

Miller and Veatch (2010) discussed what they call "Literacy in Context" (LinC). Figure 2 shows the cycle they developed to help teachers integrate literacy instruction into their content areas. The teachers gain a deeper understanding of their students' skills and background knowledge by working through the four steps: plan, teach

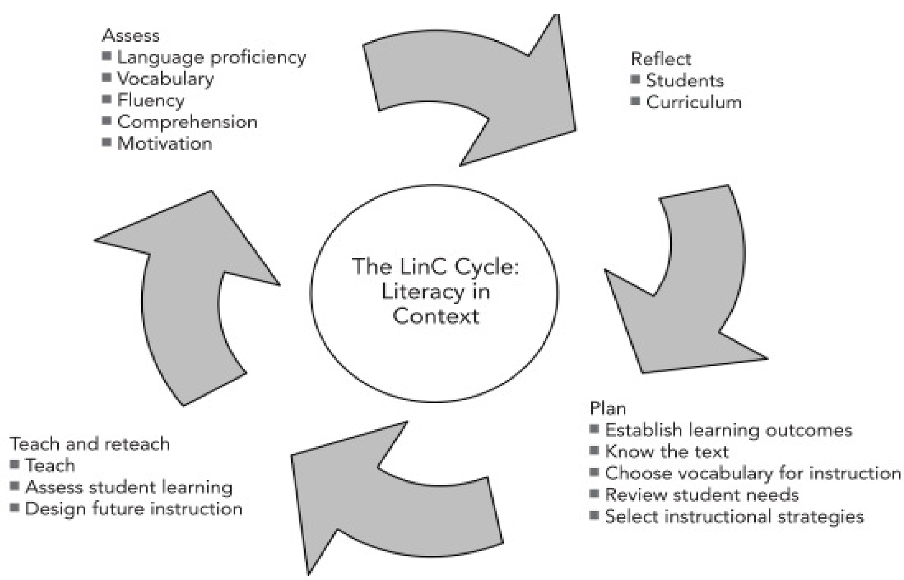


Figure 2 Miller & Veatch (2010) LinC Cycle

and reteach, assess, and reflect. Since comprehension and meaning making help develop more content area knowledge, literacy development needs to occur at the same time. Students need to be taught how to read and comprehend texts in specific content areas. Miller and Veatch's LinC cycle provides one method of how successful integration can occur with literacy and other content areas.

Shanahan and Shanahan (2008) discussed the importance of understanding the different literacy skills that are developed and required for different types of content area reading. Figure 3 shows the pyramid they developed to represent the development of literacy skills. Shanahan and Shanahan point out how it narrows as it gets closer to the top because the skills get more complex towards the top of the pyramid. These disciplinary skills also become more limited regarding how the skills should be used and

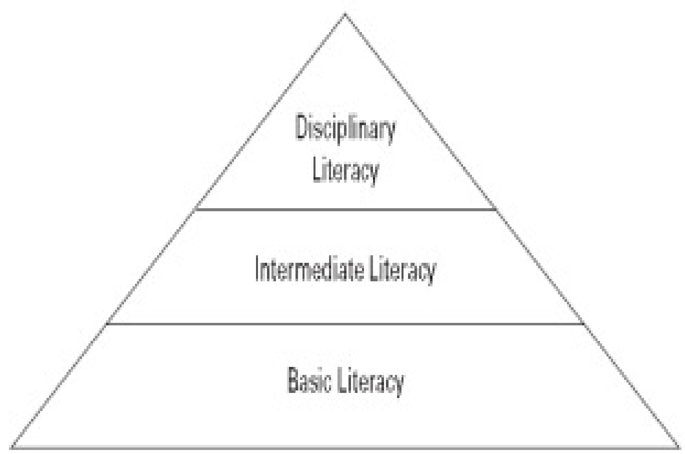


Figure 3 Shanahan & Shanahan (2008) Pyramid of Literacy Skills Development

applied in other instances. For example, at the bottom of the pyramid are basic literacy skills that are often taught during the primary elementary grades and will be used by most readers in every text they read. However, more complex skills such as vocabulary and comprehension skills needed to understand a biology text are limited in regards to the number of situations they can be applied to. For this reason, it is important for students to be introduced to and practice skills at all three levels.

In support of the idea that different content areas require different reading skills, Shanahan and Shanahan (2008) conducted a study to determine what literacy instruction and strategies were occurring in various disciplines. During the study, they visited with a range of experts from various fields (mathematics, science, etc.) and quickly realized each discipline approached reading in their content area differently and applied slightly different comprehension strategies. For this reason, each of these content teachers recommended different strategy and comprehension instruction for their students. As a result of these findings, Shanahan and Shanahan suggested that content area teachers need to have appropriate training on how to teach comprehension strategies in their classrooms. They believe the overall goal is to provide students with the instruction needed to help students to be successful across a range of disciplines.

In addition to a focus on comprehending content area texts, it is important to consider the types of tasks students are being given. Parsons and Ward (2011) made an argument for the use of authentic tasks in content literacy classrooms. They explained that students are more engaged and learn more when they see the relevance of the task to their life. For example, they explained students who are asked to complete a fill-in-the-blank worksheet using their social studies text develop an inaccurate understanding of the role of their textbook. From this activity they believe the purpose of the social studies text is to locate random facts and answer questions. They have a difficult time seeing the text as a resource to help them understand past events and history. Parsons and Ward also explained how authentic tasks helped students build their academic vocabulary through natural experiences. Authentic tasks allow students to be exposed to a wide range of oral language experiences through direct instruction of skills, group discussions, and responding to questions. Overall, Parsons and Ward believed authentic learning tasks in content area classrooms helped students become more engaged, built their academic vocabulary, and improved student learning by giving them opportunities to learn skills in context.

Parsons and Ward (2011) said it best when they identified the importance of content area literacy. They explained:

> Skill and strategy instruction is a vital component of content literacy, but content literacy is more than just skills and strategies. We also need to teach students why content reading is important and relevant. Well-designed tasks both explicitly teach students the skills and strategies for comprehending text and give students experiences that show them content literacy is a worthwhile pursuit. (p. 462)

The goal of content area literacy is to teach students the importance of reading and writing to learn. It is about helping students see reading and writing as tools to help them understand the world around them. Without the ability to read and write, students would not have a way to learn and understand anything else.

Informational Texts

One important difference in content area classrooms is the increased use of nonfiction texts. Duke (2004) has suggested, “We are surrounded by text whose primary purpose is to convey information about the natural or social world. Success in schooling, the workplace, and society depends on our ability to comprehend this material” (2004, p. 40). This quote brings to focus an inevitable fact for teachers this day and age. Students of all ages need to be introduced to informational and nonfiction texts. Integrating these texts into science is one way to go about accomplishing this task.

Duke (2004) outlined four strategies she believes primary teachers can use to improve their students understanding of informational texts. She suggested increasing the access students have to informational texts by having a range of nonfiction texts available for the students to read and view. She also suggested increasing the amount of time spent reading and talking about informational texts by integrating these texts into more instructional activities and utilizing them during read-aloud time. Her third strategy focused on helping students learn how to comprehend these types of books. Often they are organized in different ways and include more charts and graphs than fiction texts requiring students to learn how to make sense of the text they are reading. This could be done through modeling and allowing students to practice activating prior knowledge, making predictions, and asking questions. Finally, Duke suggested informational texts should be used for authentic learning purposes. It is simply not enough for students to be given an informational text and asked to answer questions teaching them informational texts hold random information. Making informational texts a focus by integrating them into relevant classroom experiences will help students learn the power of reading to learn.

Adding to the research on informational texts, Kraemer, McCabe, and Sinatra (2012) looked at the impact of listening to informational text on first graders' listening comprehension. In this study, two classrooms of students received an intervention where they heard informational texts read aloud over a four-week period while two other classrooms listened to mostly fictional read-aloud texts. The researchers used the

Qualitative Reading Inventory-3 and an individual informal reading inventory to assess listening comprehension for the student participants. At the conclusion of the study, researchers found the students who listened to informational texts on a frequent basis scored higher on the listening comprehension post-assessment. They also found students from both the experimental (informational read-alouds) and the control (fictional read-alouds) groups preferred to read informational texts when given the choice. Overall, findings from this support the claim that teachers should introduce and use informational texts with primary students.

One way to incorporate more informational texts in the elementary classroom is through sharing these texts during science time. Heisey and Kucan (2010) shared the results from their study of a multi-aged first and second grade classroom designed to analyze the impact of incorporating carefully planned read-aloud texts on students understanding of science concepts. During this study, one classroom implemented during-reading discussion scripts where students were asked questions focused on four areas: scientists at work, content-specific information, intertextual connections, and vocabulary (Heisey & Kucan, 2010, p. 669). A second classroom implemented a similar strategy only the questions came after completely reading the text. Results from the study indicated,

> First and second graders can be engaged in thoughtfully considering important text ideas in a read-aloud context and that the careful selection of texts can support their developing understanding of themes that emerge in compelling ways when more than one text is used. (Heisey & Kucan, 2010, p. 674)

Students in the during-reading group had more opportunities to talk about the story and were able to remember and make connections across the various texts. Overall, the results provide compelling evidence that using informational texts as read-alouds provide primary students with a way to better access and understand science concepts.

Science Notebooks and Writing in Science

Chamberlain and Crane (2009) said that “Through writing, students can explore the nature of science, the processes of science, their attitudes toward science, and the relationship between science and society” (p. 67.) This quote acknowledges the important power writing has in developing a better understanding of other content areas. Chamberlain and Crane (2009) explained how the integration of writing into science gives students a way to document their ideas and beliefs about various science concepts. This type of instructional strategy helps provide students with a structure to help organize their thoughts and revisit their current science beliefs.

There are several ways to incorporate writing into content areas, and more specifically into the area of science. Fulwiler (2011) described a science-writing approach she developed after her years in the classroom and as a teacher researcher. In this approach, there are three key elements to successfully integrating writing and science: science concepts, scientific thinking, and scientific skills. The first of these key elements focuses on the actual science concepts and relies on the assumption that the science content being taught allows students to develop an understanding of a given concept similar to what actual scientists do. The second element is the idea that there must be time and opportunities for scientific thinking to take place, where students should be encouraged to make observations, predictions, share findings and supporting evidence, and revisit their research questions. The final element of this approach focuses on scientific skills or "the ability to work as scientists do" (Fulwiler, 2011, p. 2). This element involves the use of note-taking or journaling, using scientific tools to investigate a topic, and planning an investigation.

With the combination of science concepts, scientific thinking, and scientific skills, Fulwiler (2011) outlined a basic structure for the science-writing approach which included both a science and a writing session. While most teachers who teach science have the science sessions, it is the writing session that makes this approach unique. During the writing session there are four parts: shared review, shared-writing mini lesson, scaffolding, and independent writing (p. 4). Students begin by reviewing what they learned during science either earlier that day or the previous day. Then, the teacher models how to make a journal entry applying the writing skill the students are working on (for example, compare and contrast). Next, the shared writing is removed and the writing structure is displayed for students to use as a reference. Finally, students are given independent work time to complete their own journal entries. By incorporating this science-writing approach into instruction, teachers ensure students are given opportunities to record their ideas about science and gain a deeper understanding of the science content.

These studies demonstrated writing is an important part of science instruction (Fulwiler, 2011; Chamberlain & Crane, 2009). Fulwiler (2011) suggested the use of science notebooks to accomplish this task. Similar to Fulwiler, McMillan and Wilhelm (2007) also supported the use of science notebooks in the classroom. In their qualitative study, they looked at the impact of nature journaling on literacy achievement with seventh grade students. In their study, they developed an integrated unit on the moon phases. During this unit, students were asked to observe the moon over a five-week time period and record in their journals a sketch of the night sky and a minimum of two descriptive sentences.

During this same unit of study, both the math and language arts teachers incorporated tasks relating to the moon study by having students read related literature, learn measurement of moon craters, research causes for the seasons, and develop creative writing pieces and poetry from their journal entries. At the conclusion of the project, the teachers found their students demonstrated accurate scientific understandings and an increase in their use and understanding of poetic and figurative language in their moon journals. McMillan and Wilhelm (2007) explained, “Rather than confining its use to their language arts classes, they were now exploring literary devices (even poetry) as expressive writing tools” (p. 376).

Gallas (1994), a primary teacher-researcher, discussed how she uses science journals as a place for students to write about their thinking. When she introduces science notebooks to her first grade students, she leaves the purpose open and vague. She wants the students to start where they are and use the journal as a place to begin to think about science. She explained,

> Yet no matter where each child begins, the focus on the journal and the discussion with their peers and me, which eventually amplify every child’s use of the journal, lead them to a larger understanding of what science is and how their personal stories can be an important part of their learning process. (p. 80)

Her goal in the use of science notebooks is to begin to give her students a place to use writing as a way to make sense of their ideas. Students have the freedom to write about science in a way that makes sense to them.

As studies have shown, writing is a powerful tool to help students learn and express their science understandings (McMillan & Wilhelm, 2007). There are many ways writing can be integrated into science instructional blocks, including the use of science notebooks (Gallas, 1994; McMillan & Wilhelm, 2007). Whatever tool or method is used, it needs to provide students with authentic ways to using writing to document and explain their scientific knowledge.

Oral Language and Talk

Often times, when students are given opportunities to read and write about science, they are also given time to engage in talk and discussion about what they are learning to deepen their understanding of the content. Chamberlain and Crane (2009) identified the importance of oral language, stating,

> Oral communication during an inquiry lesson provides students with the opportunity to share and construct knowledge together; this is consistent with the social constructivist perspective. Students pose questions, compare ideas, and suggest alternatives. They explain their ideas to each other. (p. 67)

Language is learned socially through our interactions with others and by watching how others use language. Opportunities for young children to use oral language are found throughout the day in primary classrooms. Often, these opportunities for talk occur during hands-on and inquiry-based activities in science and engineering instructional periods. For this reason, it is important to understand the nature of oral language and talk and how it should be integrated into classroom instruction.

According to Halliday's (1981) research with children age birth to five, people use language for different reasons. He suggested there are seven language functions: instrumental, regulatory, interactional, personal, heuristic, imaginative, and representational (Halliday & Webster, 2004, p. 4). Table 2 outlines the purpose for each of the seven functions of language.

Function	Purpose	Function	Purpose
Instrumental	Meet needs and wants	**Heuristic**	Explore and understand the environment
Regulatory	Control or regulate others	**Imaginative**	Create and explore
Interactional	Build interactions	**Representational**	Give information
Personal	Express feelings, attitudes, interests		

Table 2 Halliday's (1981) Functions of Language

As children develop in their use of language, their language functions will change. These seven functions of language help in understanding the purpose of language and how it is being used by students. In addition to the seven functions, Halliday (1981) developed three aspects of children's language development: learning language, learning through language, and learning about language. Learning language starts at birth and is the process of learning the structures and rules of language. In this stage, children are developing their language skills through interactions with others. The second aspect, learning through language, occurs when individuals use language to make sense of the world around them. Finally, learning about language focuses on the awareness and understanding of language and its functions. This final aspect is more complex because language is something that occurs naturally and often without a lot of thought. These three aspects of language development help create an understanding of the complexity of language and language development (Halliday, 1981).

So what does this talk look like in classrooms and what purpose does it serve? Talk provides crucial opportunities for students to expand their understanding of a concept. Chapin, O'Connor, and Anderson (2009) explained, "Classroom dialogue may provide direct access to ideas, relationships among those ideas, strategies, procedures, facts, mathematical history, and more. […] Classroom dialogue also supports student learning indirectly, through the building of a social environment—a community—that encourages learning" (p. 6). Talk in classrooms helps students develop content knowledge and improves literacy skills. Chapin, O'Connor, and Anderson (2009) discussed the impact of talk in mathematics by identifying the important role of talk in creating classroom communities. Talk provides students with opportunities to share their thinking and hear others' ideas. If this is done frequently, students will develop a sense of community where they feel comfortable sharing their ideas. It is the creation of a classroom community and expanding content knowledge that makes talk such a valuable tool in classrooms.

While opportunities for talk are important, it is also necessary to think about the type of talk that is occurring in classrooms. Scott (2008) described a study of a secondary classroom teacher who engaged students engaged in talking about science through the use of a certain type of talk. He described a communicative approach that outlines four different types of talk that occurs in a classroom. Table 3 shows the four types of talk and provides a brief description.

	Interactive	**Non-Interactive**
Dialogic	*Interactive/Dialogic* – The teacher & students consider range of ideas.	*Non-Interactive/Dialogic* – The teacher reviews different points of views.
Authoritative	*Interactive/Authoritative* – The teacher focuses on one specific view & leads students through question and answer series to establish and support that view.	*Non-Interactive/Authoritative* - The teacher presents a specific view.

Table 3 Scott (2008) Communicative Approach Types

Through the use of interactive/dialogic communication, the classroom teacher was able to get students to move from talking about the lesson in everyday language to using more scientific ways of explaining what happened. Students were presented with an experience that required the use of scientific language to explain. As the students engaged in talk surrounding the activity, they began to construct their own understanding of what occurred. Through the use of this type of talk, these secondary students were able to become highly engaged and develop a deeper understanding of the science behind what they were doing.

Adding to the research on classroom talk, Barnes (2008) described two different types of talk (exploratory and presentational) he developed from his classroom experiences and research with junior high students. In his studies in the 1970s, he worked with the students and recorded their conversations to listen for the types of talk that occurred. According to Barnes, exploratory talk often sounds more disjointed and incomplete because the individual is still putting ideas together. On the other hand, presentational talk occurs when the speaker is formally sharing ideas and taking into consideration the audience. This type of talk is more formal and refined. Exploratory talk would likely occur in classrooms where authentic learning is taking place since students would be using language to sort through their ideas and develop a deeper understanding of what is being studied.

Mercer and Dawes (2008) also discussed the importance of exploratory talk in classrooms by focusing on what they call asymmetrical and symmetrical talk. They focused on what they call "educational talk" or "the use of spoken language for teaching and learning the curriculum" (p. 56). According to Mercer and Dawes, asymmetrical talk occurs when one specific individual has control over the conversation, usually the teacher in classrooms. On the other hand, symmetrical talk occurs when there is more of a dialogue occurring and multiple individuals are part of the conversation. Symmetrical talk usually occurs during collaborative group work where students are sharing responsibility for the conversation. In an inquiry classroom where symmetrical talk occurs, students' literacy skills often improve because they interact with others and challenge their own thinking.

Expanding on the importance of talk, Lindfors (2008) focused on the connection between talk and a child's written skills. She suggested, "The connection between the expressive system he has mastered and the expressive system he is learning is crucial for the child's literacy development" (Lindfors, 2008, p. 15). Students who have opportunities to talk in classrooms begin to see this relationship as they interact with others. They begin to see how the words they are saying actually become the written words on pages. This type of connection then transfers to their writing as they begin to see writing as another form of communication.

As a classroom teacher, O'Keefe (2004) referred to a democratic classroom as one that fosters inquiry and talk. In his experiences, talk has helped his students collaborate, construct knowledge together, act with care and compassion for one another, be critical but respectful, and contribute to their classroom community (Mills, O'Keefe, & Jennings, 2004, p. 141). The use of talk helped improve his students' literacy skills because it provided them authentic opportunities to interact and learn from each other. As they engaged in conversations with each other, they learned how to share their own ideas, reflected on others' ideas, and expanded their own understandings.

Just as language is learned through talking and interacting with others, science is learned in a similar manner. Shwartz et al. (2009) explained, "Science is a social process—one that involves particular ways of talking, reasoning, observing, analyzing, and writing, which often have meaning only when share within the scientific community" (p. 44). They suggested the frequent use of science discussions in the classroom to help students develop stronger understandings of concepts. They listed three different types of discussions that allow students to express ideas, challenge their thinking, and develop explanations: brainstorming, synthesizing, and sense-making discussions. Table 4 provides a brief overview of the three types of discussions. Through the use of these

Types of discussions.

Type of discussion	Characteristics	Suggested prompts
Brainstorming	Sharing ideas without evaluating their validity or value.	• What do you know about...? • What do you or others think about when they hear the word...? • Who has a different idea/response/way of thinking about this? • What else is on your group's list?
Synthesizing	Putting ideas together. Generalizing from specific activities to a broader conclusion. Making connections to personal experiences, previous lessons, or knowledge constructed in other units, lessons, or subject areas.	• How does...help us think about other times when...? • How can we put these four ideas together into one process that we might call a cycle? • What happens first, second...? • What do we know about...so far? • Yesterday we talked about...how does today's activity help us think about it differently? • How does what we have just done connect with...?
Sense-making (reasoning for understanding)	Figuring things out or making sense of activities. Going deeper, beyond surface answers. May involve challenge, debate, or argument in which students justify their ideas. May involve revision of previous ideas as students learn new information that calls into question the limitations of what they "knew" previously.	• How does x compare with y? • How do you know it? What evidence supports that idea? • What does it mean to say...? • Why does our old model not work to explain this new phenomenon? • How could we figure this out? • What new questions do you have? • Why do you think we are seeing something so different from what we predicted?

Table 4 Shwartz et al (2009).Types of science classroom discussions

discussion types, students begin to use language as a way to make sense of the content knowledge they are gaining.

Semiotics and Pictorial Representations

The previous literature and research focused on the use of reading and writing to understand other content areas. It also described how language acquisition is a social process used to make sense of the world around us. When talking about young students, primary students especially, another aspect is important to consider. At a young age, children begin to use sketches and drawings to communicate with others. This often happens even before words are written or read. This process of communicating through drawings and symbols is often referred to as semiotics. Chandler (2007) explained:

> Exploring semiotic perspectives, we may come to realize that information or meaning is not 'contained' in the world or in books, computers or audio-visual media. Meaning is not 'transmitted' to us -- we actively create it according to a complex interplay of codes or conventions of which we are normally unaware. (p. 11)

Charles Sanders Peirce (1958) and Ferdinand de Saussure (1983) are traditionally known as two of the founders of what we now call *semiotics*. Chandler (2007) explained that the field of semiotics incorporates a wide range of symbols that can be words, images, sounds, gestures, and objects (p. 2). In other words, semiotics involves the study of symbols that are used to communicate meaning.

In the field of education, semiotics can be applied to the drawings and sketches students use to represent their understanding of objects and concepts. A small sketch of a butterfly or a scientific journal entry can signal to teachers what that child understands and demonstrates the way that the child uses symbols to communicate meaning. More specifically for this study, the focus for this section of literature will be on how drawings, sketches, and illustrations are used to communicate understanding of various concepts. It also provides support for the belief that when students transfer meaning from one from to another, they are developing a deeper understanding of the content.

A research study was conducted in Washington, D.C., to study the impact of applying a grapho-linguistics model to the development of reading and writing. According to Platt (1977), the researchers implemented three different strategies to attempt to help students understand how speech is made into written language. While their first two strategies did not result in the growth they were looking for, their third strategy of a one word labeling procedure had better results. Platt (1977) described how the students were able to transfer meaning from one thing to another by attaching the label to the object (p. 264). This process of labeling is similar to the nonfiction text features often found in books with diagrams and labels and is carried over and applied to science notebook sketches. When students apply labels to their scientific sketches and drawings, they are helping create a deeper understanding of the words and content.

Edwards-Groves (2011) provided support of multimodal instruction based on her research in seventeen primary classrooms. In her case study of these classrooms, she found the integration of technology into writing instruction caused the process and definition of writing to change. She found that, by incorporating technology, students became more creative in their writing process and production of pieces. In addition, this research identified the collaborative nature of writing in classrooms (p. 53). From this research, the teacher participants approached the teaching of the writing process differently than before. Students were negotiating their ideas and composing pieces using both written and digital formats.

Siegel (1995) expanded the use of symbols and signs to include the idea of transmediation. While originally borrowed from Charles Suhor (1984), Siegel described transmediation as “the process of translating meanings from one sign system (such as language) into another (such as pictorial representation)” (p. 456). She believed when students communicate understanding of a topic using multiple sign systems; they are demonstrating more than a general understanding. She explained that when an individual moves between sign systems, new meanings are created (p. 461). The students are moving between sign systems (written language to drawings and drawings to written language) when they take the information learned through a read-aloud and translate it to a sketch.

Alvermann and Wilson (2011) highlighted a middle school teacher’s experience with multimodal text. They described how the teacher took her students outdoors to learn about soil and erosion. By looking at the landscape and soil around their school, students were able to learn about erosion by seeing its impact on the land. Alvermann and Wilson argued that this type of hands-on experience, in addition to models and other types of experiences, are required if students are to gain an understanding of science concepts. They explained that these students were actually learning through transmediation by applying more traditional comprehension strategies in new experiences. Students were making connections, setting a purpose, determining important vs. non-important information, and making inferences while learning about soil outdoors (Alvermann & Wilson, 2011, p. 119).

Adding to the research on transmediation, McCormick (2011) applied this concept in her sixth grade language arts classroom. After reading aloud poems from Langston Hughes to her class, she asked them to develop some type of response. One student created a new poem about immigration, and then choreographed it. McCormick believed the students had to truly comprehend the concept before they could communicate it through poetry and other forms (p. 579). After analyzing the 160 observations from the ten-month study, the findings provided support that the process of transmediation required students to think about a concept in different ways.

In a study by Ozsoy (2012), drawings were used to demonstrate elementary students' perceptions of the environment. The research focused on looking at the type of environment and images the students included in their drawings. Through the use of draw-and-explain tasks, students were asked to draw a picture of the environment and explain their drawing. Then, the drawings were analyzed using content analysis to look at the cleanliness of the environment and the objects included in the environment. Results from the data analysis indicated approximately 59.2% of students drew a clean environment with the most common images including humans, birds, and trees (p. 1134). Analysis of the drawings also indicated that as students got older, a higher percentage of the drawings focused on a polluted environment. In this study, student drawings were used as a way to express their understanding of the environment. It was through these drawings and student explanations meaning was created.

Summary

The previous literature review provides important insights into the areas that help inform the research study. STEM education is a relatively new idea in education resulting in little research focusing on its implementation and impact on student achievement. This literature and research gets even scarcer when talking about implementing STEM practices in the primary elementary grades. For this reason, more studies need to address these gaps in the research and begin to look at the impacts of STEM education.

Another area addressed in the previous literature review focused on various instructional practices that occur in various content areas. From the research, it seems that literacy (reading and writing more specifically) becomes more than just skills to be learned in the content areas. Reading and writing become tools students use to help make sense of the world around them. Comprehension and strategy instruction seem to be key components to help students develop the skills needed to make sense of content area reading. Students also need to be given opportunities to talk with others and construct their own understandings of the concepts being learned. In addition to talk, pictorial representations play an important role in helping young students begin to express their ideas. Drawings and sketches are used by teachers as a way to reflect on what knowledge their students are developing.

Chapter Three: Methodology

Theoretical Framework

Paradigm

As a researcher, I believe there is no one clear truth to be found or understood. I believe every individual experiences things differently and creates meaning differently than others around them. As a result of these beliefs, I approach the research from the viewpoint of a social constructivist. Other researchers and theorists who fall into this category believe meaning is created through our experiences and interactions with others (Vygotsky, 1978; Rosenblatt, 1994). I am looking to understand the perspectives surrounding the phenomenon I am researching. In this study, I am interested in understanding how one teacher integrates literacy into STEM (Science, Technology, Engineering, and Mathematics) education with a specific focus on science and engineering units of study. Creswell (2007) explains the researcher's goal is to best understand the participant's view of the phenomenon. I used the participant's view of literacy, integration, and STEM education and her instructional practices to help answer the research questions.

Research Design

In order to accomplish the goal of understanding the participant's context and perspective, I used a case study design, allowing me to focus on understanding how the participant viewed the integration of literacy, science, and engineering. A case study design also allowed me to investigate the "how" and "why" of integration. Robert Yin (2009) explained one of the most important steps to designing a study is to determine the research questions. The research questions led me to select a case study design because they are more explanatory in nature and focus on understanding the nature of real-life events. This research design also allowed me to focus on understanding the phenomenon through the eyes of the participant. By selecting a defined case (in this study the first/second grade classroom), I collected specific data on the one classroom that provided insight into how the participant understood integration of literacy, science, and engineering.

Role of Researcher

Yin (2009) suggested it is important for a researcher to have the necessary skills to adequately carry out a case study. More specifically, he suggested five skills that are required for anyone who will be doing a case study: asking good questions, being a good listener, being adaptive and flexible, having a firm grasp of the issues being studied, and being unbiased by preconceived notions (p. 69). Each of these skills helped me design the study, the selection of participants, the data collection, and the analysis. For this reason, it is important for me to reflect on my current skills as a researcher.

Asking questions has been an important part of making the transition to an elementary school with a focus on STEM education. My current position as the STEM specialist requires me to field questions about our process, successes, and struggles with the transition. To answer teachers' questions, I spend my planning time working on lessons, creating materials, and research of other schools that have a similar focus. I continue to ask myself what our teachers should be doing if we are to begin integrating content areas and curriculums. Through my graduate program, I have also learned how to continually question what I know and am learning. Each course I took challenged me to look at my understanding of literacy, what it means to be a literate member of society, and the role culture plays in literacy development. This continuing inner dialogue was integral to the collection of the case study data as reflection was on-going. I would review the data from one perspective and then put on a different lens to see how that new perspective changed what I saw in the data. As Yin explained, questioning and analyzing the data occurs as it is being collected and not just at the end (p. 127).

Being a good "listener" according to Yin means "receiving information through many modalities" (p. 70). I realize it is important that I use multiple methods to "listen" to what is going on around me. I used a video camera to capture my observations in addition to my observation notes. This helped me ensure I was seeing as much as possible that was going on in the classroom. I also used an audio recorder during interviews and discussions. This allowed me to capture the conversation by returning to the recording when I transcribed. I collected data using a wide range of tools to ensure the findings would appear across data sources.

Another skill of a case study researcher is being adaptive and flexible. Initially I developed a data collection and analysis timeline for the study. As the study progressed, I frequently collaborated with my advisor on how the timeline was progressing and what changes needed to be made. The initial timeline served as a tool to help me plan and structure my time and data collection, but I needed to be flexible to let the data emerge. I was able to make changes when necessary following the guidance of my advisor while still sticking to my overall timeline.

Another important skill for a case study researcher is to have a firm grasp of the issues being studied. This is my seventh year in the school and second year as the STEM instructional coach; all of my time and energy at work is devoted to understanding how we are making this transition. I am responsible for identifying professional development needs, planning collaboration sessions, and sharing our process with community members. This is my strongest skill because STEM is what I think about on a daily basis. I am engaged daily with our students and staff and constantly reflect on their methods of integration.

Finally, Yin (2009) suggested the researcher should be unbiased by preconceived notions. This is an area I frequently reflected on during this study because of my position at the school and with the participants. I have been involved in this transition since the beginning so I am invested in the process. I am excited for the changes and see the positive impact it is having on our students. I also interact with the teachers and students at this school on a daily basis. As a result of this knowledge, I used my researcher journal as a place to identify any questions or conflicts that arose due to my position. I also made sure to clearly describe my relationship with the school and participants. I included this information both in the context for the study and in the limitations.

Research Questions

I developed my research questions after reflecting on what literacy looked like in an elementary school that focuses on STEM education. However, this question seemed too broad in nature to research. My decision to use a case study design and the selection of one classroom teacher at the research site required me to narrow the focus for the questions. If the overall goal was to understand the participant's experiences and practices regarding integration, then the research questions should reflect this goal. At the beginning of the study, I developed three main research questions: How does a first/second grade teacher integrate literacy strategies and practices within the context of science and engineering units? How do the students incorporate literacy strategies into their science and engineering work? How do the literacy strategies and practices used by the teacher change across units of study? After collecting the data and collaborating with my advisor, I decided to keep only the first two questions. I did not find many differences between the science and engineering units of study as I collected data, because the nature of the units was quite similar and the participating teacher had decided to modify the second science unit of study. As a result of finding similar codes for both the science and engineering units of study, I decided to remove the third research question.

In designing the study, I developed sub-questions to help guide me in the data collection and analysis. The final questions and sub-questions are:

RQ1: How does a first/second grade teacher integrate literacy strategies and practices within the context of science and engineering units?

Sub Q1: How does she use reading and writing instructional practices as tools to teach science and engineering?

Sub Q2: What are her successes?

Sub Q3: What are her tensions?

RQ2: How do the students incorporate literacy into their science and engineering work?

Sub Q1: How are students using literacy in their science/engineering conversations and discussions?

Sub Q2: How are the students using pictorial representations to communicate meaning?

Definition of Terms

Since the study has a specific focus in the area of literacy, it is important to understand my view of literacy and how I define literacy, strategies, and practices. My definition of literacy incorporates both reading and writing. As a social constructivist, I believe both reading and writing involve the construction of meaning. Lindfors (2008) defined language as an "expression of meaning to someone for some purpose" (p. 1). This definition of language is similar to how I would define the literacy skills of reading and writing. Literacy skills are socially constructed, and it is important to understand the socio-cultural aspects of the classroom and how they impact literacy. As I studied the literacy practices and strategies in the classroom, I looked for ways students and teachers create meaning. This might be through reading, writing, and talking. When I began the study, I felt I might see students writing or drawing in science notebooks, students interacting with others in a science experiment, or the teacher reading a book about engineering. All of these instances help the students and teachers create meaning, so each of these instances was used to collect data for this study.

The focus of this study is on understanding the literacy strategies found in science and engineering instruction in the participating teacher's classroom. When referring to strategies, I expand on Goodman's (1994) definition of a strategy as something taught by the teacher with the intention that students learn to use it independently to create meaning. When discussing teaching practices, I am referring to the instructional moves a teacher makes when teaching. My focus is on instructional practices and not necessarily management strategies. Another important term used in this study is "content area literacy". My definition comes from McKenna and Robinson (1990) who defined content literacy as “the ability to use reading and writing for the acquisition of new content in a given discipline” (p. 184). When I conducted the observations and interviews, I did not enter with the intent of looking for a specific list of strategies. The overall goal was for the strategies to emerge from the analysis of the data. However, I was aware there were some strategies that had the potential for appearing during the data collection. Some of the strategies I knew I might see in the classroom were comprehension strategies (Miller, 2002; Owocki, 2003; Hammond & Nessel, 2011) and thinking strategies (Keene & Zimmermann, 2007). However, after starting with these strategies I realized there was much more going on than simply comprehension strategies.

Phases of Inquiry

This study takes place in a regular primary elementary classroom over the course of one semester. The process I followed to complete the study is divided into three phases. Phase I took place prior to collecting data. During this phase, I designed the study, obtained permission from both IRB and the school district, and obtained consent/assent forms from all participants. Phase II lasted ten weeks and included the data collection and ongoing analysis. In addition to simply collecting data, during this phase I completed transcriptions of interviews and collaboration sessions as well as completed initial coding (described in detail in the analysis section). Phase III of this project occurred after all data was collected and transcribed and involved comparing descriptors across data tools and looking for larger patterns. A more complete description of this coding process can be found in the data analysis section.

Context

Research Site

The site selected for this study is an elementary school in Missouri. It serves approximately 290 students in grades K-5. This school is a Title I building with approximately 90% of students who qualify for free and reduced lunch (Missouri Department of Elementary and Secondary Education, 2011). In addition, a significant percentage of the school's population is minority students with approximately 62% African American and approximately 25% Caucasian (Institute of Educational Sciences, 2011). Bowling Elementary is a school that has struggled to show success academically on the Missouri Assessment Program (Missouri Department of Elementary and Secondary Education, 2011). According to the 2011 Report on Adequate Yearly Progress by the Missouri Department of Elementary Education, Bowling Elementary has received sanctions based on low MAP performance for 4 years (Missouri Department of Elementary and Secondary Education, 2011, p. 3). The school is also a lottery school in the district serving attendance area students and students applying to transfer in from other schools in the district. Overall, the school has approximately 85.5% of students who come from the attendance area and 14.5% who attend through the lottery.

Participants

All participants have been given a pseudonym to protect their privacy. For the purpose of this study, I looked for an exemplar case to represent the population of teachers at the research site. To determine the main participant for the study, I evaluated the teachers based on the following characteristics: availability and willingness to participate in the study, knowledge of STEM education and practices, knowledge of literacy practices, and grade-level placement. I chose to work with a primary teacher to ensure the study looked at STEM and literacy practices in the primary grades. Mrs. Martin served as the main participant in the study where I gathered the observations, student work samples and conversations, teacher reflection journal, and weekly teacher interviews.

Mrs. Martin and Students

Mrs. Martin was selected based on her average to above average knowledge of STEM education and literacy. Mrs. Martin teaches a first/second grade multi-grade classroom and has been at this elementary school for six years. She has taught for a total of fourteen years with experience in fourth and fifth grade and served a mentor for first-year teachers involved in a rigorous Induction Program. Mrs. Martin's classroom is composed of six lottery students and sixteen students from Bowling Elementary's regular attendance area. The lottery students come from homes where the parents purposely chose to send their children to the school because of the STEM focus. Her classroom had a total of twenty-two students with twelve girls and ten boys. First graders comprise one half of her class, while second graders comprise the other half. Only one student moved into the classroom since the beginning of the school year. She has approximately 50% minority students and approximately 75% free and reduced lunch/poverty students.

This split classroom was a result of the enrollment numbers in these two grade levels at Bowling Elementary. When the decision was made to create this split class, the building administration decided to select students with average to high academic ability. This decision resulted from past experiences with split classrooms at Bowling Elementary where mixed ability students were placed together. The administration thought a split classroom would be more successful if they were all average to higher ability with regards to academics.

My Role in School & Study

This is my seventh year teaching at Bowling Elementary School. I have been a classroom teacher, Title I support teacher, media specialist, and an instructional coach. During my years in the classroom, I taught second grade and a first/second split class. Currently, I work as the STEM instructional coach at Bowling. I am responsible for designing professional development around science, technology, engineering, mathematics, and literacy. I also collaborate with teachers and team-teach science or engineering units of study.

This year I have worked closely with several teachers in the building. Mrs. Martin and I worked closely together last year as she was out of the classroom as the Induction Program mentor. We worked together to develop resource lists for classroom teachers and attended professional development sessions and conferences. This summer, Mrs. Martin and I participated in a two-week professional development camp that focused on incorporating the 5E instructional model into science units of study. This camp also required us to present at local science conferences. As a result, Mrs. Martin and I have also collaborated on and presented strategies to bring in observation/science stations into literacy centers.

Data Gathering Procedures and Sources

Approval Procedures

Prior to beginning the study, I requested permission from both the University of Missouri-Columbia Institutional Review board (IRB) and the Research Office for the school district. Once I received approval from the district and IRB, I began the recruitment process and gathering consent forms. I received consent from all participants in the study including the building principal, classroom teacher, students, and their parents. The classroom teacher collected the assent forms from the students acknowledging their willingness to participate in the study. The form that was sent home with students for parent permission can be found in Appendix B. For this project, data collection occurred during the months of October, November, and December of 2012. After completing the first round of coding in December, I noticed that many of the same codes and descriptors were beginning to appear across data sources (ex: use of science notebooks, application of vocabulary, student connections). For this reason, I did not return to the classroom to collect additional data following winter break.

Data Sources

I collected data using a range of different tools. Figure 4 shows how the data tools are connected to the purpose of the study. Yin (2009) suggests case study data can come from six different sources: documents, archival records, interviews, direct observations, participant-observation, and physical artifacts (p. 102). The sources of data

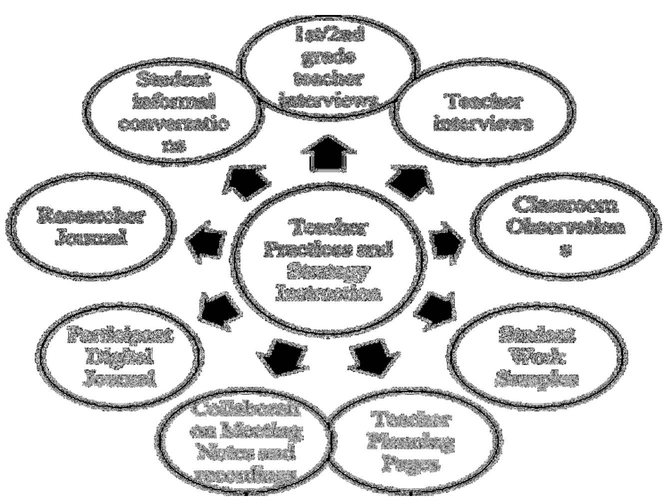


Figure 4 Study Data Sources

for this study were selected based on this information and included observations, interviews, physical artifacts, and documents. Each of these sources of data is described below in detail.

Teacher Planning Sessions

At the beginning of each week, I met with Mrs. Martin on Mondays before school to talk about instructional plans and to copy her planning pages for the week. The purpose of this meeting was to identify ways she was planning to integrate literacy and science/engineering for the week. It also was a way for me to select the three lessons, days, and times I would observe in her classroom. This planning allowed me to select purposeful observations that directly connected to the research questions and focus. Viewing her planning pages helped me gain insights into the materials and resources she was using in her integration of literacy, science, and engineering. The planning pages also allowed me to look at the teacher's plans and analyze her thinking with regards to integrating STEM subjects and literacy instruction.

There were also some grade-level planning sessions I participated in during the duration of the study. These were planning sessions where I participated as a result of my instructional coach position. The purpose of these planning sessions was to help teachers plan their science or engineering units of study. We also talked about ways to design their units using the 5E instructional model. These sessions took place outside of the school day and were recorded using a digital recorder and transcribed.

Classroom Observations

I used observations from Mrs. Martin's classroom to collect data on classroom instruction. The purpose of each observation was to observe Mrs. Martin's instructional practices and strategy instruction. Observations were also used to observe students' use of literacy strategies during science and engineering. While observing, some of my time was spent observing the class as a whole, while other time focused on selected groups or individual students. The observation protocol form I used to document my observations can be found in Appendix C. The observations took place during Mrs. Martin's science/engineering time, as well as during the literacy block when appropriate. The observation during the literacy block usually focused on the science observation station used by the students during their reading station time. The science observation station lessons I observed directly connected to the science or engineering topic the students were studying.

For most of these observations, I was able to observe in person, as well as record with a video camera. In instances where I could not directly observe the lesson, I recorded it with a video camera and went back and took observation notes from the video. A video camera was used to document anything I missed or left out in my observation notes. Over the course of the study, I observed in Mrs. Martin's classroom a total of thirty-six times over a twelve-week period.

Interviews

I used a semi-structured interview protocol to collect information on STEM education and literacy instruction from all five teacher participants. Merriam (2009) explains a semi-structured interview "is guided by a list of questions or issues to be explored, and neither the exact wording nor the order of the questions is determined ahead of time" (p. 90). This structure allowed me to have a clear focus going into the interview while still allowing opportunity to expand on ideas as they came up in our conversations. The questions and topics for the pre- and post-interviews for the grade-level partners and the weekly interviews for Mrs. Martin can be found in Appendix D.

I met with Mrs. Martin once a week for an interview and used a structure similar to the process that occurs during stimulated recall. This structure was used as a way to have Mrs. Martin reflect on her instructional practices. Video stimulated recall is a process that involves the participant viewing a video of his/her own behavior. Then, the researcher asks a "series of structured, but relatively open-ended, questions posed to the subject as soon as possible after, or during, the viewing of the videotape" (Lyle, 2003, p. 863). The main goal in using this process was to gain insights into the thought process that was occurring at that point in time in the lesson. The focus was more on Mrs. Martin's thought process than what actually happened in the video. By Mrs. Martin's request, these interviews usually occurred on Friday mornings and focused on one of the recorded lessons for the week.

Prior to meeting with her, I viewed the videotapes and selected a segment of the tape to focus on for the interview. I selected segments where students were working away from Mrs. Martin or a part of the lesson where I wanted to know exactly what she was thinking at that time. For example, if the students were working in small groups, I would select the segment of tape that showed the groups Mrs. Martin was not currently focused on so she could see what the students were doing without her guidance. I also developed questions based on the video recording, student work samples, and other observations from the week. On occasion, I also showed photographs of student work samples during the interviews and asked her to talk about what strategies she saw the students applying in their science work. When I conducted the interview, the questions from the video focused on what she saw in regards to instruction, literacy skills, student performance, and successes/barriers to integration. Each interview conversation was recorded using a digital recorder and transcribed. This tool also allowed me to focus more on asking follow-up questions and engaging in conversation instead of trying to document everything that was being said.

Informal Student Conversations

I documented informal conversations with students during my observations as an additional source of data for this study. During each observation, I randomly selected a table of students to visit with about the activity and their thought process. All the conversations with the students were recorded with a digital recorder. The prompts were usually related to making connections between content areas, how they were being readers/writers/scientists, and what instructional practices they saw their teacher using that helped them learn. A list of guiding questions and prompts I used during these conversations are included in the interview protocols found in Appendix D. These recordings and conversations with the students helped to provide insights into the successes and barriers/tensions for integration, as well as what literacy strategies the students were using independently.

Student Work Samples

Another source of data collected for this study was student work samples. Every other Friday, I collected the students' science notebooks at the end of the school day from a group of six students. These students varied each week and usually matched the group of students I met with during the observations. I made copies of the work that had been done for the past two weeks. This included journal entries from their science/engineering lessons for the week and any observation station recordings they completed. There were also times when I collected photographs of student work samples that could not be copied and occurred during the observation. For example, I took photographs of leaf creatures and student-created paper butterfly life cycles. These types of projects could not be copied and often went home with the students the day they created them. I also collected any writing samples that connected to their science/engineering unit of study. Some of the work samples were used during the teacher interviews to get more information on integration practices and instruction.

Teacher Reflection Journal

In order to gain a deeper insight into Mrs. Martin's reflection process, I created a digital reflection journal for her to use. She was asked to write in the journal a minimum of once a week and encouraged to write in it anytime she reflected on something regarding integration of literacy, science, and engineering. To develop the digital journal, I used Google Forms and included the following questions: How did you integrate literacy today? What were the successes? What were the barriers? What questions do you have? What surprised you today? Is there anything else you would like to share? Each time Mrs. Martin added to her journal, the responses were automatically sent to a spreadsheet that documented the date and time of each entry as well as organized the responses by question. The goal for using this data tool was to gain a better understanding of Mrs. Martin's thought process and reflection on her/his own practice. A snapshot of the journal page and spreadsheet can be found in Appendix E.

Researcher Journal

The final source of data was a journal I kept during the research study. The purpose of this journal was to document any conversations, comments, observations, and reflections that would not have been recorded during the interviews or observations. After each day I conducted research (interviews, observations, planning sessions), I recorded my thoughts and reflections in my journal. For example, this was a place I documented passing conversations with any of the five participating teachers outside of our interviews and planning sessions. This was also a place where I could begin to organize my thoughts and big ideas. These general thoughts and big ideas were also documented by date in a separate section of my journal. I kept this special section as recommended by my research advisor as a way to begin to organize my ideas for the findings section. I used the journal as a way for me to reflect on the research process and to record comments of the integration process between STEM and literacy.

Data Collection Timeline

Table 5 outlines the data collection process and timeline for the study. Each science and engineering unit of study lasted between three and five weeks. This study was originally designed to focus on three science/engineering units of study. However, as the study went on, Mrs. Martin began to notice ways her third science unit of study integrated easily into her first engineering unit for the year. For this reason, data was only collected during one complete science and one complete engineering unit of study.

	October (3 wks.)	November (3 wks. + 2 days)	December (3 wks.)
Teacher Planner	Copy teacher planner weekly on Friday (3 total)	Copy teacher planner weekly on Friday (4 total)	Copy teacher planner weekly on Friday (3 total)
Teacher Planning Sessions	Weekly on Monday (3 total)	Weekly on Monday (3 total)	Weekly on Monday (3 total)
Observation	3 observations per week (9 total)	3 observations per week + 1 Thanksgiving week (10 total)	3 observations per week (9 total)
Teacher Interview	Weekly (3 total)	Weekly (3 total)	Weekly (3 total)
Informal Student Conversations	Two recorded conversations each week (6 total)	Two recorded conversations each week (6 total)	Two recorded conversations each week (6 total)
Student Work Samples	Every other week: student notebooks and possibly writing or engineering pieces	Every other week: student notebooks and possibly writing or engineering pieces	Every other week: student notebooks and possibly writing or engineering pieces
Teacher Journal	1 responses per week digitally (3 total)	1 responses per week digitally (3 total)	1 responses per week digitally (3 total)
Researcher Journal	10 entries	8 entries	
Collaboration Recordings	As requested by teacher (1)	As requested by teacher (0)	As requested by teacher

Table 5 Research Study Process and Timeline

Data Analysis

Preparation for Analysis

I stored the audio recordings, observation notes, video recordings, and transcriptions on a single jump drive. Each piece of data was stored in a related folder on the drive identifying which unit of study (life cycle, engineering, or secrets of survival) the data was related to. All data sources (observations, work samples, interviews, etc.) were labeled with the date, participant pseudonym names, and line numbers. The line numbers served as a reference point when pulling out specific quotes or pieces of information from the data during analysis and write-up.

Audio Recordings

Every audio file (collaboration sessions, teacher planning sessions, teacher interviews, and student interviews) was transcribed prior to initial coding. I listened to each of the audio files and typed the conversation verbatim. The collaboration meetings I attended were also digitally recorded and transcribed.

Observations

Classroom observation data included both my field notes and video recordings of the lessons. The field notes were dated and included a space to document observations during the lessons. The video recordings were also dated and matched with the observation notes for that day. This process was completed for the weekly observations where I have both observation notes and video recordings. For the observations where I only had video recordings, I viewed the recording and took observation notes using the same structured observation form used for the other weekly observations.

Journals and Work Samples

Each journal entry that was made by the classroom teacher was marked with the date and time for the entry to track when the responses were entered. The entries were collected in a spreadsheet sorted by date and question. The teacher planning pages were copied and dated to identify the week the plans were implemented. These planning pages were compared to the observation notes and video recordings for that week. The student work samples and photographs of student work were also stored by date in the relating science or engineering folder. My researcher journal contained comments on the research process, my questions, the data collection, and the observations were sorted by date.

Initial Coding

The analysis process for this case study borrows from grounded theory methods of data analysis. Grounded Theory was originally developed by Glaser and Strauss (1967), and was later expanded on by Charmaz (2006), who described the methods as following "systematic, yet flexible guidelines for collecting and analyzing qualitative data to construct theories 'grounded' in the data themselves"(p. 2). Data analysis in grounded theory includes the use of multiple codes and is often described by the following steps: initial coding, axial coding to find out how the categories begin to fit together, and selective coding to create larger codes that develop into themes (Creswell, 2007). Charmaz (2006) explained coding as a way to assign labels to sections of data to represent what that section is about. The overall goal when coding was to think about what was happening in that section of data. By analyzing the coding through grounded theory methods, I was able to develop descriptions of what was happening in the various segments of the data.

Initially, I went through each data source and wrote descriptors off to the side. This process of open coding was done to develop "categories of information". During this round of coding, I read through each of the data sources (interviews, observation notes, and the like) and wrote descriptors to the right side of the page in line with the referred-to text. For example, instances where the data identified that Mrs. Martin was using science notebooks and asking students to record information, I would write the descriptor "using science notebooks" or "writing for purpose with science notebooks" off to the side. I continued this process for each source of data, except for the student work samples and teacher planning pages. An example of this type of coding can be found in Appendix F.

The basic descriptors from the data that were noted related to successes and tensions to integration, literacy practices, literacy strategies, and general labels to the data. When analyzing the data for successes, I coded any example (student or teacher) where there was a positive outcome regarding planning, instruction, student achievement, engagement, confidence, etc. Tensions/barriers were viewed as behaviors, actions, or beliefs that prevented integration from occurring successfully. The tensions I analyzed for could also be referred to by others as stressors, pressures, or risks. Literacy practices and strategies included teacher instructional methods, used during science time, and students' strategies, which they used to understand the science and engineering. These practices and strategies could also be referred to as teacher practices, comprehension strategies, instructional moves, etc.

Once the initial coding process was complete, I went back to the data for a second read. This time I focused on looking at Mrs. Martin's language with the students, opportunities where she took risks, and instances of teacher change. As I read through the data the second time, I used descriptors such as: "referring to students as scientists," "building agency by having students explain their thinking," "taking risk by not following curriculum, and increase in confidence in planning." This round of coding focused more on the teacher than the students. However, I did code the student conversations during this second read if I saw instances where the students were impacted by the teacher's change, risks, or language. For example, a few times in the conversations, students would identify themselves as scientists, readers, or engineers. I coded these sections with the descriptor “identifying as scientists”. This allowed me to describe instances where the teacher’s language was being used by the students. I continued this type of coding for each of the teacher interviews, observations, student conversations, and planning sessions.

Categorical Coding

The first two rounds of coding allowed me to look at each of the data sources independent of each other. The purpose of this analysis was to see the practices, strategies, success, and struggles found in each piece of data. Once that process was complete, I needed a way to look across all the data sources to see how the pieces interacted with each other. Following the two rounds of descriptive coding, I began to pull all of the descriptors (or codes) together into one spreadsheet that sorted the information by research questions. The spreadsheet contained the following information for each code: source, date, unit of study, and code. An excerpt from this spreadsheet can be found in Appendix G.

To enter data into the spreadsheet, I went through each data source and pulled out the necessary information for each code. I continued this process for all the codes on each of the pieces of data within a unit of study. Once I had completed this process for the two science units of study, and the engineering unit, I repeated the process for final interviews, and researcher journal. Then, all the codes from each of the three units of study were compiled into one spreadsheet. The next step consisted of matching each individual code with the research question it best fit with. I went through each line of code and identified the research questions(s) I felt best matched that code. For example, the code “off task behavior” would be categorized under the tensions research question.

Then, the data was sorted by research questions; this mixed the data sources together. Once the like codes were grouped together for each research question, I could begin to develop larger ideas (or themes) for these sections of data. In order to do this, I would look at a group of codes and develop a statement or phrase that best represents what those codes are describing. For example, there were several codes that described the use of science notebooks to document thinking during science time. These codes were grouped together and incorporated into the theme "purposeful integration and use of science notebooks and nonfiction texts". These statements or phrases then became the findings (or themes) for the research questions.

Ethics

An important ethical consideration was the role I played in this study. According to Ely (1991), one means of gathering observations is through being a participant observer. In this study, I played the role of a participant observer because I had other duties at this site with the participants outside of the study. Another way to understand my role would be to see myself as "an insider". Assuming this role as a participant observer or "insider" meant I had to take additional steps to ensure the participants felt comfortable and safe participating in the study.

I made sure to have another individual collect assent forms from students and share the research process and procedures with all staff members in addition to the participants. I was careful to stick to the scheduled plan the teacher and I set up for data collection. Conversations, discussions, and planning sessions that took place outside of our scheduled data collection meetings were not used for data collection. With regards to planning, the teacher was responsible for a majority of the planning. The teacher planned and designed the lessons that I observed and discussed so I would not influence those specific lessons. My role as an instructional coach and not an administrator meant the teacher did not have to change her practices in fear of being marked down with regards to evaluation. The teacher participant was familiar with the research process because of her mentoring role the previous year. This allowed us to maintain a professional relationship while still understanding the requirements for collecting data in her classroom.

The selection of a research site and participants at the school where I teach is both a strength and limitation to this study. I must acknowledge the fact that my current relationships with the participants influenced what they did and shared with me. I also acknowledge that my role as an instructional coach influences the teacher's instructional practices. Working with her during collaboration meetings and professional development sessions meant I influenced the instructional strategies she knew and used in their classroom. Using participants from my school also allowed me to select a classroom teacher I know well and who knows me. This relationship helped the research in many ways because I had already built working relationships with the participants. This allowed the main participant and her students to easily accept me into their classroom. However, I acknowledge it is possible this knowledge and comfort level had some limitations for this study. To ensure participants did not feel hesitant to take risks and share negative experiences, I provided numerous opportunities for them to ask questions before, during, and after the research process. They also were given information on how to contact the research participant resources at the local university.

Another important ethical consideration for researchers when conducting research is the protection of privacy for their participants. For this study, all participant names have been changed on all documentation to protect their privacy. Names have been changed to pseudonyms when used in transcriptions and in the write-up of the study. All participants also signed a consent/assent form and were told they could ask to be removed from the study at any time without any negative consequences. Overall, participation in this study did not expose the participants to any risks outside of the risks of everyday experiences.

Provisions for Trustworthiness

As with any qualitative research study, it is necessary to examine the validity of the research and findings. Creswell's (2007) suggests eight ways to promote validity and reliability in qualitative research studies: triangulation; member checks; adequate engagement in data collection; researcher's position or reflexivity; peer review/examination; audit trail; rich, thick descriptions; and maximum variation (p. 229). For this study, several of Creswell's strategies were implemented. First, the selection of the school and participants allowed me to collect data from participants with whom I have had prolonged engagement on a daily basis. The knowledge that comes from this prolonged engagement helped me as I analyzed the data. I also use triangulation to help validate the findings from the study by collecting data with interviews, observations, teacher journals, and student/teacher work samples. By comparing information among all the types of data, I was able to notice patterns between the information given in the interviews and what I noticed during the observations and in the work samples. This helped ensure the teacher was not doing and saying things on occasion simply because she felt that is what I was looking for. I was able to confirm the findings by providing support from a range of data collection tools and instances.

I also participated in peer debriefing during the data collection and analysis phases. I met with my advisor and other graduate research students. We discussed procedures, data collection tools, and analysis and reviewed each other's coding and provide feedback and insights to help the process. In the paper, I created rich, thick descriptions of the participant and themes. The descriptions of the themes include excerpts from a variety of data sources to ensure strong support. Finally, by using charts and cross-referencing the data and research questions, I provide a rich description of the process that occurred for this research study. I also asked the teacher participant to review both the findings section and the discussion section of the study. This allowed her to provide input as to whether she felt it was an adequate description and analysis of her and her instructional practices. By allowing her to review the themes and case description, she was able to provide additional insight in her reflection. Her insights of the description ensured I provided the best description possible of the case and findings. This type of member checking is supported with a short reflection she wrote following the reading of these two chapters. Her reflection can be found in Appendix H.

Chapter 4: Findings

Context

The Classroom Teacher

Mrs. Martin had served as the mentor of novice teachers during the school's first year of the STEM transition, which allowed her to collaborate with teachers about the transition and to model for them some instructional strategies. While she was not necessarily excited to step down from the mentor position, she was motivated to work with younger students. Mrs. Martin explained how she had yet to have an "exciting" year of teaching where she really felt her students learned as much as they could. She also shared her excitement to work with younger students where she could let go a bit and enjoy the little things that make them kids.

Mrs. Martin always looked for ways to continue learning through professional development. She made the decision to return to school to work towards an Educational Specialist degree in Administration. She was motivated to try new strategies and often asked for resources and professional development books she could incorporate into her teaching and instruction. Going into this year, she was excited to see how she could incorporate more science, technology, and engineering into her first and second grade curriculum. She strongly relied on the support and collaboration of her grade level team and administration. At the beginning of the school year, she was already setting up collaboration meetings with her grade level partners and support personnel to talk about curriculum and integration.

During our first interview, I spoke with Mrs. Martin about some of her beliefs regarding literacy. During this interview, she defined literacy as

> How we take in and make sense of language…so that looks like time when you're working with words, the printed language, and it would be times when you are listening and processing what you hear about it and it would be creating and communicating during writing. (Teacher interview, 10/19/12)

Overall, her view of literacy was the act of making meaning. She went on to explain how this looks different in her classroom and occurs throughout the day. She talked about a range of literacy experiences her students have from basic letter formation to writing in math journals to reading nonfiction texts connected to the science unit.

As a teacher who was part of the initial decision to transition to STEM, she felt she was already looking for ways to integrate in her classroom. She mentioned her excitement related to increasing her own science knowledge. She enjoyed learning about science concepts and learning more about the topics she taught. In her mind, "everything is a learning tool, everything. It just depends on what you are to focus on and what you want to bring in and expose them to" (Teacher interview, 10/19/12).

During the initial interview, Mrs. Martin seemed excited but hesitant towards working on integrating literacy, science, and engineering. Some of the hesitation seemed to stem from her uncertainty of what it would look like in her classroom. In the initial interview she explained,

> I always think it's hard to change your teaching when you get set in your ways and there are things that are comfortable to you and just stepping out of your comfort zone and having faith that it's going to be OK. That's

> what has been personally hardest for me. Um I don't mind change and I love to learn something new. (Teacher interview, 10/19/12)

This comment indicated while Mrs. Martin was somewhat hesitant about participating, she was excited to learn something new. Overall, Mrs. Martin seemed to be a highly motivated teacher who was always looking for a way to use more effective instructional practices. As a result, her initial hesitation towards integration was outweighed by her desire to try something slightly new.

Multi-age Environment

The classroom in this study is composed of both first and second grade students making it a multi-grade classroom. Miller (1990) identifies the change towards multi-age classrooms occurred in the 1960s and 1970s as a result of the focus on open education and individualized instruction (p. 1). Since then, many researchers have focused on the organization of classrooms and its impact on student learning (Pratt, 1986; Miller, 1991).

While multi-age and multi-grade classrooms have traditionally been viewed as an educational initiative of the past, there are still current classrooms that use this structure. As mentioned in the previous literature review, Heisey and Kucan (2010) conducted a study to investigate the use of read-alouds to introduce science concepts in a primary classroom. The participants for this study came from two "intact multi-age classrooms" from a university lab school that included both first and second grade students. Currently, in the school district where the study took place, there are a few other schools that utilize multi-grade classrooms. One school in particular has even adopted the idea of multi-age classrooms as their school design.

Literacy Curriculum and Pedagogy

While Bowling Elementary has been given some flexibility with regards to curriculum, teachers are still expected to use district curriculum resources in science and literacy. Two years ago, the district adopted the *Good Habits Great Readers* (GHGR)/*Good Habits Great Readers Writing* (GHGW) literacy curriculum from Pearson (Pearson Education, 2013). The reading component of this program includes both small and large group lessons with shared and guided reading plans. The writing component provides mini lessons and instruction for students to work through the five stages of the writing cycle: prewriting, drafting, revising, editing, and publishing (Pearson Education, 2013). The science program used in the primary grades is from the Science and Technology for Children (STC) curriculum. The units of study include inquiry-based, hands-on activities in the areas of life, physical, and earth sciences (Carolina Biological Supply Company, 2012). Finally, the engineering curriculum used at Bowling Elementary comes from the Boston Museum of Science. *The Engineering is Elementary* (EiE) curriculum is composed of twenty units of study each focusing on a different science topic and engineering field (Boston Museum of Science, 2013). The units come with a storybook where the child in the story faces a problem and has to design something to solve the problem. After reading the story, the students work through the same engineering design process as the character in the story. For this study, Mrs. Martin pulled resources from these literacy, science, and engineering units.

Mrs. Martin's Units of Study

There were two main science units of study that Mrs. Martin taught during the course of this research. The first unit focused on life cycles of living things. The district-created objectives are broken down into knowledge and skills that the students would gain during this unit. Table 6 outlines the knowledge and skills for the life cycle unit and is identified on the district instructional plans for this unit of study found in Appendix M.

Skills	**Knowledge**
Observing, describing and recording growth and change in the life cycle of different organisms.	Butterflies, Chickens and Frogs progress through their own unique life cycle.
Predicting, comparing and discussing the organism's appearance and change over time.	Air, food, and space are required by all organisms to live and grow.
Communicating observations through drawing, writing and discussion.	Some parents and offspring share common traits, yet each one is unique and different.
Relating observations of life cycles to students' own growth and change.	

Table 6 Life Cycle Unit District Objectives

The second unit of study I observed focused on the engineering design process and designing submersibles. Submersibles in this study were student-constructed objects that would sink to the bottom of a tub when pushed, collect a magnet on the bottom, and float back to the top. The submersibles were connected to the process submarines use to dive and float in the water. The curriculum objectives for this unit of study include: explain the work of ocean engineers and their role in designing technologies for the ocean environment, conduct controlled tests to collect data about the properties and behavior of vials based on completed tests and observations, analyze data from controlled tests and use it to explain why objects sink or float in water, and use their knowledge of density, sinking, and floating gained earlier in the unit to inform their submersible designs (Boston Museum of Science, 2013, p. 5-7).

Themes and Findings

This study was guided by two main research questions, one focusing on the teacher and the other on the students. The first question was: How does a first/second grade teacher integrate literacy strategies and practices within the context of science and engineering units? The research question about the students was: How do the students incorporate literacy into their science and engineering work? After analyzing the data, themes emerged relating to each of the questions and sub-questions. While the data were analyzed separately for the teacher and student research questions, findings for both will be discussed together in this section; when talking about the teacher's practices, it is impossible to not talk about student strategies, and vice versa. For this reason, the themes relating to the student research questions will be described in relation to the teacher practices. The following section will provide an in-depth description of the findings with examples and support from the data.

Teacher Practices and Student Strategies

Two overall themes emerged from the data regarding teacher practices and students' use of literacy. The first of these two themes centers on the teacher's application of literacy skills in content area learning. As a result, the student findings demonstrated that the students were able to see the connection between content areas with regards to literacy strategies. This section will describe this theme with support from the data.

Applying Literacy Strategies in Content Areas Leading to Strategies Viewed as Practices

One of the first patterns to emerge from the data was Mrs. Martin's push for her students to apply their literacy strategies (comprehension strategies, writing conventions, vocabulary) in their content area learning. As a result, her instruction often focused on making these connections through modeling, scaffolding, and providing students with opportunities to apply their literacy skills. Her instructional methods included moments where she focused on nonfiction features during a shared reading text to introduce a science topic. She had her students help her spell a word during shared science writing because the word followed a spelling pattern they were currently learning, or she made predictions during their science investigations and during science read-alouds.

This pattern of applying skills in science and engineering appeared multiple times in the data. A few lessons and student conversations are highlighted and discussed below as examples commonly found in the data. The first of the lessons occurred during Mrs. Martin's science unit on life cycles, after the students had been learning about the different stages of the butterfly life cycle. Prior to this lesson, they had spent time reading nonfiction books together as a group and independently during reading time and drawing the life cycle of a butterfly in their science notebooks.

Purposeful Content Connections Lesson Example: The Butterfly Life Cycle

It was literacy time in Mrs. Martin's classroom and the students were all gathered on the floor ready to begin. Mrs. Martin began by explaining, "So I want you to be thinking about what do I know about moths and butterflies so then we can fill in our Venn diagram" (Observation protocol, 10/23/12). As she read, she stopped and thought aloud to model her thinking with her students. After reading a page and a half she stopped and said, “So remember yesterday they said some of the antennas look like feathers. This is an example of that” (Observation protocol, 10/23/12). She continued reading and stopped after reading about the butterfly’s wingspan. She asked the students “What do you think a wingspan might be? Can you show me what your wingspan might be?” (Observation protocol, 10/23/12). After a few students shared, she had them model with their hands what their wingspan might look like. In the discussion, one of the students mentioned the word foot so she asked, “What is a foot compared to a ruler? More? Less? Equal? A ruler and a foot, do they have anything in common?” (Observation protocol, 10/23/12). The class agreed a foot has twelve inches so Mrs. Martin explained, “so these caterpillars have a wingspan of about a foot” (Observation protocol, 10/23/12).

As she continued to read the text, she read a fact that explained how one caterpillar had poison spikes that sting. Then she said, “I wonder why it would have spikes that would sting? Can you turn to a neighbor and explain what you think” (Observation protocol, 10/23/12). A few moments later, she brought them back together and asked students to share out. One pair of students labeled the spikes as a *defense mechanism* for the animal. Mrs. Martin agreed and reminded students of what they had previously learned about animals and their defense mechanisms. They continued through the story and she continued to stop to share her thinking with the group. At the end of the story, Mrs. Martin said, “Now remember, this book will be available in our class library in case you want to look at it again to get more facts” (Observation protocol, 10/23/12).

Following the reading of the book, Mrs. Martin moved to her computer and opened a picture of a Venn diagram. She titled the parts of the diagram with *butterflies*, *moths*, and the word *both*. As she wrote the word *butterflies*, she pointed out how it was plural and said, “One of my reading groups is talking about that. They are learning that you take off the ‘y’ and add ‘ies’.” Once the diagram was labeled, she asked students to share things that were the same for moths and butterflies. Students suggested things like, “they have wings” and “they both fly.” As Mrs. Martin added these facts to the class Venn diagram, the students recorded the same things in their science notebook. The process continued and each time students suggested a fact, Mrs. Martin responded by asking for clarification by saying, “moths or butterflies?” She also asked the class if they agreed or disagreed with each other’s statements. At times when the class disagreed, she told them, “It is important to go back to the text we if are not sure. While you are writing that down, I’ll go look it up. We just read that a minute ago so it should be easy to find” (Observation protocol, 10/23/12). She modeled for the students how to go back to the text and scan to find the fact they were looking for and even mentioned the use of the index if the book had one. The process of sharing facts and looking up facts they disagree on continued until they had completed their diagram.

The lesson concluded with Mrs. Martin saying, “Could you add to this diagram if you learn new things? We use the science notebook to write our ideas so we don’t forget it. If you learn something about mealworms, you can go back to that page. If you learn something about butterflies you can go back to that page” (Observation protocol, 10/23/12). She encouraged students to take their science notebooks to the library with them during reading time so they could add things if they needed to. While reflecting on this lesson during our interview that week, Mrs. Martin said, "I thought the Venn diagram lesson went really well and they seemed really be understanding compare and contrast too. When I looked at a few of the science notebooks they had all… Everything in the right place" (Teacher interview, 10/26/12). Figure 5 is an example of one of the student's journal entries. In his entry, he has the two circles labeled with *butterfly* and *moth* as well

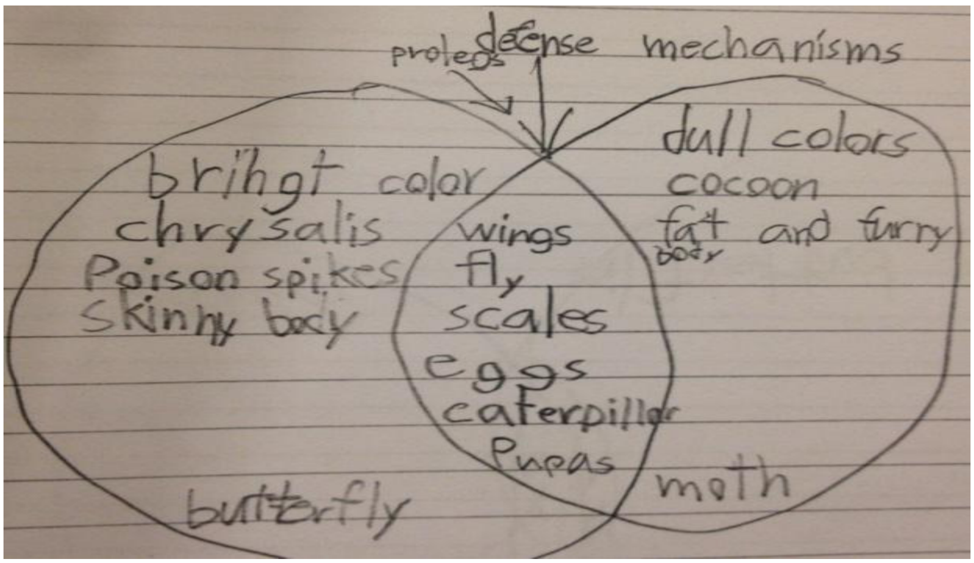


Figure 5 Student Venn Diagram Notebook Entry

as several characteristics listed in each area. Mrs. Martin also highlighted in this interview the importance of going back into the texts to support their facts. She added, "But that going back into the text instead of arguing with each other is something that I think is great to start learning this early. And so on the few questions that we got to go back and actually look it up and well this is what it says exactly. And there was no arguing it was like, 'yeah you're right… that's where it goes,' so I'm hoping to keep instilling that. So that was pretty cool" (Teacher interview, 10/26/12). By teaching the students how to go back into the text to support their ideas, she is teaching them the importance of needing evidence to support their thinking as well as the role texts play in learning about science.

In this lesson, Mrs. Martin made connections across a range of content areas including science, reading, and word work. She was beginning to move from basic integration of content areas to more seamless integration/inquiry. Throughout the lesson, she provided verbal modeling of how students could take facts from the text and add them to their graphic organizer. The questions she asked prompted students to compare what they were learning to their science content knowledge. Her modeling of how to use nonfiction features helped her students understand how to navigate through a nonfiction text while finding facts to record in their graphic organizer. Her comments about supporting their thinking also modeled for the students the importance of supporting their facts by going back to the text and using what the author said to support their ideas. In addition, by focusing on spelling patterns in the context of writing for the Venn diagram, she was teaching the students how to apply word study patterns when writing as a scientist. She was taking an isolated literacy skill, like spelling patterns, and giving it a purpose and application in the context of writing and learning about science. Overall, Mrs. Martin's focus on applying literacy skills in the context of science learning helped her students see the connections between the content areas.

Purposeful Content Connections Lesson Example: Point of View Writing

A second example of this pattern of applying skills in science and engineering came from the same science unit of study. Mrs. Martin introduced this lesson to me during our planning session for the week. She explained, "Everyone's going to read *Where Butterflies Grow* (Ryder & Cherry, 1996) and it's from the point of view of a…not exactly…it talks about if you're a caterpillar imagine you would have...And I want to have them write a point of view story from a caterpillar" (Planning session, 10/22/12). Her goal for using this story was for the students to write a point-of-view story while applying the science concepts they had learned about life cycles.

During one observation, I went into Mrs. Martin's room during their writing time to observe the students working on their stories. She began the lesson by explaining to the students how she would be returning to one of the butterfly texts they had read earlier. She said,

> I got to see some of your stories yesterday and I was really excited about some of them. A few people are making really good progress. I hope to meet with a few more today. What I noticed from a few of them that I read was really good detail. And good detail sometimes comes in the words you choose. So I wanted to go back into the story we read earlier and talk about this a little bit. I'm going to read you a page the way the author wrote it. And then I'm going to go back and take out some of the words and read it again. And we are going to see which one we want to write more like. (Observation protocol, 10/26/12)

She went back in the story and read the first page of the text twice. The first time she read it with the author's descriptive language. She reads, "This is a growing place green and warm and bright. Lift up a leaf and you may find someone ready to be born. Lift up a leaf and imagine. Imagine you are someone small hidden in a tiny egg growing bigger growing darker till one hot morning you burst your shell and creep into brightness" (Ryder & Cherry, 1996, p. 1-2). Then, she went back and read it using more simplified language. She read “Lift up a leaf and find an egg. The caterpillar comes out of the egg” (Observation protocol, 10/26/12). Then, Mrs. Martin asked the students to compare the two versions and share what they thought about the word choice. One girl responded, “Wow, that’s a lot of words you took out” (Observation protocol, 10/26/12). Mrs. Martin agreed and explained how it was important as writers to go back into their stories and add more descriptive language. She said, “So let’s think about some things the author put in that we might want to add to our stories” (Observation protocol, 10/26/12). She reread the first page and had students share the descriptive words they heard the author using. She pointed out what the author did by saying, “so instead of saying they were in an egg, he says they were hidden in a tiny egg” (Observation protocol, 10/26/12). She goes on to point out a few other examples and then explained to the students how they would be working on improving their word choice in their own butterfly stories.

The students were dismissed to their seats and Mrs. Martin called over Ashley, a female African American second grader and told her to bring her writing with her for a conference. Ashley sat down and Mrs. Martin said, “So show me somewhere in here where you changed your word choice” (Observation protocol, 10/26/12). Ashley had some trouble finding an example so they read the story together. As they were reading, Mrs. Martin stopped her occasionally and asked questions about the story. For example, at one point Mrs. Martin asked, “What do you think it would be like to be inside a chrysalis? Do you think you could talk about what happens inside a chrysalis? So what words would you use to describe the inside of the chrysalis?” (Observation protocol, 10/26/12). Each of the questions prompted the student to begin to think about what details were in the story and what descriptive words could be added. In the beginning of the story, Ashley added the word *tiny* to describe her egg and added a sentence about where her brother and sister eggs were while she was in the egg.

This process of Mrs. Martin reading and asking questions continued as they moved through the story. At one point, Mrs. Martin introduced the use of a caret to insert words in a story as the writer. She said, “Do you remember we talked about the caret and how this is a tool that can be used to add something?” (Observation protocol 10/26/12). During the discussion, Mrs. Martin focused on what Ashley wanted her reader to understand as they read the story. After they were done reading through the piece of writing, Mrs. Martin encouraged her to return to her seat and make some of the revisions they discussed.

At the end of the week, Mrs. Martin was reflecting on the progress the students were making on their point-of-view butterfly stories. She explained to me,

> One of the things I’m really excited about is we’re doing a writing project about telling a story from the point of view of a butterfly. And most of the kids did a life cycle sort of as their pre-writing and kind of talked about ‘what I’m going to say about being an egg and when I’m going to turn into a larva’. And it was pretty cool. So they just started drafting those but the ones I’ve looked at have really good vocabulary in them. They talk about being inside a chrysalis and so I’m really anxious to get to read those. (Teacher interview, 10/26/12)

In this excerpt, Mrs. Martin points out the pre-writing card sort activity her students used to prepare for their writing. By starting their writing process by brainstorming with a card sort of the life cycle phases, she was teaching the students how to take the content they were learning in science time and apply it to another context, writing. The composition of the stories required students to apply their writing skills to communicate about the content they were learning about life cycles. She gave them a meaningful way to connect writing and science by teaching them how to take the knowledge and vocabulary they learned in science and apply it in their writing.

Purposeful Content Connections Lesson Example: Making Submersible Rules

A third example of this pattern occurred during Mrs. Martin's engineering unit on submersibles. The class was in the beginning stages of the unit and students were preparing for an experiment where they tested whether an object would sink or float. This specific lesson required the students to complete a card sort displaying pictures of various objects.

Mrs. Martin began the lesson by reminding students that "how we treat each other is more important than where the cards go" (Observation protocol, 11/15/12). She explains they will be given a set of cards to sort into a "sink" pile, a "float" pile, and an "unsure" pile. She sent the students off with their partners to sort their cards and develop a "rule" for their decisions. Figure 6 shows two students working on writing their rule

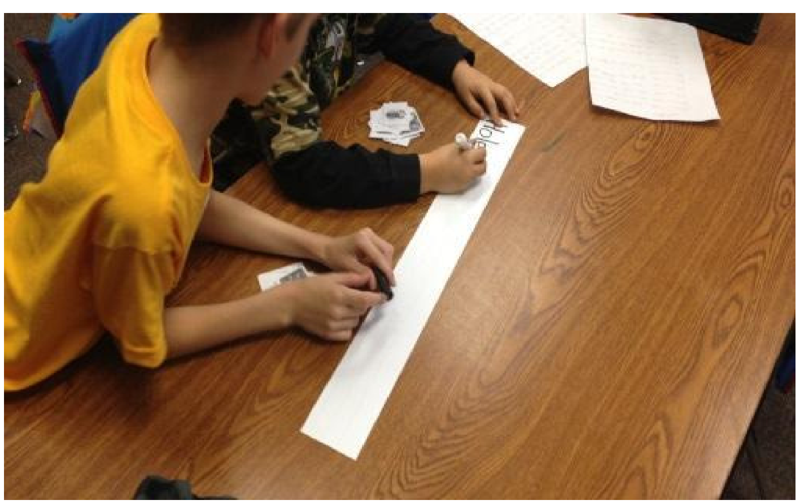


Figure 6 Students Writing Float/Sink Rule

after completing their sort. Once the partners developed their rule, Mrs. Martin explained, "once you have developed your rule, you can move to the testing station to test some of the objects" (Observation protocol, 11/15/12). After testing, students were told, "Now I want you to talk to your partner about your rule and if you need to change your rule or not" (Observation protocol, 11/15/12).

As students worked, I joined a group of two girls to listen and talk to them about their choices. Irene, a first grade female student, and Katie, a second grade female student, were in the middle of sorting their cards. Both of these students are Caucasian and attend the school as a result of living in the school's attendance area. I initiated the discussion by asking what picture they were sorting when I walked up. The conversation below is what followed.

> **Researcher:** What is it?
>
> **Irene:** A rubber band.
>
> **Researcher:** Why do you think float?
>
> **Katie:** Because I think rubber floats and rubber bands are made out of rubber.
>
> **Researcher:** OK.
>
> **Irene:** Small box. We can't decide.
>
> **Katie:** Tennis ball.
>
> **Irene:** I think it will float because I've seen my… And seen my puppy chew it up and there is like nothing on the inside. (Student conversations, 11/15/12)

In this excerpt, both Irene and Katie were using their own background knowledge to help them sort their cards. Katie makes the generalization that the rubber band will float because of the type of material. Irene, on the other hand, used some of her life experiences to help her sort the cards. In this conversation, the girls were using life experiences, making predictions, and making connections to help them better understand the science. In other words, the girls were moving from strategies to practices by using natural strategies more as practices of scientists than isolated skills that only occur in one content area.

A little later in the conversation, Katie and Irene shared with me why they decided to record their rule using a t-chart. The following transcript occurred towards the end of our conversation as the girls were finalizing their sink and float rule.

Katie: (Student reads their rule) “Small things float.”

Researcher: So where did you learn how to do a t-chart? Was it in science? Was it in reading was in writing?

Irene: Um… We do it in… Me and Katie should put our names on it.

Researcher: OK. Where did you learn to do a t-chart? What subjects?

Irene: Um sometimes we do it in science and sometimes we doing in others. (Student conversations, 11/15/12)

In this transcript, Irene shares with me how she has learned to use a t-chart in multiple content areas. As a result of this frequent use of a t-chart strategy, these two girls decided it would be the best way to document their rule for what sinks and what floats. This example directly relates to Mrs. Martin’s focus on connecting literacy strategies to other content areas and provides evidence for how the students were beginning to apply literacy strategies as scientific practices.

The final example of this pattern came from the final interview with one of Mrs. Martin's students. During this interview, the questions focused on several topics: the content she learned during the science and engineering units, Mrs. Martin's strategies to help them learn, and the student's view of herself as a reader, writer, scientist, and engineer. Below is an excerpt from my conversation with Sandy, one of Mrs. Martin's first grade students. Sandy is a Caucasian student who attends the school as a result of living in the school's attendance area. We are discussing how the content areas (literacy and engineering) work together to help her learn.

> **Researcher:** OK. So when you are writing you come to a word that you don't know what do you do?
>
> **Sandy:** You just write it. Sounded out and spell out at your best.
>
> **Researcher:** OK. When you're in science time and you are writing… Is that easier or is that harder than when you write during writing time?
>
> **Sandy:** Easier.
>
> **Researcher:** Why is it easier to be a writer in science?
>
> **Sandy:** Because sometimes we don't have much to write and we learned it fast. (Student interview, 12/18/12)

What is interesting to note here is Sandy's comment saying writing during science time is easier than writing during writing time. In all of the observations, the writing that occurred during science time related to the topic or activity they were doing that day. From Sandy's statement, it seems she finds it easier to write when she is writing about something she learned. Mrs. Martin's writing time allowed students to create both the content and the form for the stories. For this reason, Sandy did not have to think about what to write, just how to communicate what she had learned. In other words, she used writing as a practice of scientists and a tool to help her learn science.

In each of the lessons and conversations just described, Mrs. Martin modeled for her students the connection between literacy strategies, science, and engineering. The lessons demonstrated examples of how the students were beginning to change from seeing skills such as decoding (chunking), natural reading skills, and writing as isolated strategies to practices of scientists and engineers. As a result of Mrs. Martin's focus on content area connections, the students were beginning to apply their strategies and use them more as practices needed to understand science and engineering.

Purposeful integration and use of science notebooks, nonfiction texts, and talk resulting in students' use of drawings and sketches to communicate content area knowledge

Another pattern that emerged from the data regarding teacher methods involved the purposeful integration and use of science notebooks and nonfiction texts. Mrs. Martin frequently mentioned in our planning sessions and interviews her goal of teaching her students to use their science notebooks as a resource. Mrs. Martin said during one of our interviews, "I'm hoping to kind of create a sense of 'I keep coming back to my science notebook for something useful'" (Planning session, 11/12/12). Over the course of the study, Mrs. Martin incorporated the use of science notebooks as a way to document thinking and she found nonfiction texts that connected with her science and engineering units. She suggests that the use of the nonfiction texts provided her students with extended opportunities to build background knowledge and vocabulary. A few instances of her use of science notebooks and nonfiction texts have been selected from the data and are highlighted here to support this theme.

Use of Notebooks and Nonfiction Texts Lesson Example – Despina and the Engineering Design Process

This first example occurred during the engineering unit on designing submersibles. The students had been introduced to the topic through a shared reading text where the main character, Despina, attempts to design a submersible to go underwater and bring back up a pair of goggles. In this lesson, the students are listening to a shared reading nonfiction text on submersibles.

The lesson began with Mrs. Martin returning to the story as they worked together to identify where in the book Despina, the main character, went through each of the engineering process steps. This text was part of the engineering curriculum and is written in narrative form to introduce the students to the engineering field, to the engineering process, and to how one individual (main character) designs something to solve the problem. Then, Mrs. Martin explained, "Now we are going to look at submarines and submersibles" and held up a nonfiction book (Observation protocol, 11/29/12). She told the students that as they listened to this book she wanted them to think about what they knew about submersibles and Despina's problem. As Mrs. Martin read, she stopped and made comments like, "they had questions about the sea floor. Oh, we had questions about the sea floor too" (Observation protocol, 11/29/12). Each time she stopped, she made connections between what the fictional book said and what they have been learning about in class and in other books. For example, she reads a segment of the text about a crane lifting the submersible out of the water and says, “We saw that earlier in another book” (Observation protocol, 11/29/12). She also pointed out the nonfiction text features and how those helped her better understand what she was reading.

During this lesson, Mrs. Martin purposely selected a nonfiction title that provided her students with additional vocabulary and knowledge about submersibles. It also served as another opportunity to highlight nonfiction text features and how they help a reader understand the text. The discussion that took place as the students were talking about the connections between the fictional story of Despina and the nonfiction text about submersibles provided yet another way to connect the learning in their classroom to what they were reading.

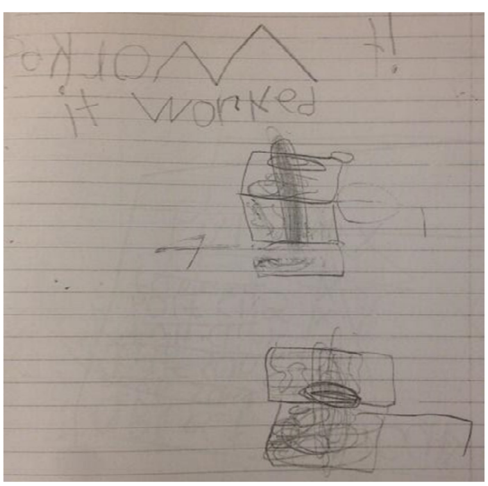
Use of Notebooks Lesson Example: Designing Submersibles in Science Notebooks

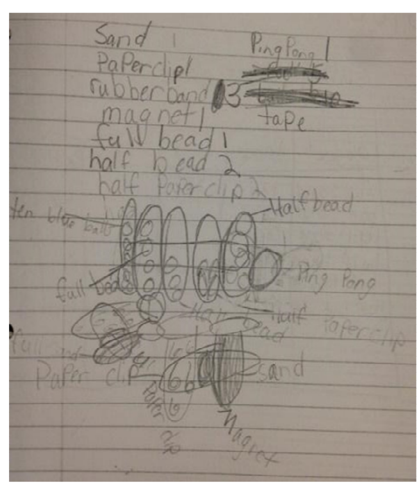
The second example of this pattern also occurred during the submersible engineering unit. The students had read several books together as a class on the design and use of submersibles, tested a variety of materials to see if they would float or sink, and read about Despina’s submersible design. Now, the students were ready to design their own submersible with a partner.

The students were asked to work together to design a submersible that could sink to the bottom of a bucket and pick up a magnet. As part of this planning process, students had to develop a materials list for their submersible as well as a sketch of their design. As the students were gathered together on the carpet, Mrs. Martin explained the various materials available for them to use to design their submersible. She wrote a list of available materials on the board for the students to use as a reference for their list.

Then, she modeled for the students what type of sketch she was expecting in their science notebooks. For example, as she drew the water, she said, “We usually represent water using blue because you can’t draw clear” (Observation protocol, 12/4/12). She had mentioned in previous interviews how she wanted students using their science notebooks just like scientist and engineers. For this reason, as she drew she pointed out how she was adding labels so others would know what she was drawing. After providing the overview of the materials and reviewing the process Despina used in the book, students were sent off with their partners to work. During the work time, Mrs. Martin reinforced the use of labels in their drawings by saying to students who were finished, “I need some labels on your scientific drawing” (Observation protocol, 12/4/12). By calling them scientific drawings, she reinforced the use of sketching and writing in science notebooks as a scientific practice.

Figures 7 and 8 show two entries from student notebooks. The first entry shows two different sketches made by the student as possible submersible designs. By looking at Figure 7, it seems the student chose to document his thinking in pictures and did not





Figures 7 & 8 Student Submersible Sketch Notebook Entry include a written description of his materials list. The sketches themselves are detailed with different shading to show the different parts of the submersible. At the top of the notebook entry, it also has the words "it worked", which were added once his group designed and tested their submersible. By returning to his notebook entry to add the results along with the sketches, it seems this student understands the importance of documenting his learning through sketches and words. In comparison, Figure 8 includes more details, using words and labels. This student also has two different sketches of possible submersible designs. In addition, she also has included a detailed list of materials she would need to design this submersible. The labels she has added to the sketches provide details so she remembers what the sketch is when she returns to it the following day. This is an important component of the sketch for this age of student, because it allows the child to return the next day and gather all needed materials without having to remember what the drawing included. Both of these notebook sketches provide support for Mrs. Martin's integration of science notebooks as a way to document their learning.

Figure 9 shows another example of a student's science notebook entry for this

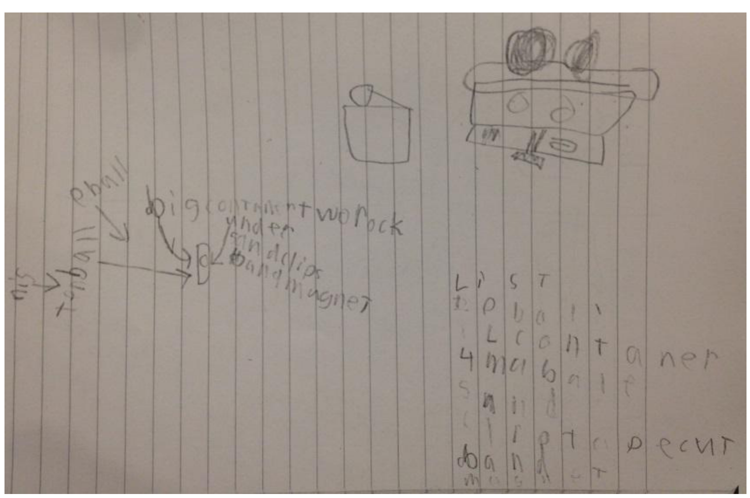


Figure 9 Student Submersible Sketch Notebook Entry

lesson. In his entry, he includes a sketch of a possible submersible design, a list of possible materials he will need, and a second sketch with labels of one part of his design. During this lesson, students were using their sketches for an authentic learning purpose. They understood from the beginning this sketch would be used at a later point when they come back to design their submersible. For this reason, many of the students included labels to help make their sketch even more specific. Mrs. Martin reinforced the students' use of sketches during the observation, when she asked to see them as the students came to see her at the materials table. She asked students questions about their sketches and had them make modifications if it could not be easily understood. (Observation protocol, 12/4/12)

This lesson is just one of many that included the use of science notebooks in Mrs. Martin's classroom. The majority of the science notebook instances I observed included both sketches with labels and short descriptions of what they were learning. Her goal was to teach students to use their science notebooks as a tool and resource to return to at a later time. She also wanted her students to use their science notebooks as a practice of scientists and engineers. As a result, the details included in the previous student notebook examples demonstrate the beginning development of the use of notebooks as a practice.

Use of Notebooks and Nonfiction Texts Lesson Example: Animal Adaptations in Science Notebooks

A third example of this theme provides a glimpse into how Mrs. Martin integrated both the use of nonfiction texts and science notebooks into her daily lessons. During their science unit on animal habitats and adaptations, the students were learning about a variety of polar animals and adaptations that helped them survive in their habitats. During one of the observations for this unit, the students were going to create a T-chart of polar animals and their adaptations. However, instead of the students sharing the facts, Mrs. Martin had selected a nonfiction text that included facts about polar animal adaptations.

As the lesson began, Mrs. Martin asked the students to grab their science notebooks and showed them how to create the structure for a T-chart. Once everyone was ready, she began to read the nonfiction text. As the students listened, they shared out when they heard something relating to polar animal adaptations. When this happened, Mrs. Martin stopped and added that information to their class chart while the students add it to their own notebooks. They continued through the book, writing down any animals and adaptations they found. (Observation protocol, 12/11/12) The resulting chart provided students with written documentation of their learning. Figure 10 is one example of a student's notebook entry. In this entry, she has the t-chart format with titles at the

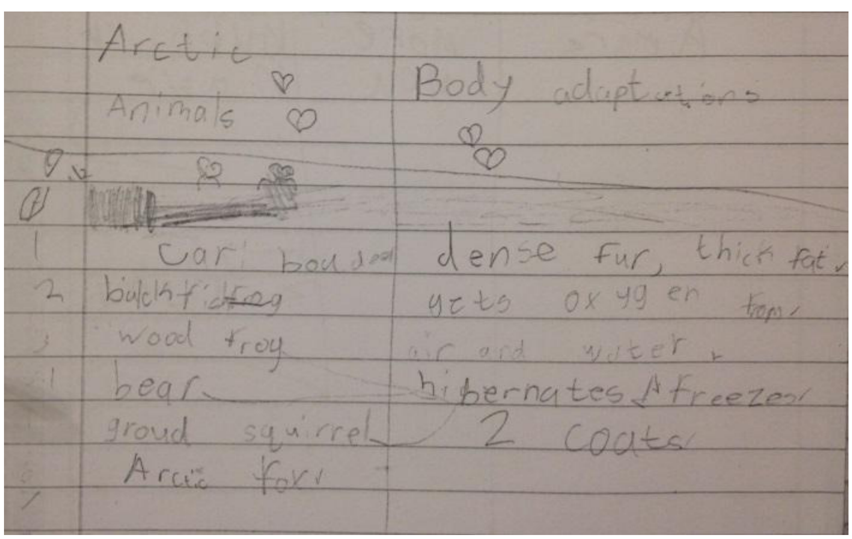


Figure 10 Student T-chart Notebook Entry

top. In each column, she has recorded animal names and their related body adaptations.

At the conclusion of the lesson, students were left with a written documentation of their learning, as well as, the understanding that they could return to the nonfiction text at a later time if needed. In this lesson, Mrs. Martin purposefully selected a nonfiction text that extended what they had already been learning about animal adaptations. She also incorporated the use of science notebooks as a way for the students to document their learning. This lesson taught students how to use a nonfiction text as a source of information, as well as how to take the information and document it as a scientist in their science notebook. Even though this type of recording is not new to many teachers, the students were using reading and writing as practices of scientists instead of as separate strategies and skills. This beginning development of reading and writing as practices occurred as a result of the students reflecting on how and when they used literacy to communicate their science understanding.

Student Conversation Example

A fourth example came from when the students were in the middle of their science unit on life cycles. During one of the observations, I watched the students as they worked at an observation station during their literacy time. Mrs. Martin's observation station center was set up so students could have hands-on experiences with the science or engineering topic they were studying. In this case, the students were given a variety of objects such as a gourd, a dead butterfly in an observation container, and a pumpkin. The objective for this station was for the students to continue to explore their understanding of life cycles. As part of their job at this station, they were to write down facts and draw sketches of what they observed. At one point in the observation I asked students about what they were doing. The students in this conversation are Kyle (mixed-race lottery student), Carl (Caucasian home attendance student), and Matt (mixed-race home attendance student). The excerpt below shows our conversation.

> **Researcher:** So why are you writing in your science notebooks at this station?
>
> **Kyle:** Because it's scientists.
>
> **Carl:** Yeah. The observation station.
>
> **Matt:** You're sketching something that's living.
>
> **Researcher:** Something that's living? And why would be important for a scientist to sketch something?
>
> **Carl:** So they remember.
>
> **Kyle:** So they know how it works.
>
> **Carl:** It's poisonous. Are you recording us?
>
> **Researcher:** So would you guys think that the…do you think you're being scientist or writers?
>
> **Carl:** Oh. Look at this one is busted open.
>
> **Matt:** Both.
>
> **Researcher:** Both? Why both Matt?
>
> **Matt:** Because you're writing and be a scientist. (Student conversation, 10/31/12)

This conversation demonstrates how the boys believe their science notebooks and sketches are just a normal part of what they do. By saying, "Because it's scientists," Kyle identifies himself as a scientist and continues to explain the importance of documenting his thinking. Kyle's statement shows he believes scientists record in their notebooks as part of their job. In other words, he is using sketching and drawing as a practice of a scientist. When the boys were asked why they were recording in their notebooks, Matt's response pulls in the use of sketches to communicate meaning. In his mind, he has to draw a sketch so he remembered what he learned. From this short segment of our conversation, it indicates the boys understand the importance of sketching and recording what they were learning as scientists.

In several of the lessons I observed, Mrs. Martin encouraged the students to think about how what they were reading to help them better understand what they were learning in science or engineering. As a result of Mrs. Martin's instructional focus on applying skills across content areas, students began to recognize these connections and to apply them in other areas. In our final interview, Mrs. Martin shared her reflection on what her students had learned through integration. She said,

> I don't know that I would have said in August…OK, my goal is that they are going to understand in the end that all the tools we use during the day are resources and that they do go back to them. You know I would have been like 'yeah right. You go girl'. (Teacher interview, 12/20/12)

Mrs. Martin realized her students were beginning to see their literacy strategies in a broader view as practices of scientist and engineers. Her students started to use their literacy strategies naturally when reading nonfiction texts in science and engineering. In addition, students also began to become more focused in their use of sketches to communicate meaning, which often occurred when using their science notebooks through drawing scientific sketches. Through the instructional strategies described in the previous theme, students developed a deeper understanding of how reading and writing are tools that can be used to learn science and engineering. Overall, her students began to see their literacy skills and strategies as practices of science and engineering.

Teacher Change

One of the most interesting findings that came from the data was the change that occurred with Mrs. Martin. The change in her language was the most significant change and was the key factor that led to the identification of the other changes that occurred. When I initially sat down to visit with Mrs. Martin about her lessons, my observations, and her integration, she would say “I am integrating this week in writing by” or “On Tuesday I am integrating by” (Planning session, 10/22/12). However, she began to change the way she explained her lesson plans to me as time progressed. By the time we met to talk about her second unit (engineering), she said “It was the whole integration thing that created the unit. Like ‘How can I try this in? How can we write about this? How we can do prompts about it?’ And then I started there and then I needed books. And I was like ‘what am I to do with the books I can’t just have the books’. So I was like well… And then pretty soon it was like this big giant thing” (Planning session, 11/12/12). The difference in Mrs. Martin’s phrasing highlights the changes she was experience in her planning and how she was beginning to approach integration. Instead of explaining how she was integrating in each subject area, she began providing an overview of how the lessons connected across content areas and built off each other. By the time she went to plan her second unit, she described it not in terms of each subject area, but by the connections she found while planning. The specific language she used in our planning sessions signaled this change in thinking.

Another change in her language was more subtle but came out in our interviews, planning sessions, and her journal. Mrs. Martin began to become more purposeful in the words she used with the students. For example, several times during our interviews and in observations I heard Mrs. Martin refer to her students as scientists or engineers. By using this specific label, she was communicating her expectation and belief in her students' ability and the application of the content they were learning. Through her language, students began to see themselves as scientists/engineers and understood the skills they were learning had a direct application to the real world. In addition, Mrs. Martin began to clearly communicate why they were learning the skills and how one skill or content area was connected to another. For example, in one observation she said, "Oh, we learned about that before and here is what they look like." (Observation protocol, 10/23/12). Here, she is using specific and purposeful language to clearly communicate to her students the connection between skills and content areas.

Concurrently with Mrs. Martin's change in language, two other changes appeared in the data; these were a change in teacher confidence through constant reflection and the refining of planning and implementation of integration. Her changes in teacher confidence and refining of planning are described here with support from the data.

Change in teacher confidence through constant reflection

Throughout the study, Mrs. Martin was constantly reflecting on her teaching, her students' behavior and learning, and her instructional practices. While some of this reflection resulted from my presence and questioning, she also indicated in interviews her frequent reflection on her teaching. In the initial interview with Mrs. Martin, she shared the impact working at a STEM school had on her teaching. She explained, "I think the biggest thing that I'm noticing is that I'm getting really excited about science and how I could integrate science. And I noticed science in the world around me" (Teacher interview, 10/19/12). This comment shows Mrs. Martin was beginning to think like a scientist herself. She noticed science in the world, which allowed her to better communicate that learning to her students. By becoming excited herself, that excitement transferred to her students and their learning. Even at the beginning of the study, her excitement level to take on the task of integrating seemed to be motivating for her. At other times during the study, she mentioned her excitement when students shared something they remembered from a previous lesson. During an interview, we were watching a video segment from a lesson. She had read part of a text when a student stopped her and asked her to read the caption. In the interview she said, "That was kind of the main thing I was thinking was that it was a celebration that they are beginning to really internalize some of the concepts (nonfiction text features) and transfer them from subject to subjects without thinking about it" (Teacher interview, 10/26/12). Mrs. Martin was sharing her excitement in this statement because her students were taking something they learned in science and connecting it to a guided reading text they were using. These types of comments signaled she was beginning to notice and recall the moments in her teaching where she was seeing the connections in her students' learning.

Throughout our interviews and planning sessions, there were several moments where I could tell she was reflecting on her methods and practice of integration. In one of our interviews during her life cycles unit of study, she was sharing her plans for the week. She said,

> I found some great ideas. I don't know why I didn't think about it this is perfect to do this in October and we need to remember this because you can do life cycle of a pumpkin. Which is a perfect tie in because you're already thinking about it; they're already reading about it they are seeing them everywhere in the stores. (Planning session, 10/15/12)

This comment demonstrated she was already looking for ways to modify her instruction and integrate more content areas with her current curriculum. In another interview during her engineering unit, Mrs. Martin shared her thoughts about her planning process. She explained how she felt she had developed more of a pattern for her planning. When she had designed her first science unit, she felt like it was more of a, "'I don't know, I think this might work' approach" (Teacher interview, 11/30/12). Later, when she went to design her engineering unit, she was more confident things would "come together" during instruction because of her successes with the last unit. Her comment of things "coming together" indicates she is beginning to take more of a seamless integration/inquiry approach to her planning. She was seeing the connections between content areas and knew how to communicate those to her students.

Another focus of Mrs. Martin's reflection was on the curriculum and her integration. Several times during our interviews, she mentioned the tension she felt regarding using the district curriculum. Over the course of the study, she began to look for ways to modify her current curriculum to integrate other areas. During her unit on life cycles, she reflected on the need to continue to teach the craft of writing while still integrating writing in the content areas. She explained how she believed it was important to still teach the craft of writing because that is an important skill for them to learn.

However, she felt the current way she integrated writing into science time did not accomplish this goal. In an interview she said,

> You know you still have to teach the craft (of writing). Which I'm finding is the part that I'm like 'oh I have to make sure I'm not forgetting to do that' because that's really important. That's what's going to help them be better writers as much as just writing more. (Teacher interview, 10/26/12)

She went on to explain how she was looking for new ways to teach the craft of writing by using nonfiction texts and models. This type of reflection occurred more and more as time went on, and she would often reflect on how she could modify it more the next time she taught a unit. In addition, the continued reflection on how to modify her integration practices signaled the increasing commitment to using integration in her classroom outside of this study.

During her final interview, I asked Mrs. Martin how she thought her perspective on integration had changed over the course of the study. She responded by explaining how it had not really changed because she felt it was similar to how she taught when she first began teaching. However, she did notice a change in her confidence and she explained, "I think of anything, I just feel more confident and being okay with leading the way" (Teacher interview, 12/20/12). This statement demonstrated how her confidence and self-efficacy had increased because she had tried integration and was successful. Her statement of "leading the way" indicates her confidence in showing other teachers how to begin to integrate in their classrooms through collaboration and modeling. This increase in her self-efficacy also came out in other ways. For example, several times during the interviews she talked about how she was happy and willing to share her lesson plans and strategies with other teachers in the building. She felt more confident in helping lead the way with regards to implementing integration. Over the course of the year, she decided to present at other meetings and conferences some of the things she had implemented in her classroom. Figure 11 shows one of the sessions Mrs. Martin presented at a regional

Figure 11 Mrs. Martin's Observation Station Presentation

conference. On the table are all of the materials she used for her observation stations during literacy time. During the presentation, she shared an overview sheet she put together with the books she used to integrate, the writing prompts and projects she used, and a list of additional resources for her life cycle unit. This unit overview sheet can be found in Appendix N. Overall, it seemed Mrs. Martin became more confident that the integration methods she was using helped her students make connections across content areas and increased their learning.

Refining of planning and implementation of integration

The second theme that emerged from the data on teacher change focused on Mrs. Martin's refining of planning and implementation of integration. During the observations, I noticed Mrs. Martin frequently pulled in related nonfiction texts to use as read-alouds to introduce science and engineering concepts. Through these observations, it seemed integrating nonfiction texts into her read-alouds during science was easy for her. However, integrating nonfiction texts into other areas of reading was a little slower to develop. During our final interview, I asked Mrs. Martin to reflect on what she felt changed the most with regards to integration. She responded,

> My reading lessons I think have probably changed the most just because so many of them are science based and nonfiction based. Where in the past it was probably not even 50/50. It was probably more fiction and then occasionally I would go into a nonfiction unit or all of these books together so let's go ahead and talk about that a little bit. (Teacher interview, 12/20/12)

Integration challenged Mrs. Martin to think in a different way regarding what type of texts she was asking her students to read. I also noticed this change during some of our planning sessions. Mrs. Martin mentioned how she was trying to look for journal articles or nonfiction texts to use in her guided reading sessions.

Another noticeable change related to her instruction focused on her use of science notebooks. She frequently asked students to record in their science notebooks as a way to document their learning during science and engineering time. Initially, she often encouraged students to document using whatever strategy worked best for them. As the study continued she began to talk more about what she was having them enter into their notebooks. During one of our interviews, she explained,

> Like I'm really being more cognizant about what I'm having them writing in their science notebook and for what purpose. This has then sometimes inspired an actual writing project. So I think that tie-in between their

science notebooking and what they're doing in reading and writing has been what I wasn't really expecting. (Teacher interview, 12/20/12)

From this excerpt it seems Mrs. Martin was actually noticing the change in her planning and implementation of science notebooks. She even found ways to use the science notebook entries as starting points for other writing activities. Her use of science notebooks seemed to change from a method of recording students' thinking to using them in a way scientists do, as a scientific practice.

Finally, the biggest change occurred in her planning and designing of lessons and units. During her first unit on life cycles, she pulled texts related to the topics, had students document thinking in their journal, and selected an assortment of activities that were related to teach the concepts. She designed her unit of study using the district's unit overview found in Appendix M. It outlines the guiding questions, key vocabulary, unit objectives, and science lessons. This unit of study seemed to have a theme unit design where all the activities were related to the main topic, life cycles. She developed her plans for the life cycles unit more on-the-go and pulled related nonfiction texts during the unit. However, the reading, writing, and science seemed to be disconnected from each other except for the connection to the topic of life cycles.

In comparison, by the time she planned her engineering unit on submersibles, Mrs. Martin was able to think through the whole unit selecting possible nonfiction texts, science notebook prompts, and purposefully connected engineering activities. This change became evident in her written plans for the units of study. In contrast to her planning of the life cycles unit, she showed me in a planning session an overview of the unit and selected nonfiction titles she had already selected to help her students build background knowledge and vocabulary. Her submersible unit plan she developed can be found in Appendix O. This unit still seemed to be theme-oriented and inquiry based, but the biggest change was the lessons in reading, writing, and science, and how they built off each other. For example, as she thought about the engineering design challenge her students needed to work through, she began to find nonfiction texts to introduce and extend the topic. This led her to begin to think about what type of writing prompts or experiences would result from the conversations surrounding submersibles and the engineering design challenge. By the time she had completed the plan, her reading, writing, and engineering lessons all had a connection and built off each other. Overall, her planning at the end of the study seemed more focused, purposeful, and integrated moving her towards a more seamless integration/inquiry approach to planning.

Teacher Successes as a Result of More Seamless Integration

As part of the research question on teacher methods, I also analyzed the data looking for the successes that occurred as a result of integration. After looking at all the individual codes relating to teacher successes, two main themes emerged and will be discussed here: 1) successes related to teacher confidence and practice, and 2) successes related to student knowledge and engagement. Support for these themes appeared throughout the data in the interviews, observations, student conversations, journals, and work samples.

Teacher confidence and practice

Mrs. Martin often talked about some of her successes in her reflection journal. On November 20th she wrote,

> Overall, I am so excited about the success I feel I am having with integration. It is becoming very natural, but I am more reflective and purposeful in my decisions. My students are certainly soaring and I am often impressed by the content they know and can transfer so easily to other subject areas. (Teacher journal, 11/20/12).

This statement by Mrs. Martin shows the high level of confidence she had at the conclusion of the study. To help demonstrate this increase in confidence and change in practice, I have included segments from a variety of data sources focused on this theme.

During our first planning session, Mrs. Martin was sharing her thoughts about the best time to observe in her classroom to see the integration of science and literacy. She explained,

> It seems to me I'm teaching more content during science and then tying that content in throughout the rest of the day. So the literacy piece is really showing up in literacy as it should be if we are integrating correctly. So if you are trying to see the literacy piece, I feel the science is not always the best time to come which is odd. It's not what I thought when we first started talking, but now that I'm like seeing how it's playing out. It's that read-aloud time, it's randomly today when a butterfly emerges and it was like stop everything. And they wanted to write about it. And they wanted to draw and you know. Those are the moments when I feel like the literacy in the science are tying in together. (Planning session, 10/15/12)

This excerpt described her comfort level with basic integration at the beginning of the study. Her comments indicated she did not expect a connection between literacy time and science time. In her mind, integration occurred during various moments during her day.

This struggle with her discomfort with integration continued into her science unit of study on life cycles. In a later interview, she stated that she felt the unit was going well but she was having a difficult time knowing how to end the unit. She said, "I don't know that I feel like I integrated really successfully. But I don't know exactly why not except that I think it's just the last couple days of the unit" (Teacher interview, 11/9/12). From this comment, it seems she was beginning to see herself as successfully attempting to integrate although she was not able to explain why. In her mind, she felt she had done some integrating but did not necessarily know how to end the unit.

Towards the end, Mrs. Martin's confidence level toward integration and her practice had increased. During her final interview, we were talking about what her next steps regarding integration would be once I left her classroom. She responded by saying,

> I just feel like I can help get this on the road a little bit because that piece of it comes pretty easily and naturally for me. So I think just more of the same really. And keep thinking about how do I make sure that I tie it in all my objectives. And again I just feel like if I can do this work that next year for me and for anybody else that kind of wants to join in a lot of that is going to be done. (Teacher interview, 12/20/12)

In this statement, Mrs. Martin says she thinks she can confidently lead the way to teaching others how to integrate more seamlessly in their classrooms. This is a big change from the beginning of the study, where she was a little unsure of the process and what it would look like in her classroom. In addition, as her confidence level increased, her questions about integration changed from general questions about where integration might occur to refining questions relating to how to accomplish it on a larger scale, with more objectives and a move towards inquiry.

During an interview, Mrs. Marin was talking about the struggle her students have with revising during writing time. She explained how she was thinking of using writing in science as a way to introduce and encourage revising in her classroom. She explained,

> We've been working a lot on descriptive words. That (the last lesson) was not a transfer of descriptive words. And so I think that's a good place to go back and reteach and then go back and let them revise because revising is what they're struggling with anyway. So finding some natural reasons to revise has been kind of what I'm doing. So that is a wonderful place to talk about science or how science is helpful in writing because it gives them a reason to revise. ‘But I've learn new things. I wanna go change what I said’ or ‘I wanna add something to what I said’ and I think that's much more difficult for them at this age to just pick something randomly. But if they are like ‘no, we did that penguin thing and now I understand’… You know… Maybe they'll go back and add the word *insulates* which is kind of the word I wanted them to take from small group yesterday. I think it the perfect reason to go back and revise. (Teacher interview, 12/14/12)

From this excerpt, it appeared she wanted to use writing in science as a tool to teach students how to revise. She thought learning new things in science would give them "natural reasons" to go back to a piece of writing and revise. This type of change in her thinking continued as she began to look at how she could be more purposeful and planned in her integration as we got closer to the end of the study.

Overall, the most convincing moment where I could tell her confidence and her practice had improved was during our final interview. We had talked about the impact I had on her instruction with my frequent observations and weekly visits about her plans. She had mentioned the confidence, support, and reassurance I had given her by simply providing a listening ear and someone off whom to bounce ideas. She ended our interview by saying

> I really do feel like it's going well. I feel like my kids are successful. I feel proud of what I'm teaching. I'm pleased to say on any day, sure, come into my classroom because I feel I really am teaching something great every day and I'm really proud of that. (Teacher interview, 12/20/12)

This final comment shows how Mrs. Martin had increased confidence in herself and her ability to effectively integrate on a regular basis in her classroom. While Mrs. Martin was confident in her abilities at the beginning of the study, her reflection and experiences with integration continued to help her increase her confidence. By the end, it seemed she felt more confident as a teacher and as a leader in the building when it came to integration.

Teacher Perception of Student Knowledge and Engagement

The second theme that emerged from the data on teacher successes was related to an increase in student knowledge and engagement in the lessons. Over the course of the observations in her classroom, more often than not, the students were focused on their jobs as scientists and engineers. This high level of engagement occurred most frequently when the students were working on hands-on activities, such as science experiments and observation stations. The data also showed that the students were able to apply science and engineering vocabulary across content areas and to retain information once the unit of study had passed. The section below provides some examples of these instances.

Mrs. Martin talked about the academic successes she saw in her students. During one interview, she was observing one of the segments of that week's video. She stopped in the middle of the video segment and said, "Did you hear what happened when I turned the page to the butterflies at the reading table? They went, 'Oh, butterflies. Those are Monarchs.' See? It just keeps happening!" (Teacher interview 11/9/12). In this statement, Mrs. Martin points out how her students are continuing to make connections and notice when a book mentions a topic they have been learning about.

At a different point in that same interview, Mrs. Martin shared how the students were transferring vocabulary from their science activity on pumpkins to a writing lesson on descriptive words. Initially, she mentioned how she did not really expect much from the descriptive words lesson, but it was an objective she believed had to be taught because of the district's curriculum. After it was over, she noticed the students had taken some of the words they learned when measuring their pumpkins and applied it to this writing task. She explained,

> They used a few science terms. I can't think now exactly what they were. But things that I knew we had talked about in class. Like they learn that word here. And so it was cool to see the transfer. Maybe part of it was just talking about the size. We had done a lot of talking about the size of pumpkins when we did all the measuring and weighing. 'How would you describe your pumpkin?' and that kind of thing. And so some of them used words like 'wide' or… You know, just things that I don't hear them say normally that I felt like they were accessing something we have learned in science to add it to their pumpkins story. (Teacher interview 11/9/12)

In this example, Mrs. Martin was excited to see the students take some of the language they had learned and used in science and apply it to another context.

Another example occurred during an observation in her room. A small group of students were working at an observation station during reading time. They had been given magnifying glasses, specimen jars with dead butterflies, and some gourds. The purpose of this station was to get students using the language they had learned in their life cycle unit. In this excerpt, the same three boys from earlier (Kyle, Carl, and Matt) are talking about the dead butterflies in the specimen jars.

> **Kyle:** It's got scales on it.
>
> **Carl:** Is it dead?
>
> **Kyle:** Mine has scales on it.

> **Carl:** Mine too. Yeah I see the scales. Look at its eyes. Knock the butterfly over and look at its eyes. I already knocked my butterfly over. I already knocked my butterfly over.
>
> **Kyle:** Wait Matt I can see its head.
>
> **Carl:** That thing is dead. That thing is dead.
>
> **Kyle:** Mine is dead. I could look upside down.
>
> **Carl:** A painted lady butterfly is dead.
>
> **Kyle:** 'Cause he can't breathe.
>
> **Matt:** No, there are holes in there so he can breathe. It's asleep.
>
> **Carl:** No, I covered up the holes.
>
> **Matt:** It's asleep.
>
> **Carl:** Oops, I covered up the holes.
>
> **Kyle:** You can't cover up the holes like this or they can't breathe. (Student Conversation, 10/31/12)

What is important to understand is this segment of the conversation is not guided by a teacher. The students are simply exploring and talking amongst themselves. In this conversation, the boys are having a discussion about the visible characteristics of the butterflies in the specimen jars and trying to decide if the butterflies are alive or dead. They are using words like scales, eyes, head, and painted lady butterfly they had learned in previous science lessons. They are also supporting their thinking with evidence as to why they think it is alive or dead. What is interesting about the conversation is how naturally the science language became part of their discussions in the classroom. In our interviews, Mrs. Martin said this happened frequently over the course of the study where students applied the language they learned naturally in conversations with each other.

Mrs. Martin also mentioned how she was beginning to see students applying skills across other areas and becoming more engaged in their own learning. During one observation, the students were working on an informal assessment of their life cycle unit. Students were given a blank life cycle of an apple and asked to place it in the correct order. This was a new task in that the students had not learned the life cycle specific to an apple. Mrs. Martin's objective was to see if they would transfer what they learned about life cycles to this task. Figure 12 is a photograph of a completed life cycle. From the image, the student transferred the skill of adding labels from her science notebook sketches to this task. While this is only one student's work, many of the students had successfully completed the informal assessment as I walked around.

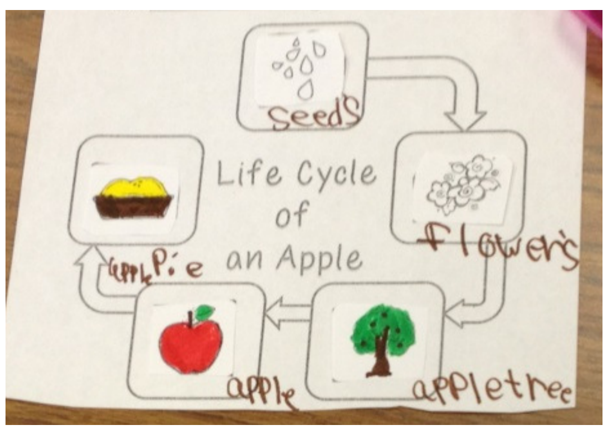


Figure 12 Student Apple Life Cycle Work Sample

In her final interview, Mrs. Martin shared a story that occurred when she had given her students their monthly writing prompt focused on space and the solar system. This was not a topic they had worked on as a class, but they had visited the school's Building Understanding Zone (BUZ room) where they rotated through various stations on space. Mrs. Martin explained,

> And I've noticed lately them really using the things in their book boxes as a resource. I can't think of what we're doing yesterday… It will come to me in a minute…We were doing something that one of the kids said, 'I need to use my book box and get some… ideas and knowledge from my book box.' And we all kind of giggled and somebody goes, 'There is knowledge in your book box.' I mean it was so priceless. It was like that sense of but something I need to know is in my book box can I go get it… Like that's what I love is that they are starting to use resources to learn. (Teacher interview, 12/20/12)

She went on to explain how the student had realized he had a book in his book box on planets so he wanted to use it to help him with his writing prompt. It was instances like this one that supported the theme of increased student learning and engagement. In all of the above examples, the students were focused on their learning and applying their knowledge in a variety of contexts.

Tensions

Another area that emerged from the data was the tensions that arose with regards to integration of literacy and science/engineering. The initial research question used the term barriers, but I changed it after analyzing the data. Looking through the codes that related to barriers, the codes more closely related to tensions than barriers because they did not prevent the teacher from integrating. Overall, the tensions that appeared throughout the data were grouped into two themes: 1) impact of logistics of curriculum integration and 2) impact of teacher confidence of methods, influence, and implementation.

Impact of logistics of curriculum integration

The first tension that emerged from the data focused on logistics relating to curriculum and content area integration. This included data relating to the amount of time required to plan and prepare for integrated units and district curriculum expectations. These types of tensions were found in Mrs. Martin's interviews, observations, reflections, and even in student comments.

At the beginning of Mrs. Martin's engineering unit, she shared with me her thoughts on planning for the unit. When we initially sat down to talk, she told me how she came in over the weekend to quickly plan the upcoming engineering unit. However, as she planned, she continued to find resources to pull in and ways to expand the unit. She explained,

> I guess I really thought this was going to be oh we'll get to this in two weeks and then I kept thinking of ways to tie in… It was the whole integration thing that created the unit. Like 'How can I try this in? How can we write about this? How we can do prompts about it?' And then I started there and then I needed books. And I was like 'what am I to do with the books I can't just have the books'. So I was like well… And then pretty soon it was like this big giant thing I have observation stations and… Which is great but it wasn't what I intended when I started. So this will need to be modified a little bit too. (Planning session 11/12/12)

In this example, there are two important ideas emerging. First, Mrs. Martin was beginning to see how seamlessly integrated her units could be because each lesson built off a previous one. Her comment of "I kept thinking of ways to tie it in" shows her excitement toward the integration process because she is beginning to see how she used reading and writing as tools to help her students get deeper into the science. However, the tension arose as she began to get absorbed in the planning and gathering for the unit of study. As she continued to see how the lessons fit together, she began to realize the significant amount of time it took to plan a seamlessly integrated unit. Once Mrs. Martin realized all the possible connections that could be made when developing an integrated unit of study, the tension appeared as a result of the increase in time commitment needed to plan.

Students also seemed to be aware of this tension regarding the time commitment integration takes. During one of the informal student conversations, I visited with two female students as the class had just finished listening to a read-aloud story comparing submarines and submersibles. We were talking about why Mrs. Martin decided to read a nonfiction text on submarines during reading time and not during science time. Ashley (African American/attendance area student) second grader responded by saying,

> I think because to try to figure out the difference probably because if we didn't have enough time. We would only really have a minute till dismissal. We would have to hurry and read the book and so we could figure it out." (Student conversation, 11/27/12)

From this comment, the student realized the need to spread out their learning during the day. The comment of "we would only really have a minute till dismissal" shows the student also felt the pressure on the class to get things done. This pattern of tension regarding the amount of planning continued to appear in Mrs. Martin reflections on the preparation for her lessons.

Another tension relating to logistics connected to the need or concern to use the district-purchased curriculum materials. Mrs. Martin did have some flexibility with curriculum as a result of teaching in a STEM-focused building and having two grade levels in one classroom. However, she still felt the pressure of ensuring she was following the district curriculum. During one of our initial planning sessions, I asked Mrs. Martin where her literacy ideas were coming from and if they were connected to the district curriculum. She responded, "No, none of these are out of *Good Habits Great Readers.* I don't know how much we want to emphasize that. It's the first week I've done it but I'm like I need to fit science in where I can and it doesn't fit anywhere else" (Planning session, 10/22/12). This comment shows the tension Mrs. Martin feels by stepping away from the district curriculum to pull in more science instruction. She felt pressured to continue to use the current curriculum but she also wanted to begin to try more integrated units of study.

In another one of our interviews, Mrs. Martin explained how she was trying to connect her lessons with the objectives of the district curriculum. She explained, "I would look at the topics in *Good Habits Great Readers* and try to make sure I was doing those topics in writing no matter what my writing prompts or projects might have been" (Teacher interview, 10/26/12). This comment indicates she was still reflecting on how her instruction connects to the district curriculum materials and her intention to follow district expectations.

Impact of teacher confidence of methods, influence, and implementation

Another tension theme due to integration related to the impact of teacher confidence of methods, influence, and implementation. This theme included uncertain teacher expectations relating to student performance and integration process, the balance between planning fun integration activities versus purposefully planned integration experiences, and the teacher's struggle with whether students or methods impacted achievement.

From the beginning of the study, it became clear Mrs. Martin was a little unsure of what integration would look like in her classroom. During one of our initial planning sessions, she initiated the conversation by sharing how she still did not understand what this process would look like regarding the research and her integration. She described her lessons using general terms and said things like "I'm still not sure yet" when we first started meeting. Reflecting on this tension at the end of the study, Mrs. Martin explained,

> I think there was a part of me that was like, 'I'll know I'm switching grade levels, I have a split, I don't know the curriculum, what on earth am I thinking? This is not the year to try something new.' But then I'm kind of adventurous and that way with my teaching and I'm also like 'it is the perfect year because I don't know any better. And I don't have a routine'. (Teacher interview 12/20/12)

From this reflection, it seemed Mrs. Martin had felt a little unsure about what the research process would look like in her classroom. She also mentioned how she still was not sure exactly what to expect from primary students because of her previous years as an upper elementary teacher. She shared this several times during our interviews and planning sessions through comments like, "I didn't really have expectations so I shouldn't have been let down" (Teacher interview 12/7/12).

Another tension Mrs. Martin seemed to struggle with the types of activities she should be integrating into her lessons. During her life cycle unit of study, she was explaining to me a craft activity she found online where the students would use a variety of materials to make a three-dimensional life cycle of a butterfly. During the planning session, she talked about all the crafting and construction that went into the project. Then, she mentioned how she wanted to limit how many materials they had, so the students did not worry so much about the craft side of it and forget the science side. This tension appeared more frequently around the holidays. For example, around winter break, Mrs. Martin explained how she wanted to share *Polar Express* (Van Allsburg, 1985) with the students. During one of our planning sessions she was telling me about various polar animal lessons she was planning on implementing. She explained, “I mean we’re focusing on polar because that makes sense with Polar Express” (Planning session 12/10/12). This comment demonstrates Mrs. Martin’s desire to pull in fun, crafty activities. However, she also acknowledged these activities were more for fun than purposefully planned lessons. Overall, in each of these examples, Mrs. Martin was struggling with the balance between fun activities that are often done with first graders related to the science content versus purposefully planned activities designed around the theme of the science or engineering unit.

Finally, another tension that emerged from the data was her uncertainty of whether it was her teaching or her students’ abilities that encouraged their success. Several times during our interviews and planning sessions, Mrs. Martin made reference to her class as “not a typical class.” Because her class was composed of higher literacy ability first and second grade students, the question arose whether it is it her teaching or the students' current abilities that were making integration a success in her classroom. Several of the families in her classroom had also been admitted to the STEM program as part of the lottery process, indicating they were purposefully choosing this program for their students. During one of our interviews, I asked her to share her thoughts on a similar subject. I asked if it was her students or her high expectations that led to student success and to integration success in her classroom. She responded that having a class with more struggling students should not mean you cannot integrate. She explained, "It's just going to change what our integration looks like. For this class (her class), I really think it is both" (Teacher interview, 11/2/12). In other conversations with her, she explained how it had to be a combination of both the effectiveness of her instructional methods and her students' abilities that had resulted in successes. However, even having stated that, she continued to reflect on that tension throughout other interviews and planning sessions.

Summary

The purpose of this study was to understand better the literacy practices and strategies that take place during science and engineering time for one primary classroom. By examining the literacy practices in science and engineering, this study provided insights into the process of integration one classroom teacher applied to make learning more connected in her classroom. This chapter described the context of the study, the findings from the data analysis, and the themes that emerged for the teacher and students.

This study took place in Bowling Elementary, a public elementary school with grades kindergarten through fifth. The main participant for this study was a veteran teacher, Mrs. Martin, who had returned to the classroom with a first/second grade multi-grade after being in a different role the previous school year. The students in her classroom ranged from middle to high academic ability, according to the teacher and principal.

The two research questions guiding this study focused on the teacher methods and strategies and the student strategies related to literacy integrated with science and engineering. The teacher research question focused on her instructional methods, successes, tensions, and changes, while the student research question focused on the application of literacy strategies and use of sketches to communicate meaning.

After analyzing the data, several themes emerged relating to the teacher and student questions. Mrs. Martin frequently incorporated comprehension strategies, writing conventions, and vocabulary into authentic learning experiences for her students. She seemed to always be looking for "teachable moments" in her classroom by verbally pointing out when content connected to something else they had learned. She also used nonfiction texts and science notebooks on a regular basis as a way to get her students reading and writing about science and engineering.

Several successes appeared in the data related to the themes of teacher confidence in her practice and student knowledge and engagement. As a result of the integration of literacy, science, and engineering, Mrs. Martin became more confident in her instructional methods and constantly looked for ways to modify them and make them even better. As she worked through the planning process for her units of study, she began to see the connections among content areas and could then share those with the students. The students' knowledge and level of engagement also increased as a result of her integration. Students began to use natural comprehension strategies in other content area texts and understood the purpose for writing and reading in the content areas.

Several tensions also appeared in the data relating to the impact of logistics of curriculum integration and to the impact of teacher confidence of methods, implementation, and influence. Mrs. Martin was constantly reflecting on her implementation of the district curriculum and expressed concerned she was not able to address some of the objectives through integration. She also felt stressed with the amount of time it took to plan and implement a tightly integrated unit. Finally, she frequently mentioned her struggle to identify the degrees to which her instructional methods, or the students' high academic levels, or a combination of both, led to the successes with integration.

When focusing on the students' strategies and use of sketches, two themes emerged from the data. It became clear that students were beginning to make connections between content areas with regards to literacy strategies. They understood why a scientist or engineer would need to read a book, write down facts, or draw sketches of objects. They also demonstrated an understanding of the role of pictures and sketches in communicating content area knowledge. Frequently, students would refer back to their sketches and drawings to continue to build on their knowledge as the units progressed.

Overall, the process of integration seemed to be a complex, challenging process leading to many successes and tensions for the teacher. However, the positive changes in the teacher's self-efficacy, students' achievement, and students' engagement seemed to outweigh by far the challenges in the eyes of the teacher. By the end of the study, Mrs. Martin was pleased by the way it concluded and she planned on continuing to implement the methods and strategies in future units of study.

Chapter Five: Summary, Implications, and Interpretations

This final chapter provides a brief overview of this study including the purpose of the study, the procedures used, and a discussion of the findings. It also provides key insights gained from this study, as well as implications for the classroom, for teacher education, and for further research.

Purpose of the Study

The purpose of this study was to examine how one primary teacher integrated literacy into her science and engineering. It also looked at how her students used strategies and sketches to help them better understand the science and engineering content. The following questions guided this study:

Research Question 1: How does a first/second grade teacher integrate literacy strategies and practices within the context of science and engineering units?

Sub question 1: How does she use reading and writing instructional practices as tools to teach science and engineering?

Sub question 2: What are her successes?

Sub question 3: What are the tensions?

Sub question 4: How does she change over the course of the study?

Research Question 2: How do the students incorporate strategies into their science and engineering work?

Sub question 1: What literacy strategies are the students applying in their science/engineering conversations and discussions?

Sub question 2: How are the students using pictorial representations to communicate meaning?

Summary of Procedures

This research was designed as a qualitative case study of one primary elementary school teacher and her class. Data were collected using nine different methods: teacher interviews, classroom observations, student work samples, teacher planning pages, collaboration sessions, teacher reflective journal, researcher journal, and student informal conversations. Data analysis methods were borrowed from grounded theory to identify themes relating to the research questions, including two rounds of initial descriptive coding, categorical coding, and theme development. As the researcher, I played the role as participant observer (Ely, 1991), working as an instructional coach in the school where I collected the data. Peer debriefing, prolonged engagement, triangulation, and rich, thick description were used as provisions for trustworthiness.

Findings and Discussion

While some teachers focused less on inquiry as they tried to prepare students for high stakes testing, many educators are beginning to revisit using inquiry. Harste (2001) provided an insight into what exactly inquiry looked like in education. He said,

> Education as inquiry means rethinking reading, rethinking writing, rethinking classroom management. Reading as inquiry, for example, is very different from reading as comprehension. While reading as inquiry still focuses on making and sharing meaning, it goes further. The meaning we make has to be used as a metaphor to deepen understanding and make sense of some other part of our lives or world. This is 'the inquiry,' the search for ever broader connections. Writing as inquiry means writing as a tool for thinking rather than as a skill to be mastered. Writing as inquiry

> means using writing to establish one's voice, distance oneself from experience, observe the world more closely, share one's thinking with others, strategically search for patterns that connect, present what one has learned and reflectively take new action. (p. 3)

This description closely aligns with the findings from this study, in that the teacher and students in this first/second grade classroom learned how reading and writing could be viewed as practices of scientists and engineers. The following discussion provides an overview of the findings and how the themes relate to the current literature. The section is organized by the two main research questions (teacher and students) that guided the study.

Teacher Findings

The first research question of this study focused on the teacher's methods, successes, tensions, and changes relating to her integration of literacy, science, and engineering. From the data, a total of eight themes emerged relating to these four areas. The following discussion will highlight each area, its themes, and their connections to the literature.

When analyzing the data looking for teacher methods, two themes emerged. In this study, Mrs. Martin found teachable moments throughout her day and purposefully pointed the connections out to her students. By noticing and identifying these connections, she taught the students how to transfer skills from one area to another. Mrs. Martin's students noticed the connections and developed identities as readers, writers, scientists, and engineers because of the purposeful language of the teacher. Johnston (2004) discussed the importance of helping develop students' identities through purposeful teacher language. Through using language like “writing like a scientist,” Mrs. Martin helped the students develop their identity as scientists. She also referred to the scientist by making statements like “Oh good. I see I have good future scientists” (Observation notes, 12/11/12). Also, by pointing out connections during lessons and providing students with explanations of how scientists and engineers use reading and writing, Mrs. Martin helped her students understand how their learning is connected throughout the day.

Lantz (2009) would describe this process as helping the students develop a holistic understanding of the world. In Lantz’s view, teaching students how to connect their learning is a key component in STEM education. This process of making connections can also be referred to as “intertextual ties” (Shuart-Faris & Bloome, 2004). Mrs. Martin helped students make connections between things they learned in science and what they read and wrote about. As a result, the students gained a deeper understanding of each of these experiences because they could see how the experiences connected. For example, by understanding how to construct a submersible through hands-on experiences, students better understood the difference between a submersible and submarine when they read a nonfiction text introducing the two objects. The experiences in one content area helped them better understand another area.

Adding to the research on the impact of integration of content areas (Kelley, Brenner, & Pieper, 2010; and Van Meeteren & Escalada, 2010) findings in this study supported the idea that integration of learning across content areas had a positive impact on student learning. In this study, Mrs. Martin worked towards integrating literacy into her science and engineering times with the hope that it would increase the learning of her students. By the end of the study, Mrs. Martin felt she accomplished that task because she found her students highly engaged in their learning and noticed connections where they applied something they learned to a new context.

The second theme related to teacher methods included the purposeful integration and use of science notebooks and nonfiction texts. In this study, Mrs. Martin included science notebooks as a way for her students to document their learning and to create a resource that could be returned to later. The use of science notebooks in classrooms has been supported by past research (Fulwiler, 2011; Gallas, 1994). Mrs. Martin used their science notebooks as a way to encourage her students to write about science in meaningful ways. Larkin-Hein (2001), McKenna & Robinson (1990), and Jacobs (2002) all describe the important role writing plays in learning. By asking students to write about their learning, students are required to process what they have learned and put it down on paper. In this study, Mrs. Martin had her students recording in their science notebooks daily as they were engaged in their science and engineering learning. They used their notebooks as a place to record their thinking and data so they could return to it later.

Another strategy Mrs. Martin frequently used was the integration of nonfiction or informational texts into her science and engineering time. She would often use these texts as a way to introduce new ideas and vocabulary to her students. The use of information texts in classrooms has been supported by many researchers and practitioners (Hammond & Nessel, 2011; Fetters, Ortlieb, & Cheek, 2011; Duke, 2004; Heisey & Kucan, 2010). Many of these previous studies found the use of informational texts to be beneficial to students and to increased their science learning (Heisey & Kucan, 2010;

Fetters, Ortlieb, & Cheek, 2011). Mrs. Martin found her students became more engaged in their science learning and returned to the shared texts during other times of the day to read more.

The successes found in this study included both teacher and student successes. At the conclusion of the study, Mrs. Martin felt confident in the ways she was integrating her lessons and units of study. She even began looking for other ways to continue and to improve her integration practices, including the use of more nonfiction texts during guided reading time. In addition, she also considered using more nonfiction when teaching the craft of writing by looking at what those authors used for word choice and details. Duke (2004) supported this increased use of nonfiction titles in classrooms as a way to help students learn the strategies necessary to comprehend these types of texts.

In addition to the teacher successes, Mrs. Martin also noticed successes relating to an increase in her students' knowledge and engagement. Other researchers found similar successes in their studies on the integration of content areas (Becker & Park, 2011; Guzzetti & Bang, 2010; Connor et al., 2010; Lutz, Guthrie, & Davis, 2006. Becker and Park (2011) found higher effect sizes for students who were taught through integrative approaches. In many ways, the methods Mrs. Martin was implementing were similar to these integrative approaches. She taught students how to make connections among content areas, to apply skills they learned throughout the school day, and to use reading and writing as tools to help them better understand science and engineering.

In contrast to the successes Mrs. Martin found with integration, two themes related to tensions also appeared in the data. These tensions resulted from a range of factors, including the significant amount of time and planning that went into developing the units, pressure to implement district curriculum, the teacher's perspective of what integration would look like, and the degree to which students or teaching methods resulted in the successes. While each of these tensions appeared in the data, the tensions related to Mrs. Martin's confidence in her methods, influence, and implementation appeared most frequently.

One of the tensions that appeared in this study was Mrs. Martin's uncertainty about which factor (student ability or teacher method) most resulted in the successes. She recognized her class was constructed with students who were of average to high ability level in literacy and had highly involved parents. She also acknowledged her excitement and high expectations she had going into the year. From her statements, it seemed she believed both factors played a similar role with regards to impact on successes. However, she questioned whether the integrative approach would have the same positive impacts on a different group of students. This tension connects to the common stereotype that children in poverty often have low academic performance. However, the successes her class had with 50% of the students labeled minority and 75% of the students receiving free or reduced lunch indicated this stereotype is not necessarily true. Mrs. Martin approached the year with high expectations as a result of having taught older students. She also looked at the composite of her classroom reading literacy abilities and determined they could learn quickly. While she believed both factors (student ability and teacher method) played a role in the students' successes, she still questioned how much each factor impacted the success.

The last two themes related to the first research question focused on teacher change. Over the course of the study, Mrs. Martin demonstrated a significant amount of change in her self-efficacy, her planning, and her implementation of integration. While her change in her confidence and self-efficacy was apparent, the greatest change occurred in how she developed and implemented her lessons. Initially, Mrs. Martin began integration by pulling in small lessons throughout her day. For example, she incorporated an observation station into her literacy block as a way for students to explore and write about a science topic. Van Meeteren and Escalada (2010) implemented something similar in their classrooms through the use of science centers to build science knowledge. In both these science centers and in Mrs. Martin's observation station, students were engaged in hands-on learning that encouraged their use of science vocabulary and writing about what they learned.

Towards the end of the study, Mrs. Martin's planning became more purposeful and meaningful and the integration was more seamless instead of fragmented. Instead of selecting an assortment of integrated activities, she designed an entire integrated unit with hands-on activities, purposefully planned science notebook entries, and supporting nonfiction texts. Figure 13 shows a continuum I developed to help describe the range of integration planning resulting from the findings from this study. The left side of this continuum begins with planning that includes instruction focused on reading, writing,

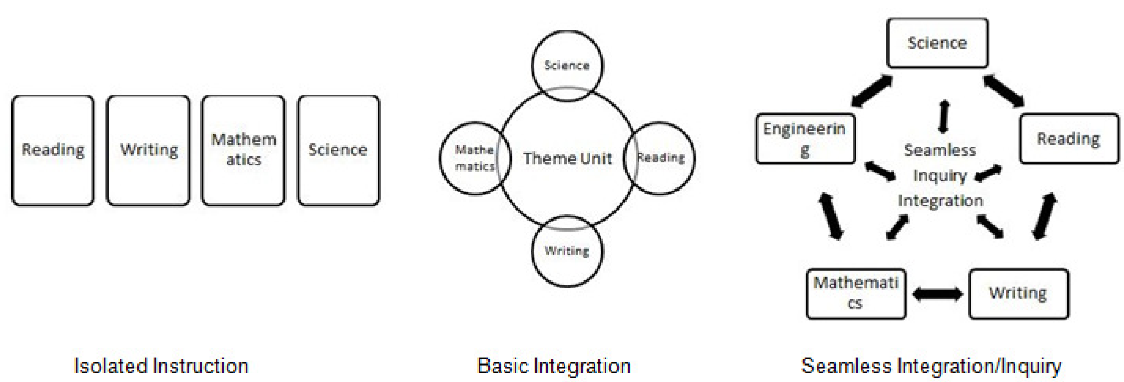


Figure 13 Integration Planning Continuum

mathematics, and some science when possible. I've labeled this side of the continuum "isolated instruction" because instruction in each of these areas is not connected. As a teacher begins to become more comfortable integrating, planning moves from isolated instruction towards a unit of study designed around a central theme (which I have called "basic integration"). However, what is important about this second stage in planning is the content area lessons do not connect to each other, only to the central theme.

On the far right of the continuum is what I call "Seamless Integration/ Inquiry". At this point, planning is connected at all points and content areas. Lessons in science lead to and are impacted by lessons in reading and writing and vice versa. The inquiry is the focus, instead of the subject. For example, Fulwiler (2011) described a writing and science approach where science sessions are followed by a writing session where students are learning writing skills needed for scientific writing. Additionally, Short and Burke (2001) described a similar view on integrated curriculum by outlining three different perspectives on curriculum. According to them, curriculum as inquiry can be understood using Figure 14. It is a curriculum that is developed that "cuts across three knowledge

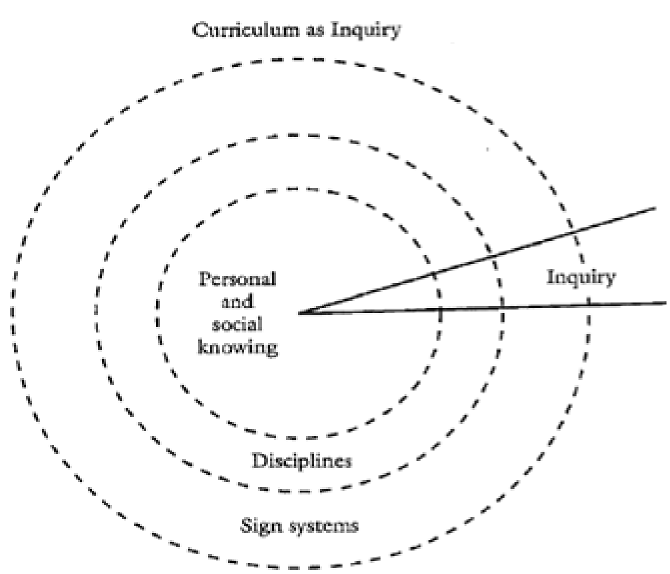


Figure 14 Short & Burke (2001) Curriculum as Inquiry

sources – personal and social knowing, knowledge systems, and sign systems" (p. 32). Personal and social knowing refers to prior knowledge. Knowledge systems refer to the disciplines while sign systems refer to alternative ways of understanding and creating meaning.

In this study, Mrs. Martin's planning moved along the continuum and moved towards curriculum as inquiry as she became more comfortable and confident with integration. She initially approached integration similar to the middle "basic integration" stage. However, as the study continued she began to move closer to the seamless integration/inquiry stage. For example, when she described planning her engineering unit, she commented on how she continued to think about how she could pull things in and how they connected to each other. These comments demonstrated her move towards the left end of the continuum and a move towards using inquiry to guide her thinking and planning.

Heisey and Kucan (2010) also indicated positive outcomes in their study on the use of carefully planned read-aloud texts connected to science concepts. By purposefully choosing nonfiction texts that introduce science concepts and new vocabulary, students began to connect what they were learning to what they were reading. In Mrs. Martin's room, the integrated units with the purposefully planned nonfiction texts allowed her students to see the content connections throughout the day. They began to understand how reading the books, writing in their journals, and doing the hands-on activities were all connected and related to each other, and, more importantly helped them learn science concepts.

Student Findings

The second research question of this study focused on the students' connections among content areas and the use of pictures and sketches to communicate content understanding. After data analysis, two themes emerged: student connection among content areas with regards to literacy strategies and students' purposeful use of sketches to communicate content area knowledge. The following discussion compares the findings from this study with the review of the literature related to student content connections and the use of sketches.

Lantz (2009) described STEM education as a way to help students make sense of the world holistically instead of in smaller pieces. One of the themes from this study indicated the increasing ability of Mrs. Martin's students to apply comprehension strategies when reading nonfiction texts in science and engineering, to apply science vocabulary in new contexts, and to use spelling strategies to help them write words in their science notebooks. By taking the skills they have learned in one context and applying it to another, the students are demonstrating a more holistic view of learning. Again, Mrs. Martin was using intertextual ties (Shuart-Faris & Bloome, 2004) to make both topics more meaningful to the students. In other words, they understand how the skills transfer across content areas and are not isolated to only reading time or only science time.

Students also learned how literacy skills could help them become better scientists and engineers by using reading and writing as tools. Warren (2013) adds to the use of reading and writing as tools by defining the difference between students learning a strategy and learning a practice. According to Warren, a strategy is a tool that is used to make meaning and “practices are more like habits, routine activities that are essential components of an area of knowledge” (p. 395). In other words, when students began to see reading and writing as practices, they began to understand the bigger picture of how reading and writing were tools to learn other content areas. Mrs. Martin’s students were beginning to see reading and writing as “practices” of scientists and engineers rather than just a strategy used in certain situations. For example, when talking to the students they would tell me they were drawing and recording in their science notebooks because it is what scientists do. They saw themselves as scientists and understood the need to use writing and sketches as a practice to help them understand the science.

Another significant component of this theme of applying skills across content areas was the frequent opportunities to use talk as a class. Chapin, O’Connor, and Anderson (2009) explained the role dialogue and discussion plays in helping students make connections. By allowing students to ask questions, share their thinking, and defend their ideas, Mrs. Martin provided her students with the necessary opportunities to make connections and therefore to gain a deeper understanding of what they were learning.

The second theme focused on the students’ use of sketches to communicate what they had learned, also known as “transmediation” (Suhor, 1984). McCormick (2011) and Ozsoy (2012) all believe the use of sketches helps students create a deeper understanding of the content because they have to transfer their knowledge into a different sign system such as drawing. When students take a concept such as the life cycle of a butterfly they learned in a book and draw it on paper using sketches, they must take what they learned through written text and express it using drawings. This process of transmediation requires the students to have a deep understanding because they shared what they learned in a different sign system.

In this study, Mrs. Martin frequently used transmediation when she asked her students to draw sketches of the things they learned during science and engineering. She also encouraged them to use labels to help them remember what they had drawn. Platt (1977) supports the use of labeling because it helps teach children the association between oral language and written language. By having her students attach labels to their drawings, Mrs. Martin helped her students make the connection between the vocabulary they were learning and the images they were drawing. In addition, the use of sketches and writing to communicate their science learning allowed students to represent their understandings using multiple sign systems. Short, Harste, and Burke (1996) support the use of sign systems to help students create a deeper understanding of a concept. They explain the use of multiple sign systems in an inquiry classroom develops a "multiple ways-of-knowing curriculum" (p. 289). Through sketching and writing, students learned how to understand science and engineering through multiple sign systems.

Implications

This study provides insight into one classroom teacher's experiences with integration of literacy, science, and engineering. While the findings from this study cannot be generalized to all classrooms, it does provide some insights to educators attempting to accomplish similar types of instructional change. I learned much from my experiences in Mrs. Martin's room that provide important implications for other classrooms, teacher education, and future research. By the end of the study I found my view of integration had also changed and developed, just as Mrs. Martin's had. I initially went into the research expecting to see Mrs. Martin selecting activities that fit her theme, but I did not have the bigger picture of true inquiry in my head. However, by the end of the study, I began to see integration as a seamlessly designed unit where content area lessons both support and build on one another.

Implications for the Classroom

The success of Mrs. Martin's classroom, which was composed of 75% free and reduced lunch and 50% minority students, demonstrates the positive impact of a purposefully integrated curriculum on student learning. While findings from this study cannot be generalized to state that all minority students of poverty will show similar success with an integrated curriculum, it does provide important insights for classroom teachers including a focus on nonfiction, a development of scientific and engineering practices in students, and the importance of professional development.

Focus on Nonfiction

One implication for classroom teachers is the power of focusing on nonfiction reading and writing in primary classrooms. One of Mrs. Martin's strategies for integration was to select nonfiction titles that connected with her science and engineering units. She looked for books that went beyond what they had already learned and introduced new vocabulary for the students. As a result of this, her students began to see books as a source for information. More importantly, her students began to understand the purpose of reading was to make meaning and that they were to learn something from the texts. Frequently during her lessons, she would introduce a book and read a portion of the text to the students. Then, she would remind the students the text would be available to them in their classroom library during the day. This use of nonfiction texts taught her students a powerful lesson…that books can be read more than once for various purposes. Students developed the belief that learning continues all day long and not during science time or reading time.

In addition to the use of nonfiction reading, Mrs. Martin placed a focus on nonfiction writing through the integration of science notebooks. During every science and engineering lesson, students were asked to record their learning through words and/or drawings. These writing experiences taught her students how to apply their writing skills to another context. Students saw writing not as a subject area itself, but as a tool that is used to document and communicate their own learning in all areas. In short, the type of authentic reading and writing opportunities created with nonfiction allowed her students to apply skills across content areas. These experiences provide support for the belief that teachers should give students opportunities to read and write across all content areas.

Transition from Strategies to Practices

Probably the most powerful thing that came from my time with Mrs. Martin was the change in her students' use of and understanding of the application of literacy strategies. By the end of the study, Mrs. Martin's students saw how their reading and writing strategies were also practices of scientists and engineers. The students viewed their science journals as resources and referred to them throughout the day when they needed information on something they had learned, similar to the way scientists use their journals. Students also recognized the purposes of reading and writing and how to use those tools to communicate. They frequently talked about how scientists and engineers read to learn facts and write to remember what they have learned. Through these discussions, students continued to develop the understanding of how reading and writing are practices of scientists and engineers.

This is an important implication because of the new Common Core State Standards in Literacy (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) and the Next Generation Science Standards (National Research Council, 2013) that have been developed for classrooms across the nation. Each of these standards emphasizes a deeper student understanding of content and application of strategies as practices. The Common Core State Standards for Literacy focus on preparing students who are college- and career-ready. According to the developers of the standards, students who are college- and career-ready exhibit the following characteristics: “demonstrate independence, building strong content knowledge, respond to the varying demands of audience, task, purpose, and discipline, comprehend as well as critique, value evidence, use technology and digital media strategically and capably, and come to understand other perspectives and cultures” (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). In Mrs. Martin’s class, students began to develop these characteristics as they learned to support their claims in discussions with facts from the text, developed deeper understanding of the science content through reading and writing, and applied their natural comprehension strategies in new contexts.

The Next Generation Science Standards outline eight science and engineering practices students should develop, which include: asking questions (for science) and defining problems (for engineering); developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematics and computational thinking; constructing explanations (for science) and designing solutions (for engineering); engaging in argument from evidence; and obtaining, evaluating, and communicating information (National Research Council, 2013). Students demonstrated a beginning application of these scientific and engineering practices during many of the science and engineering lessons. For example, when students tested items to determine if they would sink or float, they were asking questions, developing models, planning and carrying out investigations. When they developed their rule for whether an object would sink or float they were also constructing explanations, engaging in argument from evidence, and obtaining, evaluating, and communicating information. This engineering lesson was just one of many where the students were engaged in the eight scientific and engineering practices. Mrs. Martin also helped her students develop these practices by teaching them to use the strategies they were learning, such as notebooking and documenting their thinking, as practices of scientist and engineers.

Mrs. Martin's practices can be instructive for classroom teachers as they continue to help their own students develop these practices by making connections across content areas. First, as she thought about and planned her units of study, Mrs. Martin looked for authentic learning experiences for her students. Her science lessons provided a variety of hands-on, engaging activities in which students explored and talked about the topic. She also selected nonfiction and fictional texts that deepened their understandings of the science or engineering concept while also expanding their vocabulary. Finally, she planned authentic writing opportunities with their science notebooks in order to engage students in writing about what they were learning.

Additionally, Mrs. Martin made use of intertextual ties through talk and modeling how strategies could be applied across content areas for her students. While reading a text to introduce a topic, she often pointed out the specific text features or author's craft to the students. This type of "noticing" or verbal modeling taught the students how to apply what they were learning in reading (text features) in a new situation (science lesson). She would also seamlessly integrate word study and spelling patterns into the science whole group writing activities. When she came to a word that included a spelling pattern they had learned, she pointed it out. There was rarely a moment during the lesson where she would skip the opportunity to make a connection to something they had learned. She was purposeful in using her specific language to notice and name instances where there were content connections. Overall, the importance Mrs. Martin placed on sharing content connections with her students demonstrates the power that purposefully planned and integrated lessons had on helping students begin to understand how reading and writing strategies are also practices used by scientist and engineers.

Professional Development

Outside of instructional strategies and methods, this study also provides some insights into professional development and classroom support for teachers. During the study, I met with Mrs. Martin on a frequent basis to discuss observation plans and lessons. Reflecting on the impact that I had being in her classroom, she shared the importance of having someone else in the room to collaborate. In her final interview, she explained how often times classroom teachers are "on an island by themselves" when they are teaching, making it is harder to reflect. She mentioned how she enjoyed having an outside person there to talk to, ask questions, and provide support. Mrs. Martin's feelings regarding classroom support indicates the need for continued professional development and collaboration opportunities for all teachers.

My role in this study was a participant observer because of my role at this school. During times when I was not collecting data, I served as an instructional coach for all teachers in the building. My role as an instructional coach impacted the study because the support I provided could be personalized to the needs of Mrs. Martin and the other teachers. I was a member of this school which allowed me to gain a better understanding of what support the teachers felt they needed. Even amongst this "normal" support system, it seemed Mrs. Martin felt even more supported by my presence in the classroom. Meeting and visiting with her several times a week allowed her to reflect on her instructional methods and students' academic progress. One way to accomplish this on a regular basis in other elementary schools might be through peer coaching and mentoring. While the degree of support might be slightly different in traditional school settings, this study shows how in-class support through a peer teacher can have a positive impact on both the teacher's confidence and instructional methods.

Another implication that came from this study was the need for collaboration among staff at the school during a curriculum change. During several interviews, Mrs. Martin mentioned the knowledge she gained when sharing her instructional strategies and experiences with others. She mentioned how powerful it would be for the school if teachers could have more opportunities to get together to share and collaborate. Changing instructional practices is a difficult thing to do as reflected in some of the tensions from this study. As a result, any additional support classroom teachers are given through in-class support and/or opportunities to collaborate with peers help to make the transition a smoother one.

Finally, this study demonstrated the importance of supporting teachers as they create and develop authentic learning opportunities using more nonfiction reading and writing in the primary grades. From the successes she had during science and engineering time, Mrs. Martin realized the power that came from using nonfiction texts as mentor texts. She began to look for more ways to pull in nonfiction texts into her shared reading and guided reading times. For many years now, teachers have become comfortable teaching writing and reading through fictional texts. However, the new Common Core State Standards (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) are putting an increased emphasis on integrating informational texts into classroom instruction. Table 7 shows the percentage of each type of text that should be used in classrooms in grades 4, 8, and

Grade	Literary	Informational
4	50%	50%
8	45%	55%
12	30%	70%

Table 7 Uses of Genres in Grades 4, 8, and 12

12. In elementary schools, this means classrooms will need to begin integrating more information titles. The only way for this to happen is to provide teachers with quality professional development and the necessary support to learn and try these new strategies. This might include offering teacher sessions that introduce quality nonfiction picture

books to use as mentor texts or to include in their classroom library. Teachers could also attend professional development sessions that focus on how to use an information text as a mentor text and what teaching points could be taught with that genre. Whatever the focus of the session, it is important for teachers to begin to look for more ways to pull informational and nonfiction texts into their classroom instruction.

Implications for Teacher Education

Findings from this study also provide important insights for teacher education programs with regards to curriculum and content. Mrs. Martin's focus was to begin the process of integrating literacy, science, and engineering. While Mrs. Martin felt confident with integration because of previous teaching practices, it was still a challenging process for her. If new and pre-service teachers are to enter a classroom prepared to do more integration, then their teacher education programs need to focus on these areas.

First, teacher education programs need to begin or continue providing instruction on the importance of making connections across content areas. This includes applying the skills learned in reading and writing to other content areas. The focus needs to be on helping teachers develop inquiry units of study that are seamlessly integrated where reading and writing are tools to learn the science instead of thematic units that use more basic integration. Mrs. Martin accomplished this task by developing authentic reading and writing experiences for her students during science and engineering time. In a teacher education program, pre-service teachers in a field experience could teach a lesson during a content area that pulls in authentic reading and writing opportunities. When pre-service teachers have opportunities to see content connections themselves, they are more likely to help their students make those connections. For this reason, classes in the teacher education program should support and build upon one another and not isolate subjects with regards to content and instructional methods.

Second, pre-service teachers should continue to be taught how to incorporate nonfiction reading and writing into their lessons on a daily basis. Mrs. Martin's students read nonfiction books during reading, writing, science, and engineering time, in addition to writing about their learning in science notebooks. For new teachers to be prepared to incorporate some of these same strategies, teacher education programs need to teach the importance of writing in other content areas, even at the primary level. This instruction should also include a focus on the importance of talk and drawings/sketches to communicate meaning. Primary students might not have the written language abilities to fully document their understanding in words. Therefore, pre-service teachers should be taught how to incorporate talk and drawings as another form of written documentation of learning.

Finally, talk was an important component in Mrs. Martin's classroom. Johnston (2004) discussed the importance of helping develop students' identities through purposeful teacher language. Teacher education programs can help new teachers develop this understanding and skill by having them reflect on their own talk. Class conversations should focus on what teachers communicate with their words and how they say things. Instruction should also focus on how teachers can use specific language to help the students develop their own identities as readers, writers, scientists, and engineers.

Implications for Future Research

Findings from this study suggest new questions and areas of focus for future research. This study provides insights in to one teacher's experiences with integration of literacy and science/engineering. This teacher had a class composed of both first and second grade students with middle to high academic abilities. Since Mrs. Martin's class was also composed of 50% minority and 75% students receiving free and reduced lunch, findings indicate the instructional practices used with integration successfully helped her students learn. While these findings are promising, more research needs to be done to better understand similar integration practices with different teachers and different populations of students.

Additionally, this study occurred over a period of three months and two units of study. Future studies might consider collecting data for longer periods of time to look at integration practices over the course of a school year. Insights from this type of study would provide information on what integration practices look like when studying a year's worth of curriculum. Along these same lines, more research could be done to look at integration practices including literacy and other content areas, such as mathematics. Studies looking at these integration patterns could add to the findings presented in this study to provide a broader perspective of integration of literacy and content areas in the primary grades.

Finally, one tension that appeared several times during this study was the difficulty in identifying the degree to which the teacher's instructional methods or the students' abilities were the cause of the successes. While Mrs. Martin suggested the answer is probably a combination of both, future research could look into this question.

Research studies that follow the same teacher over the course of multiple years with different students would provide better insights into this question.

Final Thoughts

As research provides some findings and insights, it also raises just as many questions. The traditional method of separating content area instruction cannot continue if our nation wants to produce students who successfully problem solve and apply the skills they learned in a variety of situations. For this reason, educators need to begin to look for new instructional practices that begin to integrate skills and content throughout the day. Even at the elementary level, this becomes important because it serves as the building block for future learning. In many primary classrooms, a large amount of time is spent on reading, writing, and mathematics, leaving science as an “add-on”. In addition, very few primary classrooms even begin to reflect on how engineering should be taught at this level because of the time spent on reading, writing, and mathematics. However, this study sends a different message for primary teachers when considering the amount of reading and writing that still occurred in this classroom where the focus was on science and engineering. In fact, in many ways, the literacy was even enhanced through the focus on science and engineering. This study suggests one possible practice might be the teaching of integrated units with purposefully designed lessons, helping students move from simply learning literacy strategies to using them as scientific and engineering practices. The powerful learning that took place in this first/second grade classroom occurred not as a result of WHAT strategies and instructional methods were being used, but HOW both the teacher and the students learned about inquiry and integration through reflection. The transition from viewing reading and writing as strategies to understanding and applying them as practices moved the students from students reading and writing to scientists and engineers using literacy as a tool to learn.

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Appendix A

Becker and Park 2011: Effect Sizes for Research Questions

Grade Levels	Effect Sizes(ES)				Total # of Studies
	ES < 0.2	0.2<ES<0.5	0.5<ES<0.8	0.8<ES	
Elementary School	1		1	1	3
Middle School	4	2		3	9
High School	6	1		5	12
College	1	1	1	1	4

Table 3. Effect sizes of twenty-eight studies by grade levels

(by Grade Level)

Types of Integration	Effect Sizes(ES)				Total # of Studies
	ES < 0.2	0.2<ES<0.5	0.5<ES<0.8	0.8<ES	
E-M	1				1
E-M-S-T				1	1
E-S		1			1
E-S-T		1	1	3	5
M-S	7	1		2	10
M-S-T	3	1		1	5
S-T	1		1	3	5

E-M: Integration of engineering and mathematics;
E-M-S-T: Integration of engineering, mathematics, science, and technology;
E-S: integration of engineering and science;
E-S-T: Integration of engineering, science, and technology;
M-S: Integration of mathematics and science;
M-S-T: Integration of mathematics, science, and technology;
S-T: Integration of science and technology

Table 4. Effect sizes of twenty-eight studies by the types of integration

(by Types of Integration)

Achievement	Effect Sizes(ES)				Total # of Studies
	ES < 0.2	0.2<ES<0.5	0.5<ES<0.8	0.8<ES	
E-M-S-T				1	1
E-S-T			1	1	2
M	9	2		2	13
S	4	3	1	5	13
T	2			2	4

E-M-S-T: EMST integrated achievement ; E-S-T: EST integrated achievement; M: Mathematics achievement; S: Science achievement; T: Technology achievement

Table 5. Effect sizes of students' achievement through integrative approaches

(by Integrative Approaches)

Appendix B

Parent Consent Form

October 1, 2012

To Whom it May Concern,

I am working on my Educational Doctorate at the University of Missouri. I am working on my dissertation research that focuses on reading and writing instructional strategies of primary teachers with a STEM curriculum focus under the supervision of my advisor, Dr. Gilles. The title of this project is Literacy in Context: A Case Study of Understanding Reading and Writing Instructional Practices in an Elementary STEM (Science, Technology, Engineering, and Mathematics) School and it has an IRB project number 1204463. The goal of the research is to understand how primary teachers teach and use literacy skills and practices, more specifically in the areas of reading and writing, within a curriculum focused on science, engineering, and mathematics. You can find the details of this study below.

- The focus for this research study is to understand the literacy practices and strategy instruction of an elementary teacher at Bowling STEM Elementary School.
- Participation in this study is voluntary and you may ask for your child to be removed at any time during the study.
- Samples of your child's work will be photocopied and/or photographed to be analyzed by the researcher, Heather Lang.
- I might digitally record your child talking about the lesson with their peers.
- Participant confidentiality will be maintained during the study. All names will be changed to pseudonyms during transcription.
- Refusal to participate will involve no penalty or loss of benefits to which the subject is otherwise entitled. The subjects may discontinue participation at any time without penalty or loss of benefits to which the subject is otherwise entitled. Any data collected from participants that choose to withdraw will be identified and separated from the other data. Any identified data from discontinued participants will not be used for the research study.
- There are no foreseeable risks for participation in the study greater than those experienced in a normal school setting.
- Findings from this study will be shared with my doctoral committee, advisor, as well as other researchers and educators. Any personal information (names) will be kept confidential and known only by the researcher. Pseudonyms will be used when referencing any and all participants.
- I can be contacted at hll171@mail.missouri.edu or by phone at 573-214-3610. I am happy to answer any questions regarding the research project. My advisor, Dr. Carol Gilles, can be contacted by email at GillesC@missouri.edu and by phone at 573-882-8498.

I appreciate your support. Please read the options below and check the appropriate box.

Student Name ______________________________________

□ I give permission for my child to participate in this study. I understand that any personal information will be kept confidential. I understand that I can ask that my child be removed from the study at any time.

□ I do not want my child to participate in this study.

Parent Signature _____________________________ Date ______________

Appendix C

Observation Protocol

ID:______________________________ DATE:___5/22/12________________________

____

DESCRIPTION OF PLACE/OBJECT/SITUATION/INDIVIDUAL:

____

____

____

OBSERVATION	REFLECTION
Time Started: Time Ended:	

Appendix D

Interview Protocols

<u>October 19th Interview</u>

Guiding Questions:

- What is reading and what does it look like in your classroom?
- How and when do your students use writing in your classroom?
- How do you currently teach children to write?
- Working at a STEM school, how has your instruction or practice changed over the past year?
- What is the biggest curriculum change you and/or your school have made?
- What area of STEM Education do you find the easiest to integrate? What is the hardest? Why?
- What does integration mean to you and your instruction?
- What have you found to be your barriers to integration?
- Tell me about some effective integration strategies you have used so far?
- How can reading and writing skills be taught within the context of science and/or engineering?

Comments from Lessons

- 10/16 lesson: Is this the first time you had introduced the butterfly life cycle? If not, what was the objective of this lesson?
    - Show photo, what does this work sample/comment tell you about this child's science and literacy learning?
- 10/18 lesson: Tell me about why you chose this particular text for this reading group? What were your goals?
    - 5:45 (larvae conversation) Tell me about what happened here? Was this comment expected? What did this tell you about her science/literacy knowledge/skills?
    - 11:45 (life cycle) So you point out the wowzer box. Was this planned? What skill were you trying to teach them here?

<u>October 26th Interview</u>

Guiding Questions:

What were some of the successes you had this week with integration?
What were some of the barriers you had this week with integration?

Comments from Lessons

- Lesson 1:
    - I notice you use picture books a lot in your lessons as starters. Can you tell me a little about why you do that and your planning in selecting the text for this lesson (Venn diagram)?
    - 5:02 can you read the caption?
    - 11:00 – 12:40 prediction about page; what was your goal here? Did you want everyone to get it? What was your thought process? Did you consider coming back to that question or was it more of a connection and move on?

- 19:48 - 20:40 unsure so look it up; did you go back and look at journal entries? How did it go? What do you hope they gained from this lesson? Did you have any students add to their journals with the book during reading?
- Lesson 2:
  - 10:41-13:18 What was your goal behind drawing it again if the students already had it? What literacy skills were you purposely working on? What science content? What do you think are some of the literacy skills now? What are you thinking regarding evaluating students literacy/science skills? What is going on in your head?

November 2nd Interview

Guiding Questions:
- What were some of the successes you had this week with integration?
- What were some of the barriers you had this week with integration?

Comments from Lessons
- Measuring Pumpkins lesson
  - How did it go?
  - What was the focus?
  - Was it accomplished?
  - Have you looked at their entries?
  - What does that tell you? Literacy noticings? Book vs. writing in their journals?
- Observation station lesson – audio is 20 seconds off
  - Video 5:10
  - 7:12 (video) 6:49 (audio) – 9:10 (video)8:50 (audio)

November 9th Interview

Guiding Questions:
What were some of the successes you had this week with integration?
What were some of the barriers you had this week with integration?
Comments from Lessons
- Life Cycle Assessment
  - Photo D: What does this tell you?
  - Just from your initial informal observations…what have you noticed? You were focused on asking about 2 pumpkins…what did you find?
  - How do you think that related to integration?
  - What things would you do differently next year regarding integration and this unit of study?
- Observation station video
  - 3:15 – 5:00 What do you notice? Positives/Negatives?
  - 7:58 – 9:16 She isn't making predictions? How important is that?

    - Have you noticed other students who struggle to represent their items clearly? How do you plan on working on that? Will it be during literacy and/or science?
    - Do you think any of them have developed theories yet?

<u>November 19th Interview</u>

Guiding Questions:

- Going back to your leaf creatures? Was that developed as a connection to your life cycle unit of study or just something extra? How does that relate to your concern about integrating at end of units?
- How do you feel the KWL chart went for your ocean discussion? Have you used that to guide your discussion and/or lessons?

Comments from Lessons

- Sink or float lesson?
  - What were your overall impressions of that lesson?
  - Did you see any students who went back and revised their rule?
- Video 23:30 – 25:00
  - What successes/barriers come to mind when watching this?
  - How did this lesson impact your planning for your next unit?
  - What literacy skills did you see students using/not using?
- Audio of student conversation 11/14/12 9:38 – 10:15
  - What does this communicate to you?
  - What have they picked up? What do they still struggle to understand?

<u>November 30th Interview</u>

Guiding Questions:

- Tell me about the start of this unit. What are your thoughts so far?
- How would you say your preparation for this unit is compared to the life cycle unit?
- How do you see yourself integrating the most for this unit? What are going to be the key components?
- How do you plan on integrating science notebooks for this unit? What will their purpose be?

Comments from Lessons

- Watch 1st 3 minutes of 11/27/12 lesson
- What do you notice? What was your goal for this session? Do you feel you accomplished this goal?
- What was your thinking relating to literacy skills/strategies when planning this lesson?

<u>December 7th Interview</u>

Guiding Questions:

- What are your thoughts about your engineering lessons this week?
- If you could change one thing about how you did this unit what would it be?
- Any other comments for this week?

Comments from Lessons/Student Conversation

- Listen to beginning and end of student conversation
- Reactions?
- What literacy strategies did you notice your students applying the most? What has seemed to transfer the best?

<u>December 14th Interview</u>

Guiding Questions:

- Going back to the writing lesson I observed this week where students got to pick an animal adaptation and write about it...what were your thoughts as you planned this lesson?
- How did you feel it went?
- I noticed students ended up with one or two sentences and not a "seed". Was this the intention? How would you modify this to use it as a "seed" for a genre of writing?

Comments from Lessons/Student Conversation

- View polar bear webcam video 39-1:47 & 4:30 - 5:29
- What are your thoughts?
- How would you modify this for the next time they do this?
- What would you like to see them doing that they are not?

<u>December 21st Interview</u>

- Tell me about how the last three months have gone for you?
- How has your perspective on integration changed over the last three months?
- What has been the biggest change you have seen in your students as a result of integrating reading and writing into science/engineering?
- What has been the biggest change you have made?
- What did you find to be the most successful part of integration?
- What has been the most challenging part of integrating?
- What is the most surprising?
- If you could pick one literacy strategy that you felt was most effective for you students to learn to help understand science/engineering what you it be?
- Was there one strategy you taught over the last few months?
- What strategy did you feel was the most important in Sept and has that changed?

- What were some literacy practices you implemented that you feel were the most successful? Least?
- What are your next steps?
- What have you learned that you will take with you and build upon.
- How will you continue this process?
- Any other comments/question about this project?
- How did my being with you in your classroom impact what you taught, how you taught, and your reflection?

Final Student Interviews

- What did Mrs. Martin do that helped you learn science the most?
- How do scientists use writing? reading?
- How does writing help you learn science?
- How does reading help you learn science?
- How does engineering help you as a reader/writer?
- Do you consider yourself to be a good reader/writer/scientists/engineer?

Appendix E

Teacher Reflection Journal

Timestamp	How did you integrate literacy today?	What were the successes?	What were the barriers?	What questions do you have?	What suprised you today?	Is there anything else relating to integrating litearcy into science and engineering that you would like to add?
10/23/2012 8:02:08	This morning our focus lesson in literacy was compare and contrast. I chose to use a text on moths and butterflies since we have been studying and observing the life cycle of the butterfly. We made a Venn diagram together. The students wrote it in their science notebooks.	I was thrilled with the information my students already knew from our butterfly study. They made lots of connections with previous class discussions. Some were excited to mention facts they remembered from outside of class such as the Monarch butterfly tastes bad to its enemies. They seem to be getting more confident using a Venn diagrams and understanding compare and contrast.	Some students write much slower than others. Small motor control in some of my students creates an issue with forming smaller writing and also in fitting writing in a set amount of space. A few students appeared a little flustered or frustrated by the amount of writing.	How can I determine when it is worth the struggle to have students write everything themselves opposed to havine a template for them. For example, I could have created a Venn diagram template and a word bank and had the students cut and paste instead of write. Today that would have eliminated some of the surprise facts from the premade information.	How quickly my students are understanding the science concepts as well as the idea of a Venn as a tool to compare and contrast.	I'm thrilled to say it is easier and smoother than I ever imagined. Not only are the students benefitting, but I am feeling more confident and proud as a teacher.

Appendix F

Initial Coding Example

10/22/12 Planning Session

Dialogue	Reflection
Mrs. Martin: OK still I'm still trying to figure this all out. Here's what I have so far. So this is the meeting where we're trying to figure out where you will come in and when and what we're doing.	Unsure of research process;
Researcher: yes.	
Mrs. Martin: OK. And um I have some things all out of whack because I had to sign up for the lab when it was available. That was sometimes during my math lesson that we're trying to type stories and they are so slow that like it is taking us weeks to get typed. As I can only get it in the lab like once last week I mean it was like wow. Um so, things are little whack but I don't think it affects science.	Struggle to keep schedule with needing other resources;
Researcher: OK.	
Mrs. Martin: OK tomorrow in science I'm going to pull some science in the normal science time which is to 2:45 to 3:35, I'm going to do a review of Pumpkin Jack and retell A Plant Grows by, just so you know um and so we are going to do the plant life cycle in our notebooks. And we're going to compare and did they tell exact same things about the life cycle yes or no. Um and then I think I'm not sure yet. I think I'm going to do um the lesson I learned from Dr. Bell at Interface, not interface, STOM. That's about where you take about 15 beans and compare the beans and we talk about the beans, the seeds. And then if we have time we're also going to plant them but I don't know for sure how that's going to shake down. I also have a little pumpkin here that I want to do a little bit of work with them. Um so they don't have one for everybody. We're going to try to do as much as we can with one pumpkin. So we've we'll probably weigh it and estimate how much it is going to weigh and weigh it and we will probably sketch what do you think the inside looks like and then actually cut it open and then we will guess how many seeds there are and we will count them and then we're going to fill it with dirt. So I might end up doing that on Friday instead because I wanna get it growing.	Use of text to connect science content; Belief integration is isolated lessons; Compare and contrast science with book(questioning the author); unsure of integration lessons use of science notebooks to record ideas and understanding not sure of how lesson will go science lesson: beans to plant seeds; hands on activity science lesson: pumpkin connection to math ideas (estimation, weight); use of sketches to communicate meaning; prediction
Researcher: OK.	
Mrs. Martin: so, I'm not exactly sure but that's sort of what I'm thinking to do with seeds and planting seeds because we're going to start the plant life cycle idea. Which I think is going to go very quickly because they really get it, they really get it. They are really assimilating from one thing to the next too which is super cool. Um, OK in other subjects if you're interested. Um all week for literacy we are reading books that have to do a science. Today we read a butterfly moth book. We're going to do that again tomorrow and do a Venn diagrams comparing butterflies and moths. They have done a venn been before but it was new to them the first time so we are bringing it back up for them. And then we're going to the buzz room Wednesday and then Thursday were doing the Reason for a Flower and on Friday were doing from Seed to Plant and talking while one time about that life cycle of a	quick connections between science content; using text in guided reading to support science; Venn Diagrams (graphic organizers) talk focuses on individual

Appendix G

Coding Spreadsheet Example

Research Question (teacher methods, success, barrier, teacher change, student strategy, student pictures	Code	Unit	Source	Date
success	Successful unit	EIE	Collaboration	11/27/2012
success	Success: students applying science concepts into writing activity	Science Life Cycles	teacher interview	11/9/2012
success	Writing lesson developed from science went better than expected	Science Life Cycles	teacher interview	11/9/2012
success	Seeing transfer with science and writing lesson	Science Life Cycles	teacher interview	11/9/2012
success	Integration of books with life cycle unit success	Science Life Cycles	teacher interview	11/9/2012
success	Parents are noticing engagement and excitement	Science Life Cycles	teacher interview	11/9/2012
success	High engagement	Science Life Cycles	teacher interview	11/9/2012
success	builds vocabulary and interest	Science Life Cycles	teacher interview	11/9/2012
success	Hands-on activity increase engagement	Science Life Cycles	student conversation	11/7/2012
success	Hands-on increase engagement	Science Life Cycles	student conversation	11/7/2012
success	high excitement for lesson	Science Life Cycles	teacher interview	10/26/2012
success	Believes science writing prevented some off task writing behaviors	Science Life Cycles	teacher interview	10/26/2012
success	Venn diagram was successful	Science Life Cycles	teacher interview	10/26/2012
success	Students caught on well to Venn diagram	Science Life Cycles	teacher interview	10/26/2012
success	Excited when students are pointing things out to her	Science Life Cycles	teacher interview	10/26/2012
success	class has strong confidence in writing	Science Life Cycles	teacher interview	10/26/2012
success	Gives success credit to both her and students	Science Life Cycles	teacher interview	10/26/2012
success	Both student confidence and ability and teacher instruction leads to success	Science Life Cycles	teacher interview	10/26/2012
success	relates a good deal of success to students	Science Life Cycles	teacher interview	10/26/2012
success	Some of success comes from personality of students	Science Life Cycles	teacher interview	10/26/2012
success	Students must be motivated to learn	Science Life Cycles	teacher interview	10/26/2012

Appendix H

Teacher Project Reflection

When a teacher is in the midst of teaching it is easy to miss the shiny moments. It was wonderful for me to remember the great snippets that encourage and inspire me. Seeing how excited and knowledgeable my students have become spurs me to want to teach even better. To take everything I have done this year and move it to the next level. For example, I really want to be much more purposeful in my yearlong planning for next year. I want to find all the logical and natural connections in my curriculum and build them into meaningful and relevant integrated units of study. I think my initial hesitant vision for what a unit of study truly should be seemed out of reach to some extent. I knew what I wanted but I wasn't sure it was attainable. I realize know that I should always shoot for the stars. Even if my students and I don't always reach them, we will have a wonderful journey to share. All that we learn along the way will bond us and challenge us to try again.

I think my view of integration has just grown broader and more encompassing. Instead of just striving to make meaningful connections between subject areas I want integration to be a process of fully enveloping the student in what they are currently studying. I want them to be thinking about the concepts all day long in various ways. I want to see the importance of being able to understand the ideas of others and to communicate their own ideas to other people. For that is how we truly learn from one another. We have to be able to share and process ideas. If a child is reading about, writing about, investigating, and questioning a topic or concept they will come to fully own it. They will have a confidence about themselves when sharing their thinking with others verbally or in writing. That is my vision for integration for the rest of this year and in the years to come. My goal when I plan a unit is to surround my students with the content in as many ways I can possibly think of. I want them to have time to read about, write about, question, converse and investigate the content in as many learning styles and situations as is possible.

Being a part of this research study was intimidating at first. I wasn't sure that there would be any epiphanies from my teaching. But looking back on the experience I feel very proud and validated. As I read the findings and revisited those beautiful moments that only a teacher will understand (like getting excited because a 6 year old asked me to go back and read the caption) I am reminded that I have learned a lot in my 14 years of teaching. I do know things that are worthy of passing on to other teachers. I saw in myself that I have a gift for finding connections on the fly and making the most of those teachable moments. I am really good at seeing how literacy occurs in my classroom all day long and helping my students to see that as well. When we started this project I wasn't sure I was really good at anything teaching related and now I can honestly say that I wasn't giving myself enough credit. While I still have lots and lots to learn and I will continue to fight to hone my craft, I need to remember how far I've come and to cut myself a little slack. Thank you, Heather, for having the faith in me to study my classroom and feel assured that you would find research worthy happenings. Every teacher should be so blessed as to be afforded the opportunity at this later point in his/her career to reflect in such depth on what is happening in their classroom and why they are making the decisions they are making every day. I feel much more confident that I am doing great things for my students and more confident that I am ready and able to lead professional development on integrating content areas and literacy.

Appendix I

World Café Minutes January 26, 2011

(Example of Minutes taken from meeting with school staff, community members, and families. The purpose of the meeting was to outline thoughts and perspectives on Bowling Elementary becoming a STEM school.)

Curriculum and Instruction

Questions:
What would the essential curriculum look like in a STEM school? How would this be similar or different from the current curriculum? What would be the ideal instructional delivery of STEM curriculum?

Responses:
• Still need to have full liberal arts offerings. STEM maybe not be SOLE focus. Integrate subjects with STEM - i.e. extend music through technology, art through tech, etc…. Keep it well rounded.
• Would assessment differ? - follow district assessments - MAP etc…
• Professional development is key
• Support available from district career center
• Integrate all day long
• Embrace different learning styles
• More teacher collaboration to enhance understanding
• More field trip opportunities for real world experience, increase vocab to bridge achievement gap
• Full time specialists
• Love the science and health units! keep them but more intense instruction.
• Pods of non-STEM (art, music, PE) might be rotated the same way current counselor/ media spec. pods are.
• Must remember still teaching the basics to beginners - has to be main priority
• Add things with scientific backing - i.e. nonfiction in reading
• Still elementary school - everything needs to stay balanced. STEM info just introductory to get mind thinking a different way.
• Project Approach
• Can deliver some curriculum using more technology (integrate STEM that way)
• STEM Academy— curriculum (tied to national standards)
• Units integrate multiple academic areas
• STEM expert team teach units
• Computers for more kids - especially because they don't have this at home
• Lots of technology - cameras, video, smart board, laptop….
• Curriculum still based on GLE's etc., delivery may be different.
• Collaborative, inquiry lessons
• Keep specialists in building full time so they would develop rapport with students, teach their discipline and use other time to pull-in, push-out, support RTI.
• All curriculum is connected to a purpose… instead of silos.

Appendix J

STEM Meeting Minutes 2/11/11

(Example of STEM Meeting Minutes that outline conversations between staff members of Bowling Elementary in the planning process of implementing STEM.)

Note cards:
- Write down any questions or ideas you have about STEM

Questions:
- What does STEM mean to us? What are the central ideas that tie all of those areas together?
  - Incorporating career talk and lessons into curriculum
  - Inquiry and problem solving
  - Possibly use this as our focus for next year
- Can we make the changes to a STEM school without funding, extra resources, and control over curriculum?
  - Yes. We can focus on giving more opportunities for discussion and problem solving.
- What does this mean for curriculum?
  - There is a difference between curriculum and objectives. We still teach the objectives and standards for the city and state. It is the HOW that will change, not the WHAT.
  - Possibly incorporate some Investigations into Envisions.
  - Retrospective Miscue Analysis – a strategy that teaches students how to listen and talk about their reading.
- How are we going to incorporate more when we already struggle with time? How can we "get rid of things" to make it fit?
  - We can't "get rid of things". We have to think integration rather than separate process and content.
  - Have to think and work "smarter" and not harder.
- What kinds of support will we have without SES?
  - Possibly look at restructuring media specialists position to create a "STEM specialists"
- Where are we with SAS?
  - Board has to decide on STEM and SES. More likely to support STEM first.
  - SAS provides more flexibility in scheduling, finances, etc.

Comments:
- This is a great way for us to show what GREAT things are going on at Bowling.
- We are going to have to promote and encourage community.
- Our kids are the ones who need to have an understanding of why the learning is important and relative to them. They are not satisfied with learning because learning is fun. They want to know how it can help them.
- We should think about dividing areas among those interested so we don't each have to research everything.

Appendix K

Bowling Elementary Changes Brochure

Other Changes

STEM Showcase

Students visited stations and learned about different STEM careers. Guest included: scientists, engineers, doctors, teachers, and community members.

STEM Open House

Community members, prospective parents, and students are invited to tour the school, visit with staff, and ask questions about STEM.

Explore DAZE

Before winter break, students were able to participate in Exploration classes taught by all staff members at Benton. Students selected two classes to attend. There were a range of topics to choose from: dog training, ornament design, string art, pickling, and building buildings.

Specialists

Our specialist teachers are with us full time which allows us to do something slightly different with our specials schedule. We have our traditional music, art, and PE times. In addition, each of these specialists teach a STEM course that connects STEM content to their specialty area. The curriculum for these classes has been developed by the specialist with the support of the STEM instructional coach.

[redacted] Submarine Partnership

We have partnered with the [redacted] and students have opportunities to interact with the crew members.

Community Support

[redacted] works closely with the [redacted] to provide observation and mentor opportunities for their pre-service teachers. Also, we have received support from many of the departments (science, math, engineering, medical, etc.) at Mizzou. The [redacted] group arranged for an astronaut to visit the school and talk to students.

Physical Changes

Building Appearance

When entering the building you are greeted with our mission: Learning through Discovery Leading with Character.

The four colors from our STEM logo decorate the hallways and classrooms to create a brighter appearance and serve as a reminder for our STEM focus.

Multiple signs hang in the building to promote discovery and character.

Digital Images

We have several digital frames around the building that display photos from STEM events. A projector also displays student images from STEM events in the main hallway on the first floor. Students help create video announcements that are shared during the week.

STEM Lab

A new science lab/classroom was created for students to use. The room consists of two pods of six computers. It is the largest classroom in the building which provides ample space for science experiments.

STEM Lab Science Tables

The Science Department [redacted] donated 3 science tables that can be used for experiments. The tables have a solid top that cannot be damaged with liquids or chemicals.

Benton BUZ Room

We have created a Building Understanding Zone that is constructed three times each year. The topic for the BUZ room is voted on by the students at the beginning of the year. The goal of this room is to provide students with hands-on experiences and opportunities to expand their vocabulary. The themes for this year are: sound, solar system, and human body systems.

Our STEM Journey

Science, Technology, Engineering, and Mathematics Centered Learning

Learning through Discovery

Leading with Character

Science

Animals

Many classrooms have added classroom pets to increase the opportunities for students to interact and increase background knowledge. We have some traditional pets and some exotic or unusual which include: a gecko, turtle, hamster, hissing cockroaches, toad, bearded dragon, meal worms, rats, snake, and fish.

Science Notebooks

Students at all grade levels have their own science notebooks. They record observations and notes from experiments and activities in their notebooks. The use of science notebooks allows us to integrate literacy skills through nonfiction writing.

Nonfiction Focus

We have increased our use of nonfiction reading and writing. We have received several grants to help increase the number of nonfiction books available in our classrooms and school library. We have also purchased fiction and nonfiction e-books. The e-books can be viewed on computers or iPads.

Science Club

Thanks to the science department [redacted], college students run a weekly after school science club. Students are divided into different age groups. Topics for the club are aligned with the schools science curriculum.

Guest Speakers

We have asked many individuals to come in and visit with our students about STEM careers and interests. We have a [redacted] student who comes and does science demonstrations during lunch periods. Many classrooms also invite guest speakers such as engineers, farmers, and other experts into their classrooms to share their STEM experiences with the students. The purpose of these visits is to introduce our students to a range of careers which give them a purpose for what they are learning.

Technology

iPad and Laptop Carts

We have a laptops and iPad lab that can be used by students and teachers at [redacted]. Teachers use these technology tools in their classrooms during the day to enhance learning experiences for students. Additional iPads were provided for staff members to use in their instruction. To support this integration, staff members have been provided with professional development on incorporating iPads in classroom instruction. In the future, we are looking towards moving to a one-to-one initiative for our building.

Headphones and Flash Drives

Every student has been provided headphones to use in the building. These headphones will be kept in classrooms to use with the laptops and iPads. Students will return them at the end of the year. We also provide students in grades three through five with a flash drive. This will allow them to store and move their files easily.

Wireless Access

[redacted] has had 35 new HP wireless access points installed in the building. These new access points increased connectivity for our computers and iPads. Our trailers have new fiber optic cables run that improve the quality and speed of their internet connections and wireless.

Engineering

Engineering is Elementary Curriculum

[redacted] has adopted the EiE Curriculum for grades 1st – 5th. Each grade level selects units of study to teach during the school year. The selected units align with the curriculum objectives for that grade level.

Lego Robotics Club – First Lego League

A select group of students participate in this after school club. They design and build a robot and program it with various commands to accomplish different tasks. Next year, the club will participate in the national competition. They follow the engineering design process to create and program a robot.

Math

Study Island

Students have the opportunity to practice their math skills using Study Island. It is an online program that uses lessons and games to reinforce math skills.

Math Wizards

We have continued to implement our Math Wizard program. All students have the opportunity to become a wizard by mastering their basic math facts.

Smart Response/Senteo Response System

Some of our teachers use clickers to administer math assessments. The program provides immediate feedback to students on their performance.

FASTT Math

Our students currently use a computerized program called Fast Math to practice and learn their math facts. Students work on this program three times each week. Each time, the students are introduced to a new fact they need to work on. The computer provides opportunities for them to practice this fact combined with others they have already mastered.

Staff

Professional Development

Several staff members have attended conferences that focus on STEM topics. We also ask each of our teachers to attend one STEM professional development session each month. This can be a session hosted by [redacted], the district, or a national conference.

Entica/Emints4All

Many staff members have been through training programs for technology integration and inquiry teaching practices.

NSTA

We have a building membership to the National Science Teachers Association.

Links to Learning Grants

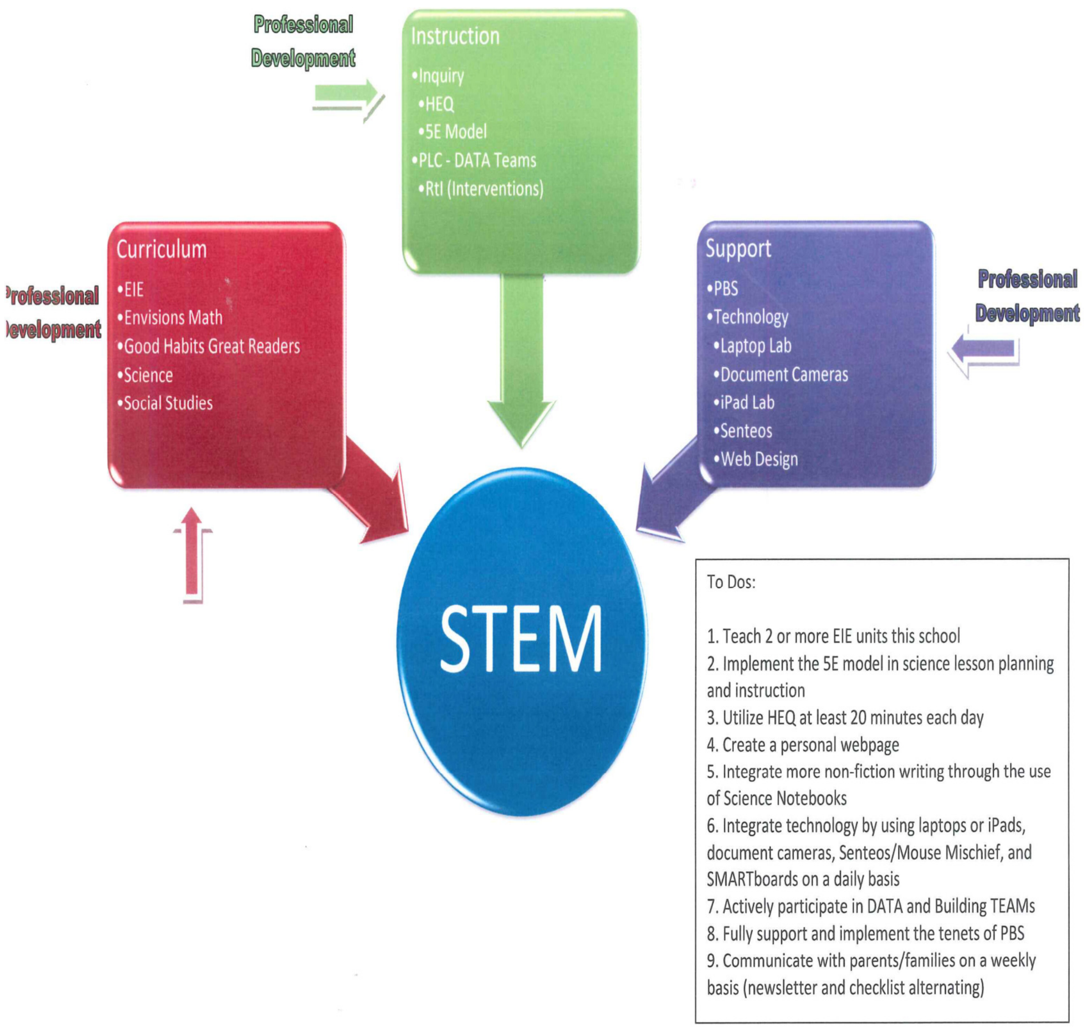
Teachers received grants to purchase classroom materials to enhance student learning.

STEM Specialist

We have a full time STEM specialist that supports teachers as they integrate curriculum and design STEM units of study. This person provides professional development, co-teaches, and models STEM lessons.

Appendix L

Administration Expectations Document



Appendix M

District Life Cycle Unit Plan

Unit Title: Life Cycles **Subject/Topic Areas:** 2nd Grade – Science
Key Words: Life Cycle, Metamorphosis, Offspring
Brief Summary of Unit: Students will investigate the life cycles of butterflies, chickens and frogs.

Resources:

- STC The Life Cycle of Butterflies Teachers Guide
- Non-fiction Trade Books:
  - *See How They Grow FROG*
  - *Tadpole Diary* (Rigby)
  - *Caterpillar Diary* (Rigby)
  - *The Science of Living Things: What is a Life Cycle*
- Living Organisms: Chick Eggs, Caterpillars, Tadpoles – Please send request to Science Kit Manager
- Internet/Digital Streaming Videos
  - The Lives of Butterflies and Moths (11:32)
  - The Caterpillar and the Polliwog (07:26)
- Web Site: www.enchantedlearning.com

What understandings are desired?

- All organisms progress through a life cycle (birth, growth, reproduction, death)
  - Frogs (Egg, Tadpole, Adult)
  - Butterflies (Egg, Caterpillar, Chrysalis, Butterfly)
  - Chickens (Egg, Chick, Adult)
- All organisms need air, food, and space to live and grow.
- Parent and offspring have similar traits.

What essential questions will be considered?

- What are the life cycle stages of a butterfly, a chicken and a frog?
- What do all organisms need to survive?
- How are parents and offspring similar and/or different?

What key knowledge, skills and vocabulary will students acquire as a result of this unit?

<u>Knowledge</u>

- Butterflies, Chickens and Frogs progress through their own unique life cycle.
- Air, food, and space are required by all organisms to live and grow.
- Some parents and offspring share common traits, yet each one is unique and different.

<u>Skills</u>

- Observing, describing and recording growth and change in the life cycle of different organisms.
- Predicting, comparing and discussing the organism's appearance and change over time.
- Communicating observations through drawing, writing and discussion.
- Relating observations of life cycles to students' own growth and change.

<u>Vocabulary</u>

-
- Caterpillar
- Chrysalis
- Embryo
- Larva
- Life Cycle
- Metamorphosis
- Offspring
- Pupa
- Reproduction
- Tadpole

Learning Activities:

Taken from STC Teacher's Guide

Caterpillars

1. Getting ready caterpillars.
2. Caring for caterpillars.
3. Learning more about caterpillars.
4. Observing the caterpillars.
5. Observing change, growth and molting.
6. Silk spinning.
7. From caterpillar to chrysalis.
8. Observing the chrysalis.
9. The butterfly emerges.

Chickens (modified from caterpillars)

1. Getting ready for chicken eggs
2. Observing eggs in incubator
3. The chick emerges
4. Learning more about chicks
5. Observing and caring for chicks.

Frogs (modified from caterpillars)

1. Getting ready for frog eggs.
2. Observing eggs in aquarium.
3. Tadpole emerges.
4. Observing changes in tadpoles.
5. Caring for tadpoles.
6. Observing change from tadpole to frog.

Assessment:

Performance Assessment: Draw and label the life cycle of a butterfly, chicken, or frog

Appendix N

Teacher Created Life Cycle Unit Overview

Life Cycle Unit (mealworms, butterflies, plants)

Books used in this unit:

Butterflies and Moths by Nic Bishop

How a Plant Grows

Waiting for Wings by Lois Ehlert

The Very Hungry Caterpillar by Eric Carle

Pumpkin Jack by Will Hubbell

Pumpkin Circle by George Levenson

I Wish I Were a Butterfly by James Howe

Where Butterflies Grow by Joanne Ryder

Observation Stations:

1 Mealworms: each cycle separately and then all together
2 Various pumpkins and gourds
3 Fishing worms
4 Painted lady caterpillars, then pupas, then butterflies, then dead butterflies in magnifying containers

Writing Prompts/Projects:

- What do you think life would be like inside an egg?
- Step by step directions using transition words that describe the pumpkin life cycle
- Venn diagram comparing moths and butterflies
- Take notes on caterpillar, moth, and butterfly facts
- Write the life cycle of a butterfly from the point of view of the butterfly
- Various science notebook entries

Additional Resources/activities/assessments:

- Sort life cycle cards into correct order
- Many guided reading books
- A to Z resources on life cycles and related careers
- Measurement activities using small pumpkins

Appendix O

(This teacher-developed lesson plan was initially guided by the curriculum lesson plans but adapted by Mrs. Martin. This lesson follows the 5E Instructional model and integrations other texts, writing, and math objectives.)

Submersible 5E Unit Plan

Engage: Student will predict whether various items will sink or float at an observation station. Once they have predicted, they will test to see. Recordings in science notebooks. Several items are taken from the kit.

Explore: Discuss in table groups what we know about oceans. Teacher will chart during a whole group discussion. Then teacher will chart what we want to know about the ocean. How do we learn about the ocean? What are scientists and engineers who student the ocean called? What is their job like? What tools might they use?

Explain: Students will complete a card sort to determine which items on the cards will sink and which will float. Write a rule on sentence strips for what makes something sink. Share sentence strips as a whole group. Test as many real objects as possible at the observation station and record the results. Change the rule as needed to match findings. (Teacher may need to prompt a discussion on buoyancy and density)

Extend: **Day 1:** Read Chapter 1 of *Despina Makes a Splash*. Add to the charts What We Know About the Ocean? And What are Ocean Engineers?

Day 2: Read chapter 2. What Do We Know About Submersibles? Read the book <u>Submarines</u> to increase our knowledge and vocabulary. Locate Greece on a map.

Day 3: Read chapter 3. Discuss density versus volume. Read chapter 4. Define technology.

Day 4: Read chapters 5, 6, and 7. Complete the activity on page 42, Ask About Sinking and Floating. Review the engineering process. Determine where in the story Despina used each step in the process.

Day 5: complete the activity on page 42, Ask About Sinking. Do you want to change your rule determining why things sink or float? Review each rule as a whole class.

Day 6: Image and plan (pg. 42). Create a drawing of your submersible. Must include a magnet. What other instruments would you like to include?

Day 7: Design your submersible (p. 43)

Day 8: Can you improve your submersible? (p. 43) See what other kids have done by visiting http://www.mos.org/eie/tryit. We can even post our own pictures and solutions.

VITA

Heather L. Lang grew up in Lee's Summit, MO where she completed her elementary and secondary education. She received her Bachelor's degree in Education from Columbia College in 2005. During her four years of undergraduate coursework, she also played softball for the Cougar softball team. After graduating, she obtained a teaching position at an elementary school in Columbia, MO. In 2006, Heather completed her Master degree from Columbia College while continuing to teach full-time. After three years in the classroom, Heather decided to return to school to obtain an Educational Doctorate in Literacy. She continued to work full-time in the elementary school as a Title I teacher and instructional coach. In her seven years of teaching, Heather has taught second grade, a first/second multi-grade class, served as a Title I reading support, media specialist, and a STEM (Science, Technology, Engineering, and Mathematics) instructional coach. At the time of her doctoral graduation, Heather lived with her fiancé, Dean McCullar, and their two dogs, Bella and Ginger.