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Elementary Teachers' Perceptions of Teaching Science to Improve Student Content Knowledge

Robert Louis Stephenson
Walden University

Walden University

COLLEGE OF EDUCATION

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Robert Stephenson

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Review Committee
Dr. Deborah Focarile, Committee Chairperson, Education Faculty
Dr. Kathleen Montgomery, Committee Member, Education Faculty
Dr. Mary Howe, University Reviewer, Education Faculty

Chief Academic Officer

Eric Riedel, Ph.D.

Walden University
2017

Abstract

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Project Study Submitted in Partial Fulfillment

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Abstract

The majority of Grade 5 students demonstrate limited science knowledge on state assessments. This trend has been documented since 2010 with no evidence of improvement. Because state accountability formulas include proficiency scores and carry sanctions against districts that fail to meet proficiency thresholds, improved student performance in science is an important issue to school districts. The purpose of this study was to explore elementary teachers' perceptions about their students' science knowledge, the strategies used to teach science, the barriers affecting science teaching, and the self-efficacy beliefs teachers maintain for teaching science. This study, guided by Vygotsky's social constructivist theory and Bandura's concept of self-efficacy, was a bounded instrumental case study in which 15 participants, required to be teaching K-5 elementary science in the county, were interviewed. An analytic technique was used to review the qualitative interview data through open coding, clustering, and analytical coding resulting in identified categorical themes that addressed the research questions. Key findings reflect students' limited content knowledge in earth and physical science. Teachers identified barriers including limited science instructional time, poor curricular resources, few professional learning opportunities, concern about new state standards, and a lack of teaching confidence. To improve student content knowledge, teachers identified the need for professional development. The project is a professional development series provided by a regional education service agency for K-5 teachers to experience science and engineering 3-dimensional learning. Area students will demonstrate deeper science content knowledge and benefit from improved science instructional practice and learning opportunities to become science problem solvers and innovative contributors to society.

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Dedication

This study is dedicated to my wife, Jamie, and children, Rebecca and Andrew. If it were not for your encouragement and understanding, I could not have accomplished this personal goal. I adore you all and look forward to more uninterrupted family time and many more vacations to our country's beautiful national parks!

Acknowledgments

I wanted to acknowledge my parents who always believed that you are never too old to learn new things and always hoped there would be a third generation Dr. Stephenson. Additionally, I wanted to thank my committee, Dr. Deborah Focarile, Dr. Georgene Risko, Dr. Kathleen Montgomery, and URR Dr. Mary Howe for their probing questions, high expectations, and commitment to the field of education.

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Section 1: The Problem

The Local Problem

Michigan elementary students are assessed annually in reading and mathematics beginning in third grade, while science knowledge is measured once in fifth grade and once in eighth. Prior to 2014-2015, the state's Michigan Education Assessment Program (MEAP) science assessment was administered to fifth and eighth grade students in the fall and measured their accumulated knowledge. While a middle Michigan county, referred to as Wise County (pseudonym), has demonstrated a steady increase in both reading and mathematics student proficiency scores during each of the last 4 years, the achievement results in science have remained static (Table 1). A 2014 Michigan School Data search revealed that the majority of students in Wise County are not proficient in science. According to the cut scores established by the Michigan Department of Education (2011), a not proficient score means that the majority of fifth graders scored below 553, in a range between 409 and 624.

Table 1

MEAP Comparison of Wise County 5th Grade Students from 2010-2014

Year	Science	Reading	Mathematics
2010-2011	18	66	38
2011-2012	18	70	39
2012-2013	15	70	46
2013-2014	19	73	48

Note. Scores depict the percentage of fifth grade students who achieved advanced or proficient levels on the MEAP according to a 2014 MI School Data county search.

Despite positive proficiency trends in both reading and mathematics, these same patterns of static science performance and high percentages of students who are not proficient have been observed in each of the 12 districts throughout Wise County, as well as throughout the state (Michigan Department of Education, 2014). According to MEAP state trends from 2010 through 2014, over half of all fifth and eighth grade students tested in the state in each of those years were not proficient in science, and another 30% of fifth graders and 25% of eighth graders were only partially proficient (Michigan Department of Education, 2014). The fact that only 20% to 25% of Michigan's fifth grade students are either proficient or advanced in science has raised concern in the county and compelled educators to reevaluate elementary science programs and instruction to improve student science content knowledge.

Science proficiency has been a national focus as well, not only for national economic reasons, but also for the sustainability of the planet and all of its inhabitants (Tobin, 2016). This push for science education also comes with an increased attention on teaching students so they can demonstrate their understanding through performance assessments that more closely resemble those experiences found in field science (Pellegrino, 2013; Quellmalz et al., 2013). While studies have shown that consistently dedicated instructional time is a key factor for positively influencing student achievement (Traphagen, 2011), nationally the weekly number of hours devoted to science instruction is at its lowest since 1988 (Blank, 2012). Therefore, it is possible that students may now be exposed to less science content. As accountability attention has turned toward other content areas, the number of K-4 science instructional hours has declined as has student achievement scores (Blank, 2012). This is true despite the national interest in science, technology, engineering, and mathematics (STEM) education (National Research Council, 2012) and the call for more graduates pursuing those fields (President's Council of Advisers on Science and Technology, 2012) to supply a pipeline of workers into STEM careers. Like many states, Michigan has been preparing to adopt a version of the Next Generation Science Standards, the Michigan Science Standards (Achieve Inc., 2013), which will likely be included in future test adaptations from the Smarter Balanced Assessment Consortium (2012) and may prompt a more earnest examination of the state's science achievement scores. In the meantime, Wise County's student proficiency data in science has paralleled the inert trends at the state and national levels.

Public trend MEAP results indicated that Wise County's fifth grade science scores have remained relatively stagnant, with only 19% of students being identified as proficient. Examining each cohort of students tested in recent years demonstrated that local schools have not been successful increasing the number of students attaining proficiency status in science (Table 2).

Table 2

Wise County's 5th Grade Science MEAP from 2010-2014

	2013-2014	2012-2013	2011-2012	2010-2011
Grade 5	19	15	18	18
State Average	17	13	15	17

Note. Scores represent the percentage of fifth grade students scoring either advanced or proficient on the MEAP science test as reported in a MI School Data county search.

Because science proficiency is calculated into the state accountability formula, such poor scores in science negatively affect a district's reputation though a publicized school ranking system (Riddle, Kober, Ferguson, Rentner, & McMurrer, 2012).

This stagnant proficiency trend is not the case in other subject areas where area schools have seen an increase in student performance. According to some Wise County administrators with whom I have spoken, they reported that since 2002 there has been an increase in time allocated to language arts and mathematics instruction in exchange for previous instructional time allocated to science and social studies. Their elementary teachers are now required to teach daily 90-minute reading and mathematics blocks, as well as 45 minutes of writing. When combined with scheduled special area classes including art, music, and gym, as well as additional time in reading and mathematics to meet Response to Intervention requirements, class schedules have shown a reduction in the time devoted to science. Prior to 2002, those elementary teachers taught science three to five times per week for 30 to 60 minutes, while the current practice in those districts includes 1 to 2 days of instruction for 25 to 45 minutes. Additionally, county administration told me that a shorter science class makes inquiry-based lab experiences more challenging to integrate.

When examining professional development opportunities offered by the regional education service provider, I found at least four mathematics and reading academies offered to elementary teachers in each of the last 5 years. These were well attended by local teachers, with as many as 109 K-5 teachers enrolled in the 2014-2015 mathematics cohort. With respect to science trainings in that year, there were two trainings offered, but both were canceled due to low enrollment.

In addition to the limited science professional development, there were few curricular updates. Only one district in the county adopted an updated curriculum in the last 10 years, and that selection was for a single grade. Curriculum directors told me that most of the schools have been using the same curriculum since the 1990s and that many of the science kits are missing materials. It appears that few changes are being integrated into science instruction or programs to reverse the static scores.

Significant attention has been devoted to improving student proficiency in reading and mathematics within Wise County over the last decade. Recent changes in the state's accountability metrics that incorporate science proficiency results (Riddle et al., 2012) have caused local administration to take an interest in improving science scores as well. In 2012 the state of Michigan added science proficiency scores to the formula for determining school accountability and established a top-to-bottom ranking of schools based upon collective performance in different subject areas (Michigan Department of Education, 2013). This formula was part of the federal waiver from the No Child Left Behind (NCLB) legislation (Riddle et al., 2012). Prior to 2012, although students took MEAP science tests, the results did not alter adequate yearly progress (AYP) status (Michigan Department of Education, 2013). As a result of this new accountability formula that includes science achievement, schools throughout Wise County were identified as a "priority school" if they were in the bottom 5% on the top-to-bottom ranking of schools, or labeled as a "focus school" if their achievement gap was too great between their top and bottom 30% of students. Local districts have been attending more closely to the state science scores and are motivated to increase the number of students proficient in science to improve their ranking on the state's top-to-bottom list and be removed from the priority and focus school lists.

Closer examination of each of the 12 school district's fifth grade science achievement scores in the county revealed that there were no consistently positive trends, which is similar to the state summary results (Table 3).

Table 3

Comparison of a Wise County's 5th Grade Science Achievement from 2010-2014

District	2013-2014	2012-2013	2011-2012	2010-2011
A	26	11	14	29
B	23	30	31	23
C	37	22	32	30
D	19	16	21	21
E	6	6	6	7
F	22	7	17	21
G	24	14	29	23
H	38	29	36	41
I	14	20	5	12
J	12	5	6	8
K	14	12	23	14
L	27	16	12	28
State Average	17	13	15	17

Note. Scores represent the percentage of fifth grade students scoring either advanced or proficient on the MEAP science test according to a county MI School Data search.

Although some of the smaller districts have had greater fluctuations in scores between cohorts of students, most of the 2014 scores resembled those achieved during the 2010-2011 school year.

On further examination, even "H," the highest performing district within the county, experienced several years of declining performance and no overall growth in science achievement since 2010. For example, their percentage of advanced or proficient fifth graders dropped from 41% in 2010, to 36% in 2011, then 29% in 2012, and back to 38% in 2013-2014. This district required instructional minutes in mathematics, reading, and writing, but no such requirement in science. They have not updated their science curriculum, with the exception of fifth grade, since 1994, and they have provided no K-4 elementary science professional development since 1998.

In the past 2 years, 23 schools in Wise County were identified as focus schools due to the large achievement gap between their top and bottom 30% of students. Searching the MI School Data site revealed the county also had 7 schools identified as priority schools because they were in the bottom 5% on the top to bottom ranking of schools. In either case, schools were required to demonstrate significant student improvement or risk being subjected to different degrees of sanctions, including state takeover or school closure (Riddle et al., 2012). Local superintendents are increasingly motivated to determine how to improve student performance in science and alleviate the pressures associated with state oversight and risk of punitive sanctions. Subsequently, county curriculum directors have been turning their attention to science and have been more cognizant of the need to evaluate their science programs and explore the kinds of professional development teachers need to improve their content knowledge and their pedagogical knowledge to effectively improve student science knowledge in each of the student subgroups.

According to 2014 county MI School Data searches, there has also been attention on the economically disadvantaged subgroups that range from 18% to 73% of each district's enrollment throughout Wise County. Table 4 illustrates the percentage by district.

Table 4

Percentages of Economically Disadvantaged Students by District

District	Economically Disadvantaged
A	35%
B	34%
C	25%
D	40%
E	73%
F	46%
G	29%
H	19%
I	41%
J	55%
K	51%
L	18%

Note. County data is available from MI School Data.

Although the concern for poor proficiency is justified among the economically disadvantaged students, the test evidence suggested that limited science knowledge is an issue that affects a significant part of the student enrollment in each of the districts and requires further investigation in order to ultimately improve student proficiency scores and positively influence student content knowledge in science. Of the 12 districts in Wise County, eight of them scored higher than the state average on the 2013-2014 fifth grade science MEAP assessment, while the four that did not have some of the highest percentages of economically disadvantaged students in their student populations (Table 5).

Table 5

A Comparison of the Percentage of Proficient 5th Graders on the 2013-2014 Science MEAP with the Percentage of Economically Disadvantaged Students by District

District	2013-2014	Economically Disadvantaged
A	26	35%
B	23	34%
C	37	25%
D	19	40%
E	6	73%
F	22	46%
G	24	29%
H	38	19%
I	14	41%
J	12	55%
K	14	51%
L	27	18%
State Average	17	

Note. Scores represent the percentage of fifth grade students scoring either advanced or proficient on the MEAP science test from a 2014 MI School Data search.

Rationale

The evidence of reduced science instruction has indicated that some students are not being exposed to, understanding, or retaining ample science content to perform well on the state assessments. Many local teachers appear to be dedicating more time to mathematics and language arts instruction than had previously been devoted to science. The reduction of time spent teaching science is an issue affecting schools around the country due to a national emphasis on reading and mathematics resulting from NCLB legislation (Blank, 2012; Dorph, Shields, Tiffany-Morales, Hartry, & McCaffrey, 2011;

Owens, 2009). The reduction in science instruction could also be the end result of administrative directives for the purpose of maximizing instruction in those heavily assessed content areas (Milner, Sondergeld, Demir, Johnson, & Czerniak, 2012). Additionally, few changes were made to the elementary science programs in Wise County over the last decade, and there could be impediments associated with those curricular materials. A curricular issue is a problem that has been associated with science teaching difficulty (Banilower et al., 2013). There are other possible theories that may contribute to the large number of nonproficient students in the county. Teachers may feel ill-equipped to effectively teach science due to personal efficacy beliefs, limited professional development support, and minimal content background knowledge (Appleton, 2013; Berg & Mensah, 2014). By researching Wise County elementary teachers' perceptions about their experiences with science content and instruction, it would reveal the gaps in practice that have contributed to the limited science knowledge students possess as evidenced by the state summative scores. Some of these reported obstacles align with those introduced above and provide new insight for county educators. To help resolve the problem, and increase the number of students proficient in science content knowledge, it was necessary to discover the impediments that teachers perceive.

The need for immediate attention to improve science proficiency scores has been further complicated by Michigan's November 2015 adoption of the Michigan Science Standards, a version of the Next Generation Science Standards (Michigan Department of Education, 2015). The level of rigor associated with the new standards, as well as the integrated nature that combines not only science and engineering practices, but also disciplinary core ideas and cross cutting concepts, is both more demanding to teach and more difficult for students to demonstrate proficiency (Achieve Inc., 2013; Bybee, 2014). Whereas previous science curriculum was largely presented in isolated concepts, these outcomes have defined performance expectations that require strong content knowledge (Achieve Inc., 2013; Krajcik, Codere, Dahsah, Bayer, & Mun, 2014), but provide little direction on how to teach the content so that the students perform successfully on the performance tasks (Bybee, 2014). The increased focus on the inclusion of engineering design process requires students to develop problem-solving skills that work through problem identification, collaborative solution generation, and the development of prototypes to test and redesign original solutions to presented problems (Bybee, 2014; Capobianco, 2011). Preparing students to be successful with the Michigan Science Standards will directly influence teaching requirements and curriculum development. Local districts will need to provide additional professional development to bolster teachers' instructional preparedness and pedagogical content knowledge in instructional methodology that includes modeling, argumentation, constructing explanations, and the engineering design practices (Bybee, 2014; Christodoulou & Osborne, 2014), as well as inquiry application and greater content knowledge in earth science, engineering, life science, and physical science to effectively improve student proficiency (Cobern et. al, 2014; Trygstad, Smith, Banilower, & Nelson, 2013). According to Banilower et al. (2013), such content is not broadly integrated in current elementary classrooms, nor do teachers feel well prepared to teach that material.

The limited number of science courses required in teacher preparation programs is another Michigan reality that may also complicate the problem. For example, Michigan State University, which has the most prestigious College of Education program in the state, only requires 3 credit hours in science for K-5 certification (Michigan State University, 2014). Such narrow licensure requirements in science may also be related to both the reduction in science instructional time, which is at its lowest in nearly two decades, and the resulting poor proficiency scores (Blank, 2012).

The evidence of limited science content knowledge among elementary students is one that interests different stakeholders and has been capturing the attention of local superintendents, school boards, and curriculum directors. At the November 2014 county curriculum directors meeting that I attended, district leaders unanimously expressed their concern about science achievement scores and charged the regional education service provider to initiate greater support. As the STEM consultant for this provider, I explored elementary teachers' explanations for their students' science knowledge, the current instructional practices employed to teach science, perceived barriers to teaching science, and their self-efficacy beliefs for teaching science.

County school district leadership requested to use this information to improve science programs and increase student achievement in science for compliance within the state accountability system. Other stakeholder groups have an interest in this issue as well. Local residents, who hold high expectations for the success of the area schools, want to see improvement in their children's science scores. During an October 2014 open meeting school board town hall that I attended, parent concerns were communicated to central office and captured in the meeting minutes regarding the need to invest in more STEM education opportunities, and families were critical of the current science programs in the elementary schools within the county. Such parental concerns prompted local school boards to also contact the regional education service provider and request a remedy to the problem. After separate contacts from districts' central administration and local school boards, the education provider has made it a priority to gather perceptual information from county elementary teachers with regard to science curriculum, instructional strategies and confidence delivering science lessons, and the barriers teachers believe may inhibit students' knowledge of science content. To improve student learning in science, it is first necessary to decipher the contributing gaps in practice.

Ultimately it is the elementary teachers who will have the most direct influence on improving student content knowledge (Trygstad et al., 2013), both locally and throughout the state. For that reason it was worth discovering and capturing the perceptions and insights that elementary teachers maintain about the barriers they experience teaching elementary science and their current practices. Therefore, the purpose of this study was to discover elementary teachers' descriptions of their students' science knowledge, the methods and strategies elementary teachers use to teach science, the perceived barriers associated with teaching science, and the elementary teachers' self-efficacy beliefs in teaching science. As part of this investigation, I interviewed teachers about their level of confidence teaching science. Research in science education has shown that the more competent an instructor feels with their understanding of the material, the more successful they are at teaching it. Conversely, educators who have negative associations with science content, or lower levels of efficacy, teach it less effectively (Bursal, 2012a). As a result of this examination of elementary teachers' perceptions about student performance, science teaching, barriers they report, and the issue of teacher self-efficacy, the regional education service provider may provide local districts with direction on how to fill the identified gap in practice and improve student content knowledge in science and attain higher science proficiency scores.

Definition of Terms

There is one conceptual term that is associated with this analysis that warrants further explanation. The term *self-efficacy* in the study refers to the confidence teachers have teaching a given topic, as well as the belief that their instruction contributes to the success students demonstrate in that subject area (Bandura, 1997). The work of Bandura (1997) and other researchers has established that one's past experiences and level of self-esteem contribute to the belief in oneself to effectively implement planned actions with specific outcomes in mind. That internal belief in one's ability is referred to as self-efficacy (Bandura, 1997; Dembo & Gibson, 1985; Koballa & Glynn, 2007), and it has been linked to effective elementary science instruction (Newton & Newton, 2011).

Significance of the Study

This study may have positive implications for many stakeholders in Wise County school districts. First, by revealing impediments elementary science teachers maintain, county level strategic action planning can be developed to overcome those barriers with the ultimate goal of improving student learning in science. School improvement efforts in science may benefit students as they better understand the content, build a strong foundation within the sciences, and potentially increase their affinity for the subject matter, which could inspire them to pursue a career in STEM. Second, the findings and subsequent action steps may benefit local elementary teachers by revealing the needs they have to more effectively teach science content and participate in targeted professional development to achieve that goal. Targeted professional learning for elementary science teachers may also influence teachers at the secondary level, who may discover that there is less need to teach lower level science skills to their students, and therefore they can invest in more rigorous science investigations. Third, it may benefit personnel at the local regional education provider organization through the identification of targeted teacher professional development on content and instructional strategies that might help teachers improve student learning. Fourth, local curriculum directors may benefit by being more informed about the challenges and strengths of their existing science curricular programs. The findings could serve as a basis for potential program evaluations or revisions to improve student learning. Fifth, this study may provide useful data to area universities, as colleges of education want to ensure that their elementary education graduates are amply prepared to successfully teach science content.

Although there is a good moral rationale for supporting students through this analysis, there are political benefits to local superintendents and school boards as well. Improved student achievement translates into a higher state ranking, better publicity in the community, and increased chances that families will want to send their children to those successful schools.

In 2012, the Michigan Department of Education was given a waiver from the NCLB legislation, and one of the provisions was to establish a top-to-bottom ranking system of schools based upon proficiency, improvement trends, and the achievement gap (Riddle et al., 2012). Schools are now identified and ranked based upon 2-year achievement trends in combined core content proficiency scores. MI School Data searches reveal that of the 82 schools in the county, 23 have been identified as focus schools with large achievement gaps between the top and bottom 30% of students, and seven schools have been classified as priority schools as they are among the bottom 5% of schools in the state. In each case, the percentage of students not attaining proficiency status on state science exams has had a negative influence on the top-to-bottom formula, which, if unchanged, could lead to additional sanctions against the district, including the school being taken over by the state. This is a problem both within the county and throughout Michigan. Consequently, area district leaders are politically motivated to better understand the issue in order to improve science achievement, their position in the top-to-bottom ranking, and prevent local schools from begin taken over.

There are many local stakeholders who will potentially benefit from this analysis, its findings, and subsequent action plans. Although the common goal is to improve student knowledge of science, greater clarity must first be determined to achieve that end.

Research Questions

The purpose of this instrumental case study was to discover elementary teachers' descriptions of their students' science knowledge, the methods and strategies elementary teachers use to teach science, the perceived barriers associated with teaching science, and the elementary teachers' self-efficacy beliefs in teaching science.

The study centered around four primary research questions:

RQ 1: How do elementary teachers describe their students' science knowledge?

RQ 2: What methods and strategies do elementary teachers use to teach science?

RQ 3: What do elementary teachers perceive to be barriers to teaching science?

RQ 4: What are elementary teachers' self-efficacy beliefs for teaching science?

To investigate these perceptions, a sample of 15 Wise County elementary teachers were interviewed to discover perceived factors that they believe may be associated with the students' knowledge in science, their science teaching practices, and any impediments they encounter teaching science. Because evidence has suggested that teacher confidence in science is related to student success (Berg & Mensah, 2014; Gunning & Mensah, 2011), capturing a sample of local teachers' confidence levels was relevant.

According to the literature, there are several factors that have had an effect on elementary science instruction and student achievement. First, the effects of NCLB legislation led to a greater emphasis on reading and mathematics, resulting in teachers reducing the total number of instructional minutes in science (Berg & Mensah, 2014; Blank, 2012; Keeley, 2009; Milner et al., 2012). Second, because science achievement scores were not part of the original accountability requirements in elementary school, administrative attention focused more on improving achievement in reading and mathematics (Keeley, 2009). Third, studies showed that when examining professional development, teacher preparation, and certification prerequisites, elementary teachers could benefit from additional training in science to support content and pedagogical content knowledge (Gunning & Mensah, 2011; Saçkes, 2014; Shen, Gerard, & Bowyer, 2010). Fourth, there is evidence that a teacher's confidence in science teaching, or efficacy, directly influences student achievement and influences the teacher's instructional methods (Cakiroglu & Isiksal, 2009; Downing, 2011; Ucar & Sanalan, 2011). Finally, although there are many benefits to integrating an inquiry-based model of science learning (Blank, 2012; Havice, 2009; Inel & Balim, 2010; Olgun, 2009; National Research Council, 2012; Tessier, 2010), there are many barriers that inhibit teachers from its inclusion (Carlone, Haun-Frank, & Kimmel, 2010; Marshall, Horton, Igo, & Switzer, 2009; Sahin, Isiksal, & Ertepinar, 2010; Seung, Park, & Jung, 2014; Sindel, 2010; White & Harrison, 2012).

County trends demonstrated the limited science knowledge among elementary students and the resulting static science achievement scores. Because districts are required to demonstrate growth for state-level accountability in Michigan's formula for the NCLB waiver, it was necessary to investigate the impediments local teachers believe may be associated with the poor student achievement in elementary science and discover how the standards are currently being taught.

Review of the Literature

When examining the theoretical framework related to successful student learning experiences of science, a significant amount of research has been devoted to the theory of social constructivism (Amirshokoohi, 2010; Dorph et al., 2011; Vygotsky, 1978**)** and teacher self-efficacy (Bandura, 1997). At the same time, evidence also suggested the conceptual framework of inquiry-based models of instruction is an instructional paradigm that also improves student achievement in science (Forbes & Zint, 2011). Within this study it was pertinent to discover if these theories were relevant.

Theoretical Foundation of Social Constructivism

Social constructivism is part of the theoretical framework in this analysis, as researchers have asserted it to be the most appropriate instructional design to support science learning (Zion & Mendelovici, 2012). The social constructivist method describes a student-centered environment that is rich with collaborative interactions as they are considered to be integral for discovery and learning (Downing, 2011; Ergül, 2009). In a social constructivist framework, students engage in interactions with both the teacher and other students, enabling them to construct knowledge (Inel & Balim, 2010; Syh-Jong, 2010). The content the teacher presents must be personally meaningful to the student, and the process for learning it requires both collaboration and active participation (Amirshokoohi, 2010; Dorph et al., 2011; Vygotsky, 1978). Finally, the concept of children's play is emphasized in a social constructivist framework as a necessary component of learning (Vygotsky, 1933). The interview data from the teacher sample revealed how frequently a social constructivist method was employed to teach science content at the elementary grades.

Constructivists like Bartlett (1932) expanded attention beyond the conditioning strategies employed by the behaviorists and the information processing beliefs of the cognitivists to emphasize the importance of personal interpretation of experience and the interaction with materials to construct knowledge. This philosophy further evolved with

Piaget's (1954) definition of cognitive constructivism and the recognition of developmental sequential stages that all young learners experience through the act of discovery. Most would agree that the constructivist approach to learning closely aligns with the strategies associated with effective science instruction (Dorph et al., 2011; Olgun, 2009; Qualter, 2014), particularly with the potential for exploration and inquiry. Piaget asserted that a classroom should offer a variety of activities to challenge learners in personally meaningful ways, but his position limits the role and value of both the teacher and peers during the learning process. According to the work by Zion and Mendelovici (2012), the teacher is instrumental in designing experiences in which students can work together through a process of guided inquiry and construct science-related knowledge. Through a social constructivist inquiry approach, students are afforded experiences that mirror the authentic work of research and experimentation practiced by scientists in the field (Zion & Mendelovici, 2012). At the same time, field science is largely collaborative in which scientists rely on the insights of one another throughout the scientific process. Therefore, it is necessary to provide similar experiences for students of science (National Research Council, 2012).

Vygotsky's (1933, 1978) emphasis on the social influence of learning, however, makes the social constructivist model even more comprehensive and better supports the modern interpretation of an effective constructivist approach to the teaching and learning of science content through interaction, critical thinking, and problem-solving (Marshall et al., 2009). Research has demonstrated that young learners have already constructed a great deal of science knowledge through self-directed experimentation with objects in their world; therefore, schools must continue to provide opportunities to construct understanding while offering adult guidance (National Research Council, 2012). Such a learning environment offers an abundance of resources that enable students to collaboratively work together while exploring content in an active way (Dorph et al., 2011; Olgun, 2009). This kind of constructivist setting maximizes student desire to interact with, observe, analyze, synthesize, and reflect on information under the guidance and facilitation of the teacher. Such firsthand student experience is touted as the ideal way to teach science (National Research Council, 2012) and has the potential for building a level of enthusiasm that could later inspire students to seek out science-related careers (White & Harrison, 2012; Zhe, Doverspike, Zhao, Lam, & Menzemer, 2010).

Finally, as referenced by Vygotsky’s (1978) zone of proximal development, although learners have an optimal developmental time to learn specific content, the complexity of the content can be enhanced when coupled with social interactions and active involvement, and in the case of science content emphasized in the elementary years (Dorph et al., 2011; Osborne, 2003; Qualter, 2014). The research supported the inclusion of a constructivist approach to learning institutions, as the evidence demonstrated improved student learning across content areas regardless of the age of students (Blank, 2012; Fang, Kang, & Feng, 2009; Heafner & Friedman, 2008; Sulaiman, Suan, & Abdullah, 2009). As a result of these findings, it is evident that elementary students who receive this manner of instruction experience enhanced achievement in science. Therefore, it was my intent to discover teacher perceptions on the value and inclusion of social constructivist learning within their current science instruction.

Theoretical Foundation of Teacher Self-Efficacy

The concept of teacher self-efficacy, or confidence in teaching specific content, has been linked to influencing a teacher's actions in the classroom (Aydin & Boz, 2010); however, it is also necessary to examine what influences teacher efficacy. Bandura (1997) suggested that there are four modes that affect self-efficacy, which include mastery experiences, vicarious experience, verbal persuasion, and physiological and affective states. By definition, individuals who have had a history of successful experiences in certain areas will develop a sense of mastery and confidence (Bandura, 1997). Conversely, repeated failures would likely inhibit one's efficacy, confidence, and resilience to persevere. Mastery experiences have the most profound effect on determining one's level of efficacy. Vicarious experiences also contribute to one's efficacy, but they develop when observing the success of others. As the observer witnesses another's success, they visualize themselves in that same activity and develop confidence to emulate them, thereby enhancing their own efficacy. According to Bandura, other people's remarks or verbal persuasion can also foster self-efficacy. When words of encouragement are offered and belief in one's potential for success is communicated, the recipient's level of efficacy could be enriched. Finally, Bandura's fourth identified experience that could influence efficacy relates to one's physiological or affective state. For example, if one is stressed or has poor associations about a specific task, he or she is less likely to believe he or she will be successful. Bandura explained that the combination of both self-efficacy and outcome expectations effect teacher performance and behavior.

With respect to science instruction, Oleson and Hora (2014) found that teachers emulate their former teachers and, depending on their role model, might enhance or diminish their level of confidence for teaching science effectively. Researchers found similar patterns of students emulating their instructors in teacher preparation courses (Bergman & Morphew, 2015). Because people are the product of their experiences, if teachers had negative associations as a science student or when learning to teach science, their confidence level would be compromised, compelling them to spend less time teaching science or to be less willing to invoke strategies that are not familiar to them (Knaggs & Sondergeld, 2015). Due to the required content knowledge, material preparations, and classroom management considerations, for some teachers the thought of teaching a science lesson may be a stressful one, particularly for a self-contained instructor who is teaching multiple subjects (Strohl, Schmertzing, Schmertzing & Hsiao, (2014).

Studies have supported the importance that efficacy has in teacher preparation and classroom instruction. For example, Aydin and Boz, (2010) investigated 492 preservice teachers in Turkey, measuring their self-efficacy and content knowledge in teaching science. They not only found that preservice teachers' efficacy was high resulting from the coursework mastery experiences, but also that their level of efficacy affected their classroom actions and teaching confidence. Bayraktar (2009) found similar results in his study of preservice teachers who took two semesters of science methods courses after completing requirements in physics, chemistry, and biology. The additional classroom experience improved not only their efficacy, but also their attitudes toward the content, which carried forward into their in-service work.

As Bandura (1997) suggested, prior negative experiences in science can negatively affect one's efficacy and inhibit success, regardless of the number of content courses taken. Because most elementary teachers teach all content areas, they may be required to teach subjects that have been historically challenging for them. If teachers have poor associations, they may generalize or transfer those memories into later instructional experiences (Yürük, 2011).

Negative prior experiences in science can inhibit teachers wanting to not only learn science content, but also teach it. Bleicher (2009) found that teachers who reported being fearful about learning science based upon personal history had more difficulty teaching science content and were less inclined to use constructivist-learning strategies than teachers who felt confident learning science. The study confirmed the predictive nature that teachers who are confident to learn science will have improved efficacy and greater content knowledge (Bleicher, 2009). Therefore, a teacher's experiences result in associations and attitudes for specific content and influence classroom instruction. A teacher's negative attitudes about science influence his or her self-efficacy, which translates into less effective instruction (Bursal, 2012a).

Bandura's (1997) theory further emphasizes the role of the social environment as an instrumental source of self-efficacy; particularly through mastery experiences learned collaboratively, vicarious experiences modeled by peers, and verbal persuasion from collegial support. Bursal (2012b) corroborated this belief in his study of preservice science teachers, noting the predictability of those who perceive peer support in the learning environment to develop greater self-efficacy in teaching science. Consequently, there are certainly implications for the benefits of students and teachers learning in groups. Bursal found that the social environment was an integral factor in developing content knowledge and predictive of the level of efficacy that resulted. When teachers collaborate during the planning and evaluation of science instruction, their confidence to teach the material increases. With this study, I wanted to discover if such collaborative planning and evaluation opportunities were afforded to Wise County elementary teachers.

According to Gunning and Mensah (2011), many preservice and in-service teachers have low efficacy with respect to science teaching. The authors asserted that many elementary teachers have inadequate content knowledge and negative associations that equate to heightened anxiety and a decrease in instructional confidence. Having a low efficacy with science teaching is also associated with less time dedicated to science instruction (Bayraktar, 2009; Dorph et al., 2011; Özdilek & Bulunuz, 2009). Other studies have demonstrated that teachers with low efficacy in science instruction tend to be more authoritarian and teacher centered than a teacher with higher efficacy who has higher confidence and utilizes student-centered inquiry based instruction more readily (Önen & Kaygisiz, 2013; Özdilek & Bulunuz, 2009; Sindel, 2010; Yürük, 2011).

Within the context of Bandura's (1997) theoretical framework, the concept of self-efficacy had significant implications in this study, as it is apparent that improved teacher efficacy is related to improved student learning (Albion & Spence, 2013; Aydin & Boz, 2010; Bleicher, 2009; Bursal, 2012a; Duran, Ballone-Duran, Haney, &

Beltyukova, 2009; Liang & Richardson, 2009; McDonnough & Matkins, 2010; Özdilek & Bulunuz, 2009; Riggs & Knochs, 1990; Sindel, 2010; Yürük, 2011), and therefore is an element in this study that should be explored.

Review of the Broader Problem

This section provides details on the national trends in elementary students' limited science content knowledge, evidenced by static science achievement, and introduces a number of themes within the literature that have been linked to a decline in science achievement. Keyword searches in current scholarly peer-reviewed journals on elementary science and proficiency scores brought forward barriers associated with science achievement. Identified topics included the results of NCLB legislation, limited teacher preparation and professional development among elementary science teachers, teacher self-efficacy, and instructional methods for teaching science. Each of these factors contributed to the science knowledge of Wise County's students.

While static achievement has been the trend in elementary science for districts in Wise County, that same pattern has been evident at the national level when researching national and international assessments. Stagnant science achievement scores are a reality that have been captured nationally on the Trends in International Mathematics and Science Study (TIMSS), an assessment administered to fourth graders every 4 years. According to the National Center for Education Statistics (2014), there was no significant change in the fourth grade average score from 1995 (542), to 2007 (539) or the average result in 2011 (544). Similarly, eighth graders on the TIMSS had an average score of 520 on the 2007 test and 525 four years later. The same trend was captured in the National

Assessment for Educational Progress (NAEP, 2011a) where the first-time science tested eighth graders had an average score change of 2 points between 2009 and 2011. Those same students were surveyed on how often they engaged in hands-on experimentation in their science classes. Eleven percent of the eighth graders reported that they engaged in such tasks nearly every day, while those selecting once or twice each week fell from 55% in 2009 to 47% in 2011 (NAEP, 2011b). According to these data, 42% of the eighth graders surveyed reported that they may experience hands-on investigations one to two times per month if at all. At the same time that science scores have plateaued, the United States has been seeking out more students gravitating to STEM fields. It has been routinely reported that there is a shortage of STEM professionals entering those fields within the United States (White & Harrison, 2012; Wyss, Heulskamp, & Siebert, 2012) and that the United States is underperforming when compared to other countries in mathematics and science (National Center for Education Statistics, 2014; Shen et al., 2010). Consequently, in 2009 President Obama challenged the United States to make STEM education a priority to become globally competitive (Obama for America, 2009). Meanwhile, national scholars have directed attention to the inadequate instruction that is taking place in elementary classrooms (Dorph et al., 2011; Keeley, 2009; Sanghee & Ramsey, 2009). It has been reported that many elementary educators lack the necessary knowledge and confidence to effectively teach science, both of which are correlated to inquiry investigations and integral in STEM education (Milner et al., 2012).

According to the NAEP (2011b), 69% of Michigan eighth grade students reported that they liked or really liked science. This is significant because Archer et al. (2010)

reported that between the ages of 10 and 14 student interest in and attitudes about science falls sharply. At the same time, students in that age range were found to maintain positive associations with the content when it was presented in a real-world hands-on application manner (Rukavina Zuvic-Butorac, Ledic, Milotic, & Jurdana-Sepic, 2012), so sustaining opportunities and interest in science are just as critical as its initial introduction (Dejarnette, 2012; Qualter, 2014). By addressing the needs of elementary science teachers, it may be possible to increase the number of children interested in science. Bagiati, Yoon, Evangelou, and Ngambeki (2010) found that introducing STEM activities at an early age improved student opinions of those subjects. Additionally, according to Alexander, Johnson, and Kelley's (2012) longitudinal study of 192 children between the ages of 4 and 7, there has been evidence that early interest in science was predictive of students pursuing later learning in science. Increasing student interest in STEM fields has implications both in Michigan and throughout the country.

The desire to improve science education has been a national priority for numerous decades. In 1983, the National Commission on Excellence in Education published a report that identified the need for education reform in order to lead to national prosperity and successful global competition in the "information age" (p. 3). In addition to offering rigorous curriculum, the report identified the areas of science, technology, and mathematics as serving as the means for achieving that global security (National Commission on Excellence in Education, 1983). By 2007, there were 105 separate government-subsidized kindergarten to postgraduate programs that were designed to foster STEM education (Academic Competitive Council, 2007).

Although it is generally accepted that there is a need to fill many future STEM positions in order to remain globally competitive (Bybee, 2010; Dejarnette, 2012; Wyss et al., 2012) and increase engineering opportunities in classrooms (Brophy, Klein, Portsmore, & Rogers, 2008; Rockland et. al, 2010), the United States has not increased the number of postsecondary STEM graduates (Roberts, 2012; Shaw & Barbuti, 2010). Conversely, many other countries that aspire to the same kind of increase in STEM professionals have experienced a dramatic increase in a relatively short time (Kuenzi, 2008). For example, in 2008 China produced 500,000 engineers, India provided 200,000, and the United States contributed 70,000, which concerned American business leaders and politicians (Hughes, 2009), as innovations that result from these fields stimulate the economy (Roberts, 2012). This trend has continued with the percentage of STEM graduates rising in numerous countries (Brown, Brown, Reardon, & Merrill, 2011; Craig, Thomas, Hou, & Mathur, 2011). The Organization for Economic Cooperation and Development (OECD) periodically reports on the percentage of STEM graduates countries produce and then ranks them by the percentage of STEM graduates compared to graduates in other fields within the country. Although the top 10 countries shift positions in each scorecard, the Unites States has not changed its percentage of 16% STEM graduates, the same statistic from 2002, and places the United States in 39th position out of 41 countries in the study. Table 6 illustrates the contrast of the number of college graduates earning degrees in STEM fields among the 41 countries studied.

Table 6

2015 Rank Order of the Percentage of STEM Graduates by Country

Rank	Country	Percentage of STEM Graduates
1	Korea	32
2	Germany	31
3	Sweden	28
4	Finland	28
5	France	27
6	Greece	26
7	Estonia	26
8	Mexico	25
9	Austria	25
10	Portugal	25
11	Spain	24
12	Indonesia	24
13	Switzerland	23
14	Japan	23
15	Russia	23
16	Slovenia	23
17	United Kingdom	23
18	Czech Republic	23
19	Ireland	22
20	OECD overall	22
21	Belgium	21
22	Canada	21
23	New Zealand	21
24	Slovak Republic	21
25	Denmark	21
26	Italy	20
27	South Africa	20
28	Colombia	19
29	Israel	19
30	Hungary	19
31	Latvia	19
32	Iceland	18
33	Luxembourg	18
34	Australia	18
35	Turkey	18

(table continues)

Rank	Country	Percentage of STEM Graduates
36	Norway	17
37	Poland	17
38	Chile	16
39	**United States**	**16**
40	Netherlands	15
41	Brazil	11

Note. *Source:* OECD (2015), *OECD Science, Technology and Industry Scoreboard 2015: Innovation for growth and society*, OECD Publishing, Paris. DOI:http://dx.doi.org/10.1787/sti_scoreboard-2015-en

There is national consensus that supplying a pipeline of STEM professionals is warranted to remain globally competitive and that there is currently a shortage (Chang, 2009; White & Harrison, 2012). According to the United States Department of Commerce, Economics, and Statistics Administration between the period of 2008 and 2018 STEM careers are predicted to increase by 17.8 % nearly doubling the rate of growth in non-STEM positions and 274,000 of those will be in Michigan (Langdon, McKittrick, Beede, Khan, & Doms, 2011). In order to support the development of student interest in STEM within a larger educational context and meet the local needs of districts to improve student achievement in science this research could have significant implications.

Within the professional literature, many studies examining elementary science achievement focused on five themes: teacher preparation, the effect of NCLB legislation, teacher self-efficacy, science teaching methods, and the complexity associated with inquiry-based instruction.

Teacher preparation. Teacher content knowledge in science is another factor that has been associated with influencing student achievement (Berg & Mensah, 2014; Cobern et. al, 2014; Saçkes, 2014; Shen et al., 2010; Zambon & Lempinen, 2011). Miller (2010) points out that elementary teachers are considered subject generalists who tend to favor content areas other than science. This view was corroborated in separate studies in which surveyed teachers identified writing and science as their least favorite subjects to teach feeling most equipped to teach reading (Berg & Mensay, 2014; Wilkins, 2010). Elementary teachers also reported uncertainty with respect to teaching science demonstrating their low efficacy (Capobianco, 2011). Such lack of confidence effects teacher motivation and effectiveness to teach the content (Liang & Richardson, 2009). This insecurity (Forbes & Zint, 2011) may be a result of the small number of teacher preparation courses they took in science, or how those experiences supported their confidence (Avery & Meyer, 2012; Cobern et. al, 2014; Saçkes, 2014).

Studies have shown that a single semester course does not provide enough experience to alter attitudes toward the content or instill confidence in teaching it (Amirshokoohi, 2010; Cobern et. al, 2014; Ucar & Demircioglu, 2011). In most teacher preparation programs, teachers are rarely required to take more than a few science courses (Roychoudhury & Rice, 2010). For example, in the state of Missouri, Sindel (2010) pointed out that the state elementary certification only calls for one three-credit science methods course for state licensure communicating that science is not a priority content area in elementary schools, nor requires much advanced training. Michigan has similar certification requirements even in its top education university (Michigan State

University, 2014), which requires a single three-credit methods course. Although preservice teachers could elect to take more science courses to improve their content knowledge, Bleicher (2009) discovered that elementary teachers would take as few as possible. Preservice teachers found the science classes too difficult and not engaging, often experiencing the instruction in a lecture setting covering too broad a range of material, which provides little guidance for effective classroom application (Bergman & Morphew, 2015). As limited as most state certification science requirements are, researchers found that few elementary teachers seek out additional science professional development once in the classroom. Dorph et al. (2011) found that more than 85% of classroom teachers surveyed received no science professional development in over three years, which compounds the problem of ample teacher preparation for science content and pedagogical methods. Limited professional learning in science might influence teacher confidence, dedicated time for science teaching, and the quality of instruction that occurs.

There is a need for teachers to acquire both sound content knowledge and pedagogical content knowledge to improve student achievement (Cobern et. al, 2014; Shen et al., 2010; Zambon & Lempinen, 2011). When combined with a teacher who is enthusiastic for the material and uses an inquiry-based instructional approach, educators not only improve student achievement, but also increase student curiosity and affinity for the subject (Bolshakova, Johnson, & Czerniak, 2011). Their investigation further asserted that teachers who are more effective science instructors employ student-centered methods that stimulate student confidence and increase the likelihood that their students will eventually select science-related careers. Subsequently, one's science teaching style yields a variety of student outcomes thereby requiring teachers to secure professional growth in both pedagogical and subject content knowledge (Gunning & Mensah, 2011).

Although additional science courses taken during teacher preparation programs can bolster teacher confidence and competence once in the classroom, the final grades preservice teachers receive could also negatively affect later confidence (Yürük, 2011). Yürük (2011) asserted that earning a poor final grade in a college science course is predictive of the level of anxiety a teacher feels teaching that content. Teacher preparation can positively build teacher confidence in science instruction or inhibit that teacher through associations of anxiety.

The degree to which science teaching anxiety affects a teacher influences classroom practice as well. Yürük (2011) found that teachers whose anxiety levels are high tend to be more authoritative, initiate teacher-directed instruction, have an increased likelihood that they will abandon a science lesson prematurely, spend less time on science instruction, and employ less creative instructional methods in their classroom. Conversely, educators who have less anxiety employ more student-centered approaches while integrating guided inquiry experiences (Önen & Kaygisiz, 2013). Therefore, teachers' prior experiences and moments of success in science, and resulting level of anxiety, are directly related to the kind of science instruction they will practice.

Student achievement in science, as in other subjects, is directly linked to the quality of the instructor (Bulunuz & Jarrett, 2010; Shen et al., 2010), so effective teacher training is integral. Discovering the teacher preparation and professional learning Wise

County teachers had experienced provided additional insight into the limited science content students demonstrate on state assessments.

NCLB legislation. Since the inception of NCLB legislation, there has been a reduction in the amount of instructional time devoted to teaching science at the elementary level (Blank, 2013; Keeley, 2009). According to studies by Griffith and Scharmann (2008), this equated to a reduction of 31 to 60 minutes per week among K-6 teachers. These data were corroborated in a study that found that 40% of California's elementary teachers devoted an hour or less to science instruction each week (Dorph et al., 2011). The documented reduction in science instruction was most apparent after the **NCLB** legislation was enacted, and the amount of time devoted to reading and mathematics instruction increased (Milner **et al.**, 2012; Riddle et al., 2012).). This exchange led to ever decreasing time devoted to science instruction, which is at its lowest in over 25 years (Blank, 2012).

When NCLB was first enacted, states were not required to include science achievement scores in their AYP calculations. Omitting science scores in the federal AYP calculation was the norm even during the 2007-2008 school year when districts were directed to test Michigan students in science three times during grades 3-12 (Judson, 2010). Because science was not an integral component for AYP accountability, educators elected to emphasize mathematics and reading (Dorph et al., 2011; Keeley, 2009). However, in time some states chose to include science scores in their AYP calculations, which resulted in statistically higher science scores on the fourth grade NAEP test for those states (Judson, 2010; Milner et al., 2012). The same trend was not noted in the eighth grade science NAEP scores. By that age most core content instruction is already departmentalized with dedicated instructional time, and therefore seemed to be less effected by the NCLB legislation.

Milner et al., (2012) surveyed a total of 672 elementary teachers before and after the enactment of NCLB with respect to their beliefs about science instruction. Although teachers' attitudes about the importance of science remained constant, the amount of science instruction delivered to students had been reduced. Florida and Pennsylvania were two of the states that opted to include science in their AYP formulas, and as a result, increased their science instructional time compared to before the NCLB accountability measures. However, teachers also reported that due to the pressures they felt from high stakes testing, they resorted to more fact memorization and drill and practice in their instruction than on hands-on inquiry based methods (Milner et al., 2012). The survey further reports that some teachers were given administrative directives to reduce the amount of time devoted to teaching science in order to focus more instructional time to reading and mathematics.

The increased stress associated with accountability and high-stakes assessments caused many classroom teachers to teach directly to the test (Pinder, 2013). Judson (2010) found that teaching to the test was a common practice particularly among teachers in low-income minority school settings where students had to complete more paper pencil tasks rather than engage in hands-on investigations. Economically disadvantaged minority students benefit more from hands-on experiences to master content (Aydeniz & Southerland, 2012). The paradox lies within the fact that NCLB was intended to increase the rigor associated with content, yet the tests required a shallow level of knowledge thereby reducing the level of rigor in both the instruction and the accompanying assessments (Owens, 2009). In the midst of calling for greater emphasis in inquiry science, the accountability system led to assessments that rely on multiple-choice questions requiring little depth of knowledge and prioritize different content (Judson, 2010).

According to a survey of 161 teachers representing 14 states, those educators reported the sentiment that NCLB challenged the science education reform movement with its overreliance on multiple-choice standardized testing and a de-emphasis on fostering higher order thinking skills (Aydeniz & Southerland, 2012). The study revealed that the teachers surveyed felt that the depth of knowledge in tested science content was becoming too superficial, and that NCLB accountability testing caused 93% of the educators to alter their science assessment practices by reducing project-based assessments in exchange for multiple-choice exams. Instructional time was further compromised with 90% of the teachers reporting an increase in time dedicated to test taking strategies rather than delivering content (Aydeniz & Southerland, 2012). This is in direct opposition to the science reform movement that calls for an increase in project-based experiences, as they not only improve student affinity for the content, but also clarify the links between abstract theories and real world scientific applications (Dorph et al., 2011; Forbes & Zint, 2011).

Even with the addition of NCLB requirements for science testing, there has not been an increase in dedicated instructional time for science. Rather, many surveyed teachers identify administrative directives to disregard or reduce science instruction in order to support students in mathematics and reading (Milner et al., 2012). In Upadhyay's (2009) study the author explored the conflict that teachers feel to make science content meaningful for their students juxtaposed against the administrative pressures to have the students perform well on the assessments. The findings revealed that teachers believe authentic science experiences requiring active participation and construction of knowledge are critical, yet the time required for inquiry based participatory science is not a priority (Berg & Mensah, 2014; Upadhyay's, 2009).

At the same time, Miller (2010) discovered in his qualitative investigation of two schools that elementary teachers already shy away from teaching science. Miller asserts that the constraints associated with NCLB warrant districts to provide more professional development, coaching, and increased content knowledge for elementary teachers.

Every Student Succeeds Act (ESSA) is the legislative replacement for NCLB. The new accountability system still heavily relies on state testing and identification of a percentage of schools that underperform (Penuel, Meyer, & Valladares, 2016). In addition to the state student achievement proficiency results, additional accountability indicators in the ESSA include English proficiency, evidence of student growth, and a fourth indicator of school excellence or student success outside state testing (Penuel, Meyer, & Valladares, 2016).

Teacher self-efficacy. An elementary teacher's attitude toward a subject has the most significant influence on a student's attitude toward that subject (Akgun, 2009; Ustuner, Demirtas, & Comert, 2009). However, many elementary teachers report feeling reluctant to teach science, while others openly admit to dreading it (Dorph et al., 2011; Sanghee & Ramsey, 2009). Therefore, these attitudes and level of confidence or personal efficacy influences elementary science instruction (Bulunuz & Jarrett, 2010; Newton & Newton, 2011).

Bulunuz and Jarrett (2010) studied 53 preservice teachers and administered a Sciences Background Experiences Survey. Preservice teachers who had an interest in teaching science demonstrated a significant difference in recalling positive science experiences growing up and included memories of real world science experiences and exploration as an elementary student. This study has implications for not only the importance of elementary classroom science experiences and its relationship to subject affinity in later years, but also for its relationship to teacher efficacy for teaching that content.

Most elementary teachers feel confident to teach reading and mathematics while only 30 % share that same confidence to teach science (Dorph et al., 2011). The anxiety that most elementary teachers report for teaching science has been attributed to their science experiences during their K-12 learning experience (Gilbert, 2009). These incidents include descriptions of lecture-based instruction and a reliance on textbooks that were challenging and boring, which led to their aversion for the content (Bergman & Morphew, 2015; Gilbert, 2009; Fitzgerald, Dawson & Hackling, 2009). These experiences were not limited to college courses, but also could be traced back through the elementary years as being influential on their affinity for the content and their self-efficacy beliefs for teaching it (Mansfield &Woods-McConney, 2012). Collectively, these researchers asserted that teachers need an increased level of content knowledge to create a science-rich environment to actively engage students through inquiry while mastering science concepts. However, to increase teacher confidence and content knowledge, it is necessary to provide different learning experiences in which teachers become engaged with the content and develop meaningful connections for themselves and with students (Bybee, 2014; Houseal, Abd-El-Khalick, & Destefano, 2014). These experiences align with Bandura's (1997) findings on the importance of mastery and vicarious experiences, as well as memories and feelings that influence teachers' attitudes. Developing successful mastery experiences for elementary science teachers has implications for ongoing professional learning (Mansfield & Woods-McConney, 2012).

Educator professional development seldom focuses on the ways in which science is taught or the belief that teachers maintain about science teaching, but rather focus more on training to expand content knowledge (Milner et al., 2012). The self-efficacy that does result from ample teacher preparations in pedagogical content knowledge (Goodnough & Woei, 2009) however can, and does, influence the affinity for the subject and reduces potential anxiety for teaching it (Downing, 2011; Ucar & Sanalan, 2011). Additionally, one's efficacy positively affects both the methods and the quality of instruction (Cakiroglu & Isiksal, 2009). Coupled with professional learning that generates a repertoire of instructional strategies that engages students through inquiry and investigation, teachers are more likely to effectively teach science (National Research Council, 2012). Those more confident teachers recognize the value of inquiry models and report wanting to use a constructivist approach of inquiry and experimentation in their own classrooms, and most feel equipped to do so (Ergül, 2009). This assurance and improved self-efficacy (Sindel, 2010) in turn is directly related to the amount of time teachers devote to inquiry-based instruction in their daily instruction (Marshall et al., 2009).

Science teaching methods. Researchers have found that active learning models in science have better student outcomes than traditional teaching strategies (Wieman, 2014). Within such models students spend the majority of their learning time interacting with materials and peers to investigate phenomenon, grapple with problems, collect data, and apply information. Conversely, traditional science instruction is described as a more passive experience with students spending the majority of class time listening to teachers sharing factual information, taking notes, and reading from a science text (Bergamn & Morphew, 2015; Wieman, 2014). Science students in traditional instructional models have greater difficulty relating to the abstract content and disengage from the learning (Jordan et al., 2014), and they are 1.5 times more likely to fail than students in an active learning setting (Freeman et al., 2014).

Active learning models generally involve experimentation (Chamundeswari & Franky, 2015) in which students conduct experiments around disciplinary core ideas in science. During active learning students observe phenomenon and consider prior knowledge to explain their interpretations (Christodoulou & Osborne, 2014; Stewart & Eick, 2010). Students also engage in exploration to test their hypotheses (Oppong-Nuako, Shore, Saunders-Stewart, & Gyles, 2015). Within an active classroom model, students engage in discourse and argumentation, in which they provide explanations based on evidence (Christodoulou & Osborne, 2014). Each of these elements has been identified as being effective for teaching science (National Research Council, 2012). Additionally, students who experience active learning perform better in science, math, and on engineering tasks (Freeman et al., 2014).

The method elementary science teachers elect to launch a classroom investigation may differ. Some instructors successfully teach their students incorporating a problem-based start (Inel & Balim, 2010). Investigating the problem could lead to a project-based learning opportunity, which improves science achievement and interest in the content (Rivera Maulucci, Brown, Grey, & Sullivan, 2014). It may also involve place-based investigations in which students examine problems in real-world settings (Buxton & Provenzo, 2012) and researchers have found that these experiences surpass the learning that occurs in traditional models of instruction as well (Adams, Miller, Saul, & Pegg, 2014). Other elementary teachers may rely on the integration of trade book literature to support their science instruction. This may be problematic, however, as researchers have found that the narrative nature of the literature can lead to misconceptions and may not provide enough science context for students to understand the content (Smolkin & Donovan, 2015). The authors assert that reliance on such literature may be traced to educator insecurity with teaching science content. The use of science kits is also a common practice among elementary teachers, however without ample professional learning they may not get used or implemented correctly (Dickerson, Stewart, Hathcock, & McConnell, 2014). The use of kits does not guarantee improved student learning without informed teacher facilitation (Slavin, Lake, Hanley, & Thurston, 2014).

What sets apart active models from traditional ones is the students' mental and physical connection to the content. Additionally, such active science education has been shown to positively influence student achievement (Blank, 2012; Inel & Balim, 2010; Schmid, 2015), requires higher order thinking skills (Zion & Mendelovici, 2012), leads to better retention of material (Schmid, 2015), enhances confidence with the subject (Rivera-Maulucci, Brown, Grey, & Sullivan, 2014), as well as improves teacher attitudes toward the content (Olgun, 2009; Tessier 2010). Discovering the instructional methods employed by Wise County science teachers may help interpret their perceptions about student content knowledge.

Inquiry-based instruction. Inquiry-based instruction is an example of an active instructional approach that has been researched extensively. It encompasses the idea of hands-on experimentation with materials, stimulated by an intriguing problem to solve, and follows the scientific method. Havice (2009) reported that inquiry-based instruction motivates students to understand the material, stimulates improved engagement, perpetuates satisfaction in the learning process, and inspires them to communicate their classroom enjoyment and pride in their accomplishments.

The inquiry process has several discrete steps that begins with a scientific question. Students then make hypotheses or predictions that can be investigated with collected and analyzed data. Finally, students answer the original question using evidence from their data, which can be compared with other explanations (National Research Council, 2012). Within the framework of inquiry, there are several approaches educators could take. Zion and Mendelovici (2012) describe the difference between structured, guided, and open inquiry models. Structured inquiry is teacher-directed and includes sequentially working through steps, but is deemed insufficient for generating strong content knowledge. Guided inquiry is more student-centered and requires students to work through the entire process with the exception of determining the question to be investigated, which is provided by the teacher. In an open inquiry design, students also generate their own questions, which most resemble the work of field scientists. A guided inquiry approach is deemed the preferred method for teachers to utilize in the elementary grades and involves guided hands-on problem solving, however the model is not commonly practiced (Zion & Mendelovici, 2012).

The inquiry process in the United States was influenced by the work of education reformer and prior science teacher John Dewey (1910), who emphasized a more student-centered approach in science instruction and the need for students to engage in real-world science experiences and challenges. Prior to this movement, Dewey was concerned about the prominence of learning facts without understanding scientific principles (Dewey, 1910). He recommended that content align with student's intellectual ability so that their active interactions with the materials permitted them the opportunity to find the answers to problems presented (Dewey, 1938). Under Dewey's model for science instruction, students would work through the scientific method process in which they identify a problem, formulate a hypothesis, collect information through experimentation and develop conclusions (Barrow, 2006). This practice emphasizes student active engagement with the teacher serving as the facilitator.

For over 30 years field scientists and science educators have stressed the significance of inquiry-based models of teaching to be the most appropriate method for students to understand science-related content (Forbes & Zint, 2011). In doing so, the classroom method of inquiry learning mirrors how field science is actually conducted and gives students experience constructing knowledge in a real-world fashion (Zion & Mendelovici, 2012).

Researchers demonstrate the learning benefits of inquiry-based instruction as well. In Houseal's (2010) study, elementary students exhibited an increase in science content knowledge. Deslauriers, Schelew, and Wieman (2011) found similar results noting that not only did the students perform better on the post-tests, but also demonstrated better attendance and engagement than the control group who were taught in a traditional lecture style format. Marshall and Alston (2014) found in their five-year study that students exposed to inquiry methodology attained higher proficiency in each subgroup than students not taught within an inquiry model. Medical researchers have also found that the inquiry process of learning reduces the body's emission of cortisol reducing stress (Yang, Han, Shin, Lim, & Lim, 2014), which could affect the level of anxiety students associate with science learning.

The inquiry-based approach is effective for preservice and in-service teacher training as well. Özdilek and Bulunuz (2009) analyzed the influence of a 14-week inquiry-based science methods course on 101 preservice teachers. Their findings indicated that the constructivist inquiry approach helped the teachers develop sound content knowledge, even with abstract concepts. Additionally, the inquiry process increased their confidence and efficacy to teach science and influenced their perception that a guided inquiry approach is the most effective way to teach science. Sanghee and Ramsey (2009) found similar results after researching in-service teachers who took a three credit inquiry-based course and measured their change in attitudes toward science. After the conclusion of the course, the teachers reported being more knowledgeable about an inquiry approach and felt more confident to include the method in their classrooms.

Teachers and students benefit from a constructivist inquiry approach (Sindel, 2010). However, there is evidence that many teachers do not understand how to teach using an inquiry model and that they need more professional learning to effectively integrate it into instruction (Sanghee & Ramsey, 2009; Seung et al., 2014; Sindel, 2010; Tan & Lim, 2014). Those teachers who have been trained in inquiry support the idea of its inclusion in the elementary grades and believe it is valuable for improving student content knowledge in science (Forbes & Zint, 2011). Currently, teachers find inquiry-based instruction incompatible with the restrictive daily instructional demands making guided inquiry not commonly practiced in elementary science instruction (Zion & Mendelovici, 2012). According to Gilbert (2009), even though 80% of the elementary teachers he studied intended to incorporate a constructivist inquiry-based method within their classrooms, many abandoned the approach once in the field due to several reported obstacles. These included time constraints, the requirement to use scripted programs, an emphasis on testing, and that the chaos associated with constructivism was too hard to manage (Berg & Mensah, 2014; Gilbert, 2009). Dorph et al. (2011) supported these findings, and also found that lack of parental support was another inhibitor. Other reported impediments include limited materials, having no curriculum, and administrative disapproval (Milner et al., 2012).

When support for inquiry-based instruction is institutionalized, the outcome is very different. For example, the constructivist movement for science instruction is not limited to the United States, as other countries are grappling with a similar challenge, the need to fuel the pipeline in STEM careers and the best ways to support the teaching and learning of those content areas (Langdon et al., 2011). Australian schools, for example, identified that only 3% of their elementary instruction was dedicated to science and in their efforts to increase science instructional time and expand its inclusion in the elementary grades, institutionalized an inquiry-based curricular model (Albion & Spence, 2013). Inquiry methods training was predicated on the fact the elementary science teachers lack confidence and need both pedagogical and content knowledge. The effects of the initiative in Queensland, Australia have been the inclusion of inquiry-based instruction, embedded cooperative learning and practice problem solving, and an increase in dedicated science teaching time (Albion & Spence, 2013).

Turkey too has conducted numerous studies measuring the influence of guided inquiry on teacher efficacy and student achievement (Aydin & Boz, 2010; Bulunuz, 2009; Inel & Balim, 2010; Olgun, 2009; Özdilek & Bulunuz, 2009; Ucar, 2012). Studies reveal a much more comprehensive teacher preparation background in science content than what is required in the United States with many Turkish university programs requiring courses in general physics, chemistry, calculus, biology, molecular biology, evolution, and optics. The scores that preservice teachers received in their classes were also correlated with their level of efficacy, which led to greater teaching confidence (Aydin & Boz, 2010).

The guided inquiry-based model of instruction has been associated with improved student achievement (Aydin & Boz, 2010; Bulunuz, 2009; Deslauriers, Schelew, & Wieman, 2011; Houseal, 2010; Inel & Balim, 2010; Olgun, 2009; Özdilek & Bulunuz, 2009; Sanghee & Ramsey, 2009; Ucar, 2012). It is therefore an aspect to include in this research study, as there are potential implications for professional development training for elementary teachers with the goal of improving teacher efficacy and raising student achievement in science.

There is already a reduction in the amount of time devoted to inquiry-based instruction (Marshall et al., 2009) and after a child turns 11 their interest in science wanes unless it is capitalized on when they are younger (Osborne, 2003; Milner et al., 2012). By the age of 14 students find science uncreative and are disenfranchised stating that the content is too difficult, an attitude that carries forward as the student gets older (Archer et al., 2010; White & Harrison, 2012). However, there is evidence that this sentiment can be avoided with the inclusion of inquiry-based teaching. Students who experience inquiry-based instruction in science report feeling more motivated and interested in the material (Rukavina et al., 2012). Inquiry based learning has similar results with adults, and such experiences increase the likelihood that teachers will provide such opportunities to their students (Furtado, 2010; Ireland, Watters, Lunn Brownlee, & Lupton, 2014; Sindel, 2010; Tessier, 2010; Varma, 2011; Zambon & Lempinen, 2011; Zion & Mendelovici, 2012).

Although it is generally accepted that young minds are naturally inquisitive (Blank, 2012), if educators fail to take advantage of that natural curiosity, they may inadvertently perpetuate misconceptions about science or fail to engage students in the subject matter (Keeley, 2009). Therefore, it seems prudent to involve learners with active inquiry-based experiences throughout their elementary years as student enthusiasm and interest is enhanced (Deslauriers, Schelew, & Wieman, 2011; Dorph et al., 2011; Milner et al., 2012; Qualter, 2014). Nevertheless, even experienced elementary classroom teachers who tend to be the educators who most favor inquiry-based instruction (Sahin et al., 2010), find that due to time constraints, inadequate resources, and curricular limitations, there is not ample class time available for inquiry-based science instruction to occur (Carlone et al., 2010; Dorph et al., 2011). Even when instructional time is not a barrier, many teachers lack the efficacy (Sindel, 2010), positive attitude, or support necessary to maintain a successful science program (Milner et al., 2012). Teacher perceptions on this topic can help identify ways to support elementary teachers in order to improve student achievement in science.

Implications

According to Forbes and Zint (2011) there is evidence that many elementary teachers lack confidence with respect to science teaching, that they view the subject as less important, they report having limited materials, and that they spend less time teaching science than they do other subjects. These were findings I anticipated among Wise County elementary teachers as well. At the same time, researchers assert that a constructivist model of teaching and learning leads to improved content knowledge

(Bleicher, 2009; Paik, Zhang, Lundeberg, Eberhardt, Shin, & Zhang, 2011) and that hands-on practices improves attitudes about science and science teaching (Bursal, 2012a). Furthermore, surveyed teachers report that effective professional development on the modeling and inclusion of inquiry-based hands-on science instructional methods positively influence teaching confidence, their understanding of inquiry instruction, its development of higher order thinking skills among students, and their appreciation for collaborative learning (Duran et al., 2009; Furtado, 2010; Seung, Park, & Jung, 2014; Varma, 2011). I anticipated that some of the county's elementary teachers struggle with incorporating an active instructional model and might benefit from professional development opportunities. Teachers who recognize the significance that inquiry-based instruction has on teaching and learning tend to feel more confident and incorporate those methods in their own practice (Forbes & Zint, 2011). Therefore researchers suggest additional exposure to teachers that provide positive associations to influence confidence, as well as content and pedagogical content knowledge (Bursal, 2012a; Duran et al., 2009; Forbes & Zint, 2011; Gunning & Mensah, 2011; McDonnough & Matkins, 2010; Owens, 2009; Tan & Lim, 2014; Yürük, 2011; Zambon & Lempinen, 2011).

Summary

It is evident that although there is a societal need for a growing number of citizens proficient within science fields, and that such affinity for the subject begins at an early age, today's elementary schools may struggle to establish this foundation. The documented reduction in science instructional minutes, the emphases on reading and mathematics content, the limited science certification requirements for teachers, the anxiety associated with science instruction, and the recent attention to science standards and inquiry-based teaching models have all combined to magnify the situation. At the same time, schools continue to see students with limited science knowledge and poor growth on science proficiency scores. Due to the complex nature of this issue and its societal relevance, it is necessary to research elementary teachers' perceptions about teaching science to improve science teaching and learning.

Section 2 of this paper describes the methodology, including a description of the participants, the sequential data collection strategy, analysis methods, and results. Section 3 will describe the project (Appendix A) that emerged from the data analysis, the rationale for the project, as well as describe how the project will be evaluated, and the potential to influence social change.

Section 2: The Methodology

Instrumental Case Study Design and Approach

I conducted an instrumental case study design to qualitatively capture elementary teachers' perceptions about their students' knowledge in science, the strategies they used to teach science, and the barriers affecting science teaching and learning, as well as to discover teachers' self-efficacy beliefs for teaching science. In addition to a description of the design, a rationale for the setting and sampling methods for county participants appears in this section, as well as the plan for data collection and analysis.

Because I was researching teacher perceptions, I determined that a qualitative design was most suitable. By using a qualitative study, I would be better able to capture the broad range of teacher responses in a narrative format and present the findings with greater context. Specifically, I would conduct an instrumental case study, as it reasonably derives from the identified problem. Stake (1995) described the bounded nature of an instrumental case study, Wise County in this examination, with a defined focus on a specific issue. The specific issue in this study was the limited science content knowledge that elementary science students had demonstrated on the annual state assessment. Integral to an instrumental case study is the development of generalizations about the issue, and/or the formulation of theories to address it. With respect to the assumptions relating to students' limited science knowledge, researchers have suggested many variables including instructional time, teacher confidence, teacher content knowledge, instructional methods, and resources (Blank, 2013; Corben et. al, 2014; Dickerson, Stewart, Hathcock, & McConnell, 2014; Milner et. Al, 2012). Although the case itself is of significance in an instrumental case study, the purpose is to better understand something about the case itself (Merriam, 2009; Stake, 1995). In this case, I wanted to attempt to better understand Wise County teachers' perceptions about the poor student achievement in science. The design was also appropriate because the participants could be classified as a bounded system, which limits the number of potential teachers in the study (Lodico, Spaulding, & Voegtle, 2010). Although the study would focus on teachers from different districts, they are bound within the county and consist of one system of teachers who are directly serviced by the same regional education service provider. Because the intent of this examination was to discover the factors that Wise County teachers perceive to be associated with limited science knowledge among county students, an instrumental case study design was appropriate. In an instrumental case study, researchers focus on the phenomenon associated with the case leading to exploration and additional insights.

There were numerous other research designs considered for this examination, but they did not align with the problem and purpose of the study. An experimental study was rejected because it is best suited for establishing a cause–effect relationship with a comparison between a control and experimental group noting the influences on the dependent variable (Creswell, 2012). Because this study was exploratory in nature, examining a broad range of teacher perceptions, there were not specific variables that could be tested. Although the instrumental case study is not generalizable, it does permit the analysis of a specified phenomenon and the formulation of potential actionable theories.

I also considered a survey research design in which census sampling of the K-5 teachers in the county could be surveyed with the Science Teaching Efficacy Belief Instrument (Riggs & Knochs, 1990). As an efficacy instrument, it has good reliability; however, that would only address one aspect of the research questions and would only provide descriptive statistics, whereas a case study would explore each facet of the research questions in greater depth, formulating a thick description. According to Merriam (2009), a thick description case study is a detailed account of a situation being studied. The limited subject knowledge elementary students have demonstrated on state summative assessments required broad analysis due to the number of potentially perceived variables involved. An instrumental case study design could effectively be used to gather, analyze, synthesize, and present findings in a manner that could inform local district leadership about current elementary teaching and learning practices. Similarly, the analysis phase revealed patterns and emerging themes that suggested more focused direction for improving student learning in science.

Phenomenological research was another design that I rejected. Merriam (2009) emphasized the importance of participants living a shared experience. Although there are phenomena that are of interest in Wise County, the focus was not on interpreting an experience but rather the internal and external conditions believed to be associated with limited science knowledge in elementary students. Narrative research was not an option because its focus is a retelling of one’s life experiences (Merriam, 2009). Although capturing perceptual data from teacher participants was of interest, the focus was on their professional interpretations and assumptions about science teaching and learning.

Ethnography was similarly inappropriate because its focus on culture was not aligned with the problem and purpose of the study.

Once I determined a case study would be most suitable for the study, I considered and rejected the intrinsic design. According to Stake (1995), the purpose of the intrinsic case study "is not to come to understand some abstract construct or generic phenomenon" (p. 445). In an intrinsic design, the researcher focuses on the case itself, whereas the researcher in an instrumental case study intends to explore a phenomenon associated with the case providing greater insight. Stake asserted that the intent of the instrumental case study is "to provide insight into an issue to redraw a generalization" (p. 437) associated with the case. Therefore, an instrumental case study seemed the more suitable method.

From its inception, this study followed a process of inductive reasoning, which aligns with a qualitative research design (Creswell 2012; Lodico et al., 2010; Merriam, 2009). The static trends of district science proficiency scores were observed, leading to general queries to explore the situation. An instrumental case study provided a format for capturing the complexity of the situation, the varying perspectives teachers maintain, and a method for synthesizing the information for transferability purposes (Lodico et al., 2010). Because the design aligned well with the problem and guiding research questions being investigated, an instrumental case study method was used.

Participants

There were 54 elementary schools with various grade configurations and 458 kindergarten-to-fifth grade teachers in Wise County. However, because this study examined a broad scale problem with the majority of the county's elementary students demonstrating limited science content knowledge on state assessments, representation from across the county was sought out. The case study participants would consist of 15 K-5 teachers in the county who were actively teaching elementary science to be eligible to take part in the study. Fifteen participants would permit a broad range of in-depth perspectives while keeping the qualitative data manageable.

Potential participants who volunteered for the qualitative interviews were to be sorted by district, grade level, and years of service: 0 to 5 years, 6 to 10 years, 11 to 15 years, and 16 or more years. If there were more than 15 county elementary science teachers who chose to take part, they would be sorted and purposively selected so that a range of districts, grade levels, and years of experience teaching were fairly distributed. Because there was a potential for extremely different perceptions, this would further be defined as maximum variation purposeful sampling (Lodico et al., 2010). Using 15 participants would enable deeper analysis and comparisons of responses from early to late career professionals, as well as varying perspectives among grade level teachers and different districts.

As an employee of the county's education provider, I had access to contact information for each superintendent, administrator, and teacher throughout the county. Contact information includes both telephone numbers and e-mail distribution groups sorted by position. Because I have worked in the county for over 20 years as a teacher, principal, and educational consultant for each of the local districts, that would serve as an advantage when contacting superintendents and potential participants. Within my current role, I routinely reach out to local districts to invite them to take part in or make them aware of different professional development opportunities. At the same time, I have conducted countywide program evaluations in different content areas and reported findings to central office leadership. This science research not only aligned with my general work responsibilities, but also resembled the kind of past work I have conducted in the county.

After securing approval from Walden University's Institutional Review Board (approval number 02-25-16-0294090), permission was to be secured from the regional education provider superintendent and any of the 12 area superintendents who wished to participate in the study. I intended to first submit my research plan to the county superintendent to secure his support before reaching out to local superintendents. Once attained, I planned to request to be added as an agenda item on one of the monthly superintendent roundtable meetings where I would present the county proficiency trends in science, describe the problem to be investigated, outline my research plan, describe how findings would be shared with district leadership, and invite local superintendents to provide access to their elementary teachers through a letter of cooperation. For districts whose superintendents elected to participate, I planned to craft and send an e-mail to building administrators to make them aware of the study and inform them that district access had been granted to conduct the study with willing teachers. Elementary teachers within those districts would each be sent an e-mail invitation with a short Google form survey. The survey would provide a brief overview of the purpose of the study, a sample consent form, an option to request more information, and a link where teachers could register and provide their preferred contact information. This second link was going to ask teachers to provide demographic information, including if they currently taught science, the number of years teaching science, district, building name, grade level assignment, and additional contact information.

Google form information would merge into a Google spreadsheet to facilitate the next round of contact conducted by phone or face-to-face, based upon potential participant preferences. During these discussions, I planned to explain the safeguards for anonymity and confidentiality and again provide consent forms for teachers to review. Taking ample time to review the consent form was a critical step to ensure that the participants felt they would not only be protected, but that the study itself had the potential of benefiting their practices for science teaching and learning. Teachers had the option to sign the consent form at the end of the face-to-face session or send a signed electronic copy by a specified date. The number of teachers who expressed interest in being interviewed would determine if maximal variation could be implemented to narrow the sample.

As a way of protecting participants, I followed specific protocols to attain informed consent, ensure confidentiality, and minimize any risk of harm. During the initial information meetings, each participant was provided a comprehensive consent form. This document included the background and purpose of the study, the requirements for participation, the voluntary nature of the study, the minimal risks associated with the study, verification that there was no compensation, a description of their rights to end participation at any time, an assurance of confidentiality, and my contact information and that of the internal review board overseeing the research.

With respect to the interviews, participants would be assigned a pseudonym from the start and any identifying consent information would be kept in a locked file and redundantly archived electronically in a password-protected folder. During the interviews, participants would be reminded that they were free to end the sessions at any time if they became uncomfortable or felt any sort of stress. Because I did not have a supervisory role to any of the potential educators involved in the study, there was minimal risk to them and I communicated such assurances. It was critical that the teachers involved in the study have no fear that their participation could have negative professional outcomes. During the initial information sessions, I would define that I was the sole researcher, the only one to have access to the original surveys or identifiable information, and would be the single interviewer. Interested teachers could complete demographic information, and once the defined deadline had elapsed, I would purposively select the sample of 15. Each teacher would be notified by phone and informed if they had been selected to participate in the study or not and initial interviews would be scheduled at that time. As defined by the IRB application, specific steps would be taken to contact participants, ascertain written consent, define and schedule data collection procedures, and share the findings with appropriate stakeholders.

Data Collection

Firsthand interviews are an appropriate source of data collection for instrumental case studies, and often serve as the only source of information (Merriam, 2009). The focus of these data would be to examine teachers' perceptions of their students' knowledge in science, the methods and strategies elementary teachers used to teach science, the perceived barriers to teaching science, and the teachers' self-efficacy beliefs in teaching science. Because efficacy has been associated with more effective instruction (Bursal, 2012a), it was also necessary to determine if there was a confidence issue for local elementary science teachers. Those findings would augment the perceptual data that teachers identified providing a more comprehensive description of the situation.

During the interview portion of the study, teachers would participate in one to two 45- to 60-minute semistructured recorded interviews. A second session could be requested of participants for further probing if deemed necessary. I planned to give teachers the option of my coming to their school before, after or during school, or they could join me at the regional education service site, or a location of their choice at a time convenient for them. However, these sessions would be private. Each session would use a researcher-developed interview protocol form for greater consistency and each discussion would be digitally recorded using a Sony digital recorder. I would attempt to keep my note taking to a minimum during the interview to ensure participant comfort and establish better rapport; however, I planned to document key ideas or follow-up questions that seemed pertinent. At the beginning of the session I would review the purpose of the study and their voluntary participation, reminding them that they could stop the interview at any time.

The interviews would follow a researcher-developed interview guide (Appendix B) and use the same series of open-ended questions with integrated follow-up probes as appropriate (Merriam, 2009). The interviews would be used to explore teacher perceptions on their students' knowledge in science, the strategies they use to teach science, the barriers effecting science teaching and learning, as well as their self-efficacy beliefs for teaching science.

All raw interview data would be audio recorded and immediately transcribed with pseudonyms for organizational purposes and confidentiality. The interview transcript would be formatted with line numbers on the left margin of the page and single spacing between the lines of someone's statements. A change of speaker would be denoted with a double space line separation and the pseudonym listed. The right margin would leave a third of the page open for note taking and coding for later analysis and retrieval (Merriam, 2009). E-mailed transcriptions of the audio-recorded interviews would be submitted back to each participant within a week for transcript review for validation of the recorded responses (Hagens, Dobrow, & Chafe, 2009). Amendments made to the original transcript would be noted as such and saved digitally. The electronically stored data would facilitate the transcript review validation process, as well as the coding process (Lodico et al., 2010; Merriam, 2009).

As a current educational consultant employed by the county's area education provider, I work as a servant leader supporting and coordinating professional development opportunities in the areas of mathematics and science. Although most classroom teachers in the region would perceive me as an equal colleague, the teachers in one district where I served as a building administrator could be less inclined to participate, and those who did, might not be as forthcoming with their perceptions. From my experience working with elementary teachers for over 20 years, I have found that most prefer to teach subjects other than science (Capobianco, 2011). This is a bias that I recognized, and although researchers report a significant number of elementary teachers preferring other subjects, I had to remain cognizant of my preconception. With that in mind however, extra precautions would be taken to develop interview questions that were open-ended to avoid projecting my expectations and generalizations. By designing more non-leading questions about their beliefs associated with the barriers that influence science teaching and learning, I hoped to discover their perceptions without leading them to my expectations.

Throughout this past year, I have conducted trainings with over 300 of the elementary teachers in the county. In that time I have forged mutually respectful relationships with all of the teachers and routinely receive positive feedback on the trainings. Teachers readily contact me to observe in their classrooms, provide private targeted support, and model lessons. They recognize that my job is one of nonevaluative support, so I was hopeful that those positive professional relationships would not only increase the potential sample of participants, but also encourage teachers to be more forthcoming with their insights.

Data Analysis

As is typical of qualitative data analysis, the collection and analysis sequence would be simultaneous and inductive in nature (Merriam, 2009) using an analytical analysis technique (Forman & Damschroder, 2008). I intended to analyze and interpret the interview data as I collected it, knowing that the recursive nature of the analysis would reveal deeper insights and connections moving toward a deductive process (Merriam, 2009). With each transcript and field entry reviewed, I planned to note exploratory themes and identify follow up questions for the participants. The insights would inform the next analyzed transcript in which similarities and contrasts would be noted, which in turn would inform the next data interpreted. To make sense of the data and look for answers to the research questions, it would be necessary to repeatedly merge, condense, and interpret the information. When analyzing the data, this would begin with a classification of relevant units of information. According to Lincoln and Guba (1985), each unit should be succinct enough to stand alone while also providing insight to the study.

To manage the data and the tentative themes that emerge, I would employ an open coding process (Creswell, 2012). To begin the coding process, the data would be repeatedly reviewed looking for patterns and common ideas. These ideas would be highlighted within the electronic transcripts and retyped field notes and labeled with keywords in the right margin, and each time data was reviewed, new codes would be added, (Merriam, 2009). Groups of the open codes would be clustered together according to their alignment within each research question and subjected to analytical coding (Merriam, 2009). This reflective interpretive process would reveal the patterns, overlap, and emerging categories that captured combinations of the identified codes. I then would reexamine each of the codes to determine that they were properly classified in the appropriate theme until I had exhausted the data. Creswell (2012) suggested a reduction of the codes into five or six categories to facilitate the communication of the findings. The entire process would begin as an inductive exercise in which I would discover the individual coded units and possible categories. As the analysis continued, the process would become increasingly more deductive in nature once the categories were identified. At that point in the analysis, units of information would be scrutinized against the categories and subcategories through a code-and-retrieve process (Merriam, 2009).

Although software applications could help decipher the embedded themes, this study would be coded by hand. Lodico et al. (2010) suggested limiting initial codes to 30 or 40 to make the data more manageable, and then merge them to a smaller number of codes once major and minor themes become more apparent in the data. The benefit of electronic color-coded data that I intended to use was that it could be printed and physically combined or electronically cut and pasted into a new document displaying common themes that address each of the research questions.

Before completing the project, the findings would be summarized in report form and presented to the Superintendent and Cabinet of the regional education service provider. At that time, I would request to be on the agenda for an upcoming Superintendents Roundtable meeting where I could share the report with the local Superintendents. This information would be used to define the subsequent project to increase elementary students' content knowledge in science. I would present the findings as well as the tentative project plans.

Data Quality

Qualitative study researchers strive for internal validity, or credibility, by presenting synthesized data that aligns with the reader's reality. To ensure proper interpretation of the interviews, I would use member checking (Creswell, 2012). After completing the interviews I would assemble my findings and e-mail them back to the participants to verify the accuracy of their own data (Merriam, 2009). I would request that they respond with their comments by e-mail within 5 days and I would amend my synthesis accordingly. I was open to initiating member checking more than once throughout the analysis phase to ensure the most accurate depiction of their experience and improve the trustworthiness of the data collection and analysis process. The collection of synthesized detailed interview transcripts from each of the participants would add to the thick description of the situation and establish greater credibility for the reader (Merriam, 2009). Additionally because I had elected to interview 15 teachers at different times, from a variety of grades, and from different districts within Wise County, multiple sources would provide the opportunity to triangulate the information through a data triangulation method (Denzin, 1978). According to Denzin (1978) there are four distinct forms of triangulation, which include methodological, theoretical, investigator, and data. Because I was applying a single method of data collection, methodological triangulation was not applicable. Similarly, because I was the sole researcher, investigator triangulation would not be applicable. Data triangulation, however, was applicable since I would be interviewing a variety of teachers, and in some cases conducting a follow up interview with the same teacher. Theoretical triangulation was applicable as well because I would be interpreting the data from two theoretical frameworks, that of social constructivist theory and from a self-efficacy perspective. Finally to ensure that my researcher-developed interview protocol was without bias, I planned to seek feedback from a number of my science colleagues within the county, as well as pose them to several science teachers who were not participating in the study. Based upon their feedback I would edit the questions to ensure that they were not leading or are biased in nature. Minimizing the effects of researcher bias would improve the integrity of the interviews.

Discrepant cases, or information that seem to contradict the emerging themes, could have become evident in the analysis (Ravitch & Carl, 2015). If that were the case, it may indicate that I had overlooked information in other transcript data, or it may suggest additional research was required. In either case, further analysis would have been warranted. Additionally, I might have needed to reevaluate the questions that elicited the discrepancy and consider posing additional follow up questions to my participants. If confronted with discrepant cases, I planned to integrate those findings into the description for transparency, and include situational information that described why that case might have been unique. However, because there are many potential variables associated with elementary students' understanding of science content, the more broadly it was explored, the more strategically those variables could later be researched.

Data Analysis Results

This study used an instrumental case study design that qualitatively captured elementary teachers' perceptions about their students' knowledge in science, the strategies they use to teach science, the barriers effecting science teaching and learning, as well as teachers' self-efficacy beliefs for teaching science. Stake (1995) describes the bounded nature of an instrumental case study, Wise County in this examination, with a defined focus on a specific issue. The specific issue in this study is the limited science content knowledge that elementary science students demonstrate on the annual state assessment. Although the participants included teachers from five different districts, they are bound within the county and consist of one system of teachers who are directly serviced by the same regional education service provider.

I was able to secure a Letter of Cooperation from the county superintendent to reach out to local district superintendents in the area, five of whom signed Letters of Cooperation to take part in the study. Once I secured central office support in those districts, I sent e-mail invitations through building principals, which were forwarded to their teaching staff. The invitations to county K-5 science teachers initially led to a response of six participants and eventually, 15 teachers completed a demographic Google form (Table 7).

Table 7

Participating Teacher Demographic Information

Teacher	Gender	Current Grade	Number of Years Teaching
PA1	Male	4	17
PA2	Female	3	28
PA3	Female	4	11
PA4	Female	5	5
PA5	Female	3	6
PA6	Female	1	14
PA7	Male	1	10
PA8	Female	K	10
PA9	Female	1	5
PA10	Female	1	24
PA11	Female	2	38
PA12	Male	5	10
PA13	Female	4	14
PA14	Female	3	21
PA15	Female	5	44

Note. Number of Years of Teaching includes teachers' entire teaching experience, not necessarily always at the grade they were teaching at the time of the interviews.

As intended, my participants represented each of the five participating districts, involved teachers from each of the grades K-5, included both male and female educators, and had a range of teaching experience spanning 5-44 years. Because there was a potential for extremely different perceptions, this would further be defined as maximum variation purposeful sampling (Lodico et al., 2010). Using 15 participants enabled deeper analysis and comparisons of responses from early to late career professionals, as well as varying perspectives among grade level teachers and different districts.

I contacted each of the teachers by e-mail within 2 days of completing the Google form survey and arranged a date, time, and location to review and sign the consent form and conduct a one to one interview using my established field-tested interview guide. Each of the fifteen participants elected to take part in the study.

The data collection process included consisted of a 60-minute open-ended individual interview structured by a field-tested interview guide. At the beginning of the sessions I reviewed the purpose of the study and their voluntary participation, reminding them that they could stop the interview at any time. Each participant was asked the same questions, however follow up questions were dependent on teacher responses and posed for clarification or to attain more information. Each of the interviews took place at the teacher's location of choice, most of which were conducted after school hours in their classrooms. Each interview was digitally recorded and I drafted field notes for reference. I kept my note taking to a minimum during the interviews to ensure participant comfort and establish better rapport. However, I did document key ideas for follow up questions that seem pertinent. The digital recordings were immediately transcribed into Google docs and teachers were assigned a pseudonym for organizational purposes and anonymity protection. I e-mailed the transcriptions of the audio-recorded interviews back to each participant within a week for transcript review and validation of the recorded responses (Hagens et al., 2009).

As is typical of qualitative data analysis, the collection and analysis sequence was simultaneous and inductive in nature (Merriam, 2009) and I used an analytical analysis technique (Forman & Damschroder, 2008). To manage the data and the tentative themes that emerged, I employed an open coding process (Creswell, 2012). My process for analysis included initial readings, noting keywords, which I tracked in the printed margin of the transcripts. The next part of the process included rereading the transcripts multiple times and color-coding the keywords according to their alignment to the four research questions. Each key idea was highlighted in one of four colors linked to the research question, and within that color cluster were the numerous key words and themes that had emerged. I then developed a digital master spreadsheet, in which I recorded the clustered keywords for each participant. The spreadsheet facilitated the comparisons among the participant responses and made the commonalities and differences more apparent. I then magnified each distinct interview guide probe element within the research questions ending up with 14 separate areas of interest. At that time I developed 14 separate digital spreadsheets to compare the themes that had emerged in each of those interest areas, and wrote summaries for each. As I assembled the interest area spreadsheets, I wrote the findings summary for each and selected specific quotations that clearly articulated a participant's position. These were merged within each of the four research questions.

Summary of Findings

Because I elected to interview 15 teachers at different times, from a variety of grades, and from different districts within Wise County, multiple sources provided the opportunity to triangulate the information through a data triangulation method (Denzin, 1978). Teachers were interviewed on four research areas: their description of their students' science content knowledge, the strategies they use to teach science, the barriers they perceive for teaching science, and their self-efficacy beliefs for teaching science. Each of these will be explored in the following subsections. In order to ensure the accuracy of the data, members were asked to review digital transcripts for verification.

Participant quotations are included in each of the following subsections that represent positions that were presented and aligned to the four research questions.

RQ 1: How do elementary teachers describe their students' science knowledge?

Although the teachers in the study represent each of the K-5 grades, teach in different districts, are both male and female, and range in experience from five to 44 years, there are commonalities among their responses. When asked to describe their students' understanding of science content, the teachers reported that their students had limited science knowledge, that it was surface level, and that they often maintained misconceptions.

> I also feel a lot of their understanding is very basic, very surface-level. They might know the facts and it doesn't get to the why or the how. It is just things that they have either heard over and over or in shows, or in basic books that they have read. They don't have that deeper understanding of any of those concepts. (PA3)

Teachers who had more than 10 years teaching science also noted a difference in understanding among today's science learners when compared to students they had taught in the past. "I don't know how to quantify it, but I would say it is not where I would like it to be. I would even say it is not where it was 15 years ago." (PA1) Some of those same teachers commented that their students had few opportunities to engage in the practices of science. "They have very little background knowledge and content of science or how to go about even doing science." (PA15)

Science areas in which student excel and struggle. Teachers were asked to identify science topics in which students excelled, as well as concepts that were more challenging, and reflect upon why that might be the case. Twelve of the teachers reported that life science was the area in which students most excelled in science understanding. Most attributed this to young children's affinity for animals and the fact that the concepts were tangible and observable.

> I think that a lot of children gravitate towards the life sciences early on because they can see fuzzy cute animals and that is interesting to them. They can see things in the zoo and they can relate it to turning over a log or a stone in the backyard or playing with a pet. (PA1)

Physical science was also referenced by two of the upper elementary teachers, however they stressed that the experience had to be introduced in a visible and concrete way first before it could be understood at the abstract level.

> Like life science, they can tell you a lot about those things because they have lived life, and seen those things, probably read about them, versus the concept of electricity which they know it exists, but they have not really thought about where it comes from or how it's made….You know, when it is hidden from them, I think it is harder. (PA13)

There was similar consensus among the teachers when identifying the science concepts that were more challenging for students. Ten of the teachers specifically identified physical science and earth science concepts as being ones students most struggled with. "I think that any of the earth science and physical science topics are ones that they struggle with, they don't really know how to go about looking at those concepts." (PA15)

Teachers articulated that the concepts are generally too abstract to result in deep understanding unless thoughtful instruction occurs to make the content meaningful. Even then, teachers commented that making some abstract concepts more visible eludes them. “Rocks and minerals are much more difficult. Because I can't take that apart, superheat it, and put it back together. It is tough to show them how that all works.” (PA14)

Perceived actions required to improve student science content knowledge. Teachers were asked to identify and prioritize what they thought needed to occur to improve student content knowledge, and several priorities were routinely shared. First, it was determined that districts must set aside dedicated instructional time to teach science.

> I would say that instructional time probably influences student content knowledge most. I mean, they [the district] are tracking our literacy scores and looking at them. They are tracking our math scores and we are getting feedback on that from September. We automatically have that feedback in reading and math...if science doesn't happen for the kids, nobody's looking at that. If science is something that is important to us, which it is something that should be important, then we are going to need to make it a priority, which means that we should be dedicating time to teach it. (PA8)

Second, teachers felt they need to improve their own content knowledge in order to effectively guide students in the practices of science and deepen their learning. “Well, I think we need to help the adults that are teaching it because they are perpetuating a lot of the misconceptions. When they don't understand the content, they have a hard time helping kids understand the content.” (PA15) Third, teachers felt students would benefit from teacher training on science pedagogy so that they could more effectively teach phenomenon-based science and integrate strategic hands-on experiences to make the abstract concepts more meaningful. “I think classrooms look more chaotic when we are doing hands-on, but in the end their understanding is deeper, but that is probably the thing I use least often. I'm just not very well trained in hands-on science instruction.” (PA12)

All of the teachers in the study expressed a concern about the science understanding their students possess, particularly in the areas of physical and life sciences. They asserted that consistent dedicated instructional time, and sustained professional development to support both content and pedagogical content knowledge would improve student content knowledge in science.

RQ 2: What methods and strategies do elementary teachers use to teach science?

Participants were asked to describe the teaching strategies they use with students during science instruction, which revealed a variety of methods that teachers intentionally use. All 15 referenced their desire to integrate hands-on instruction during science class and verbalized the value they perceive that it has for building conceptual understanding. “So I think that when we can have more hands-on and interactive opportunities, those are definitely the ones where they make the connections.” (PA3) The teachers referenced that when dealing with abstract content, students may not have the background knowledge from prior experiences to understand phenomenon that occurs in the natural world and that hands-on learning experiences can build that foundation.

> So we work really hard to try to give these kids those experiences, hands on, in the real world to make those connections because we know the abstract is really hard for them to connect those ideas to things they have never seen or touched. (PA5)

Nine of the teachers interviewed discussed the importance of exploration time with materials and prompting students with questions to encourage them to make discoveries, as opposed to always presenting the material.

> As much as you can do the hands-on and the exploration and the discussion around that has the biggest impact. I now hold science talks with the kids. Talk, talk, talk. Years ago when I taught, I lectured. I gave the kids the information, but they didn't understand it. But I have seen how exploring the materials and my questions encourage students to discover, and it was a flip for me. (PA2)

Another common theme was that teachers noted the use of classroom discussions where students could talk to one another under the guidance of the teacher as being influential on student learning. Nine of the teachers described how including discussions in their instruction led to discovery.

> I do want to push them to higher-level thinking, but it doesn't necessarily mean to talk to them all of the time. They should have time to talk too. So I have gone back and had a different shift letting the kids talk more, which is really hard. But they come to really awesome conclusions! So it is almost like, "Yes, they are getting it!" I almost underestimated how intelligent they really are. (PA9)

There were several other teaching methods that were valued and practiced among the teachers. Nine of them referenced the value they hold for investigating student-generated questions, and empowering students to research the answers to their own science related questions. Eight of the teachers include study trips at some point in the year to immerse the students in real-world science learning and deepen their conceptual understanding of the content. Six of the teachers interviewed, referenced using literature to further support the understanding of science concepts, but commented that the use of literature could not serve as the entirety of the science learning.

"So teachers have been told or believe that by supplementing the science reader, it stands in and counts for science. How can you build science knowledge there if you don't do science?" (PA12) Six of the participants referenced the importance of engaging the kids in science modeling.

> So for me having the kids engage in hands on his huge, but also the consensus discussions and the modeling process. That to me is the most important thing because it makes the students begin to justify their reasoning based on evidence. If they couldn't, they had to figure out why they couldn't, and instead of ignoring someone when they were speaking, they are listening to one another to see if they agreed with different positions and could incorporate that into their own thinking. "Yeah, that's what I meant when I was saying this." I just think that diagramming models and discussions leads to explanation. I don't think they can get to the abstract until they can genuinely explain why something is occurring. (PA13)

Three of the teachers described the use of integrating phenomenon to pique student interest, motivate inquiry, challenge misconceptions and support the collective sense making process.

> Like starting with a phenomenon are the ones that kind of hit them in the head and they go, “ What? Huh?” I have always started my units with those discrepant events. That gets them to start thinking, and then that whole sequencing of events from there, like what the kids are already knowing, and what their misconceptions are, and then how you sequence activities that can help build that knowledge. (PA15)

There were several incidental strategies referenced including, use of videos, vocabulary, nature walks, making how to books, journaling, research projects, text readings, and demonstrations. However, the commonality among the teaching strategies seems to be an attempt to make the science concepts more accessible, engaging, and understandable to students.

Teaching methods believed to support conceptual understanding. When asked about how their students respond to these science-teaching strategies and which were most influential on improving student learning in science, teachers reported that inquiry-based hands-on explorations and student investigations led to higher engagement, increased excitement, and better conceptual understanding among their students.

> I think if they are engaged in trying it, then it is just going to stick with them more. If they are watching me, they might be kind of impressed that a magnet can

> drag something, but when they try it themselves, you can just see their little sparks. (PA9)

> When we are doing hands-on, I think their understanding is deeper. The text base and video based resources definitely feels more like a classroom but in the end I think you have that core group of students, a third or a quarter of them, that get it, but the rest of them need to see something or do something to really understand. (PA12)

That deeper understanding was not only apparent in class, but also on classroom assessments where students made connections during the hands-on investigations.

> And even when we took the test, there was a question, not about a zip line, but a short answer where they had to talk about two things colliding at different speeds and what was going to happen. And several of them referred back to "Well when we did the zip line we did it at the same speed and this is what happened." So they were able to kind of draw on that experience to explain the science concepts. (PA3)

Additionally, all of the teachers referenced the level of excitement students demonstrate during science class, particularly when they were engaged in an exploratory investigation.

> They were so excited. They did not want it to end! It is so sad that we can't do it more often. This class is very self-directed and if I give them permission to set up the schedule for the day, they always put in science. They come up with the

> agenda and science motivates them. I need to take that motivation and do something with it. (PA11)

Aside from the excitement, teachers also commented that such experiences motivated their students to want to learn more, helped them to clear up misconceptions they held, and gave them opportunities to learn perseverance.

> Kids just get energized when they are able to do something hands-on. They get so excited about it, and it always generates more questions, and they become more curious. And for some kids it brings out the frustration when something doesn't work right. So they have to learn perseverance, and learn to keep going, or try something in a different way, but you see kids who are really engaged and happy. (PA13)

All of the teachers used preferred methods for teaching science and believed that when practiced they have a positive effect on student content knowledge. However, each referenced the many obstacles that elementary teachers face with respect to teaching science and how those challenges likely contribute to the poor achievement scores on the state summative science test. It seems that all 15 of the participants see themselves as science advocates and felt compelled to take part in the study as a way to improve science teaching and learning in their districts.

> The younger they are, the worse it is. Because when you are teaching AP physics or you're teaching chemistry and you want your kids to be college ready, science matters. It matters when your kid is taking high school science, but it doesn't matter when kids are in first grade learning about the weather. You know, that's

why I felt like I wanted to talk to you because it would give me a chance to advocate for science. (PA6)

The consensus among the teachers interviewed demonstrates a value of inquiry-based learning of which there are many benefits to student learning (Blank, 2012; Havice 2009; Inel & Balim, 2010; National Research Council, 2012; Olgun, 2009; Tessier 2010), but there are many challenges that inhibit teachers from its inclusion (Carlone et al., 2010; Marshall et al., 2009; Sahin et al., 2010; Seung et al., 2014; Sindel, 2010; White & Harrison, 2012).

RQ 3: What do elementary teachers perceive to be barriers to teaching science?

Teachers described barriers associated with teaching science that they confront and believe negatively affect student learning (Table 8). The identified barriers were independently identified, yet the responses followed similar themes.

Table 8

Identified Barriers Elementary Teachers Believe Inhibit Science Teaching and Learning

Barrier	Percentage of Teachers Who Independently Identified it as a Barrier
Reading/Mathematics Emphasis	100%
Lack of Materials/Aligned Curriculum	100%
Limited Time to Teach Science	93%
Teacher Content Knowledge	87%
Teacher Anxiety and Avoidance	87%
Classroom Management Concerns	73%
Science is Not Taught	60%
Lack of Administrative Support	53%
No Collaborative Planning in Science	53%
Science is Not a District Priority	53%
No Professional Development	33%
Challenge of Integration	27%

Note. Teachers identified the above barriers as ones that they confront teaching science to their elementary students.

Although not directly asked, nine of the 15 teachers reported colleagues who teach no science to their students. “I know that there are some buildings that weren't teaching science at all to some of the kids.” (PA5) “As the building science leader, years would go by without the science kits being opened or touched.” (PA6) “In my district it really isn’t taught in kindergarten through second grade, and really third grade.” (PA13) “If kids don’t have a good background in it, it’s tough to drop them in fifth grade for the first time.” (PA12)

Even in classrooms where science is taught, teachers reported that many students receiving tier two or three services, are pulled out during science instruction and miss the content and experiences. “I will do science at a time when my tier 2 reading kids are gone, which is unfortunate for them, but again it’s a time juggle.” (PA1) “We are pulling kids out for interventions when they would be getting science. So kids that are already going to struggle in certain areas, we are taking them out of something that might be super interesting to them.” (PA8)

> Because we have been told that science is one of the things that struggling students can miss. And the kids are like, “I don't want to go to reading if that means that I'm going to miss science.” But for a lot of teachers that's when they teach science. (PA15)

The practice for struggling learners to miss science instruction was common in a number of the districts, which troubled the teachers, not only because the students lack exposure to the content, but also because they may miss a learning area that could boost their self concept.

> You can take a struggling reader and give them science and they flourish right? Science can be more accessible to kids who struggle with literacy, which is great. You know, keep them engaged in school because it is something fun, something they enjoy, and something that everyone can be good at. (PA6)

According to some of the interviewed teachers, their districts do not locally assess science, which reduces the sense of accountability to teach the content. Other teachers report that if they teach in a building whose students are too young for the state science assessment, they too feel little obligation to dedicate time to teaching science, and in some cases, administration directed them not to teach science. “I know that in some buildings in this district teachers were told not to teach science at all. It is very sad." (PA6)

> My former principal told me that I was not to teach science. I was directed not to teach science because it is not on the M-STEP. As a fifth grade teacher who tests social studies, I was told not to teach science. I was furious! (PA4)

Over half of the teachers interviewed stated that science was "not a priority" in their buildings and described a lack of administrator support to dedicate any time or attention to teaching science.

> The necessity for learning how to read is known, so we are provided resources and support to teach that. The necessity for high math scores, that's not the goal, but we want our graphs to look good. But we are provided with the resources and training in math. So yeah the things that educational leadership find important, right? They are going to take steps to put that in front of us and give us what we need to do it well. And science isn't there. (PA6)

There was concern among 14 of the teachers that science was undervalued as a subject, not earning district attention. "Science is an afterthought in schools, with the kids, and the teachers…whether implicit or explicit, we are told what is important, and science is not important." (PA7) Five of the teachers interviewed maintained the perception that time spent teaching science also had to be justified in some way. "I feel like I have to defend myself when I am caught teaching science. It shouldn't be that way." (PA14)

Based upon the responses, it appears that that students in Wise County have less exposure to science content during the elementary years than they had a decade ago.

When describing the barriers associated with teaching elementary science, there was consensus among the participants that emphasis is placed on reading and mathematics at the expense of science instruction. “Teachers feel so overwhelmed with the math and reading curriculum, so they just don’t get to science.” (PA12) Although this was an open-ended probe, there is a common perception that science instruction is reduced as more time is spent teaching reading and math. This belief was shared among teachers from each of the districts regardless of the grade they taught or building they work in. PA1 referenced the connection to the influence of NCLB legislation and the resulting emphasis on reading and mathematics to meet state accountability requirements. With the onset of evaluations being tied to student growth in reading and math, he described his decision to teach less science.

> I guess No Child Left Behind came in around 2002. So once that was in place and all that focus went on to reading and math. I think we just started to shift and say, “More time in these areas, more time in these areas.” And when they started to link student performance to teacher effectiveness, people got a little nervous and said, “Hey if you're going to be testing, you're going to be evaluating me on these areas, I'm going to ignore the other areas.” I mean, I fell victim to that too. (PA1)

For many teachers they described feeling as though their administrators cared more about an emphasis on reading and mathematics even if it was at the expense of teaching science.

> I can tell you when I started in this district, they basically said to me, “We are really worried about math and reading, so if you get to science that is okay, but if

> you don't, that is okay too." So I feel like science has been kind of swept under the rug, (PA8)
>
> Science as a second-class citizen in elementary, and I can only speak for this building. Literacy and math get the most emphasis, get the most resources, get the most time, have the most oversight. ELA and math comes first and if a teacher is not teaching enough minutes, or the content expectations are not being met, there's a question about that. Right? At the expense of science. No one asks, "Are you teaching all of your science?" No one asks. (PA6)
>
> You know for years we've had this, "It's all about reading and math." And you know, "Hey, if you want to read a book about science or watch a little video, that is okay, but we don't really have any time to teach science." (PA15)

The emphasis on reading and mathematics has affected elementary schedules, which teachers referenced as a significant barrier noting the lack of time dedicated to science instruction. Although the challenge of time was a part of a follow up probe within the interview guide, each of the teachers brought up the challenge prior to being asked. The only teacher who had no issue with instructional time restrictions was one of the fifth grade teachers who teaches in a departmentalized setting, which enables him to teach mathematics and science every day. On average, the remaining teachers described required daily instructional content blocks, that often consisted of 90 minutes of reading, 60 to 90 minutes of mathematics, 30 minutes of intervention time, 45 minutes for writing, rotating special area classes, lunch, and recess. Most reported this left little to no time to teach either science or social studies.

> It's the time and the schedule to actually teach science. I mean that's what's going to give them the understanding. I agree that we can connect it to other content, and that's fine, but it also needs its own spot. It is just as important as math. (PA11)

Eight of the participants have worked to try to fit science in to their schedules, however, they continue to be dissatisfied with the limited opportunities for the students.

> It is hard to fit science in with the quality for what it should be. I feel bad. I am squeezing in the magnets unit in 3 days at the end of the year. They are having a great time, but I don't know if I have actually increased their content knowledge. (PA10)

The issue of science content misconceptions was raised as well in the context of time. Participant six stated that due to the limited instructional time in science, students did not have opportunities to confront and challenge their own misconceptions and understand the material.

> And perhaps maybe that goes back to time. If kids had more experiences, if kids had more opportunities, to think, to talk, and observe nature, then maybe those, I want to say foolish, the ideas that don't make sense wouldn't keep coming back. (PA6)

The teachers reported that because their districts' value of science is not equivalent to the other content areas, when time has to be pulled for various reasons, it usually limits science and social studies learning.

> And I know second and third grade if we don't finish reading, we push it into science time, or we didn't finish today's math or we have an assembly so we will have math during science time, science and social studies. But they're the ones that kind of, “Okay where do we have an extra 20 minutes that we can lose?” We’ll pull it from there. (PA3)

Thirteen of the teachers spoke about colleagues or self-reported avoiding science instruction due to their own anxiety. “Elementary teachers aren’t super geared towards science.” (PA8) When pressed on this, teachers attributed that anxiety to their limited content knowledge, which led to the avoidance for teaching science.

> I have had colleagues share with me how much they hate science or that they don't understand science or there is no point in teaching science. One of our first grade teachers said, “No, I am not teaching science. I don't get it. I don't understand it. I'm afraid of it.” (PA14)

Many of the science concepts introduced during the elementary grades can be challenging to educators, particularly if their own conceptual understanding is challenged.

> One of my colleagues doesn't like science. She struggles with it. Her challenge is that she doesn't know how to do it…She doesn't see the concept. She is not into the sciences and so, if you are not into the sciences and you can't see the concepts to recognize how you get the concept across…So there is the avoidance of the subject. (PA2)

Five of the teachers interviewed teach science to multiple classes in their grades to try to accommodate some of the anxiety that their colleagues maintain for teaching science.

> Science is scary to some teachers. I think as adults they don't believe they know a lot, like when I talk to a lot of people they are like, “Oh my Gosh, I don't know anything about forces or energy or things like that.” And I am like, “It shouldn't be scary.” Number one, that’s a barrier, not one that I necessarily face, but one that I believe others face and why they let me teach their kids science. (PA5)

Other participants saw examples of escalated science teaching anxiety among their colleagues.

> I think some teachers have science discomfort. If a teacher is not plugged into science and they don't love it, it is probably going to be harder for them. And then wrap that in with a lack of support and feeling rushed. I'm thinking of a particular teacher in this building. Every week she was like, “I hate this. I hate this. I just feel like they are not learning, and I am not very good at it.” She wasn't loving the content, and maybe her self perception as a scientist wasn't real strong so she struggled with it. (PA6)

Participant thirteen also referenced the challenge of pushing oneself to engage in an activity that causes anxiety. Science avoidance could be a preferred option especially when there are time constraints within a required schedule.

> I think there is fear that many teachers experience that prevents them from even trying to teach it because they feel so ill equipped. If no one is going to make you do something that is a fear for you, people don't typically go out there and push themselves to do it. Right? So this is the subject I am most trepidatious of and I'm going to do it anyways? Oh, and it doesn't fit in my schedule? Okay! (PA13)

Teacher science content knowledge was generally described as a barrier among 13 of the educators. "The teacher has to see the connections, if the teacher doesn't see it, how is the teacher going to bring it to real life especially if it is a science concept that the teacher is not comfortable with?" (PA4) There was agreement among 13 of the participants that elementary teachers struggle with limited content knowledge in science, however, eight also noted that they did not have strong pedagogical knowledge for teaching science.

> I think a lot of it is training that we just don't know how to be effective science teachers. We are effective teachers, but I think science is a different animal. You don't teach science like you teach math. I think background understanding is a barrier. (PA12)

Another point of unanimity was the concern of poor or unaligned curriculum, as well as limited materials and science supplies. Five of the teachers described using personal money to acquire the necessary consumables in district teaching kits. Other barriers that were described included classroom management challenges, the fact that teachers require collaborative planning in science, the need for sustainable professional development, and the challenge of integrating content.

How district leadership might alleviate barriers in science teaching. Teachers were asked to reflect upon what district leadership could do to help minimize the barriers they identified for teaching science and prioritize which barriers should be addressed first. (Table 9)

Table 9

Primary Barriers Elementary Teachers Believe Inhibit Science Teaching and Learning

Barrier	Percentage of Teachers Who Identified it as a Primary Barrier
Limited Time to Teach Science	80%
Teacher Content Knowledge	46%
Science is Not a District Priority	33%
Lack of Materials/Aligned Curriculum	33%
Reading/Mathematics Emphasis	26%

Note. Teachers generally identified two barriers as their primary inhibitors to science teaching and learning.

Time was identified as a major barrier for 12 of the responding teachers, and they described the need to dedicate instructional time to teach science. Six of the teachers emphasized the belief that limited teacher content knowledge and insufficient training is one of the most significant barriers elementary science teachers face, and that additional training in science teaching would benefit both teachers and students. Five of the teachers stated that because science is not a district priority, the subject is deemphasized and in many cases not taught at all. Districts must communicate their commitment to science and require that it be taught. Limited or outdated curricular resources and materials were identified as a primary challenges for five of the respondents. Those teachers felt that district investments in aligned resources and a commitment to supplying recurring consumable materials could eliminate that barrier. Four of the teachers identified the emphasis on reading and mathematics and stated that schedules must be more flexible and that science needs to be a greater focus. Some of the teachers explained that the attention to those content areas limited time available for science instruction.

Causal theories for poor science lessons. As part of RQ3, teachers were asked to reflect upon science lessons that went awry, and what causal theories they had for those outcomes. Their responses could be classified into one of two areas, material management and limited content knowledge. With respect to materials, teachers reported having not prepared the class on how to properly use the materials for a positive experience and ended up with paper clips scattered around the room or students going home covered in cornstarch. A number of the teachers commented on the challenges associated with materials. “Science tends to have a lot of stuff, or at least it should have, so having everything out and ready can be a little more challenging than other content areas.” (PA10) “I’m not sure any of us are very well trained on how to deal with materials management.” (PA12) The more common issue teachers reported as the reason a science lesson failed was simply not having enough background knowledge on the content they were teaching. “I hadn’t studied fossils and never taught it. I didn’t have the background knowledge and so it was a little choppy.” (PA3)

> Anything that has ever gone wrong is always because it is an area where my content knowledge is not very well developed and because of that, one, I don't feel very confident teaching it, and two I don't feel like I can answer their questions and constantly feel like I have to refer to an expert manual....Even though you know that the right thing to do is to dig into that content to become more of an expert, there isn't always the time or the concept may be quite sophisticated. (PA13)

With Michigan’s adoption of a variation of the Next Generation Science Standards, teachers are recognizing that the changing disciplinary core ideas will mean they will be teaching unfamiliar content. If teachers have not had exposure and training in three-dimensional learning, the performance expectations could be misinterpreted.

> I believe limited content knowledge is one of the largest barriers that elementary science teachers face, and that's why I believe that professional development is really important. In fact I am nervous about teaching a unit on weather because I have not taught that content in a very long time. You know having that knowledge and doing some of that background work on their own is harder and harder for teachers. I worry about the new standards, because if you just look at them, and you have people who don't know what they mean, it may look just like writing an opinion paper. (PA14)

Perceptions on how to overcome barriers. Teachers were asked what measures they felt needed to be taken to overcome the barriers elementary science teachers face teaching science. A common theme that emerged was the need for sustained professional development that could boost teacher content knowledge and model effective pedagogy to align with the Next Generation Science Standards and three-dimensional learning. Twelve of the teachers thought this was a necessary element to support teachers and improve their effectiveness to positively influence student science content knowledge. “Additional training would help build a teacher's confidence, but also help them improve their own content knowledge, as well as discovering what science teaching should be like, the pedagogy.” (PA10) “We’ve been saying for years that people need to be trained, but all the training we keep getting is for reading and math.” (PA15) “I think a lot of it comes back to materials and professional development so that teachers can learn how to do it themselves.” (PA14)

> Well if you look at our professional development schedule, science is never a topic of discussion. It is never on the agenda. If we were to start prioritizing and dedicating time toward it for discussions and planning, that would help. (PA13)

Ten of the teachers interviewed discussed the need to make science an explicit district priority, five of which also specified the need for dialogue among the district faculty. This was largely in reference to the idea that science is not taught frequently enough to enhance student content knowledge. Additionally, 11 of the teachers called for a more flexible schedule to establish sacred instructional time for science.

> If science is something that is important to us, which it is something that should be important, then we are going to need to make it a priority. I think priority does not mean that we need to test the wazoo out of it. It means that we should be dedicating time to teach it. (PA8)

> Well I think we need more time on science with the kids, I mean that is where their content knowledge is going to increase...if I don't have the time in front of the kids, then they are never going to learn it…I think making science a curriculum priority would alleviate some issues in saying, “It's okay if math and literacy get cut back by,” even if it was like 10 to 20 minutes and adding that. (PA5)

> There is no bare minimum [expectations]. There is a bare minimum in reading, and there is a bare minimum in math with our set curriculums and things like that, so at least you're experiencing this. There doesn't seem to be that in science…I think we need to open up the discussion, where you can start to be honest, so you can be transparent, and start to move forward. (PA7)

Thirteen of the teachers referenced the importance of district provided accessible hands-on materials, aligned curriculum, and resources to support even the least confident science teacher. Another way nine of the teachers envision improving the teaching and learning of elementary science is through mentorship, collegial planning, and teachers observing one another's teaching and providing feedback.

> If we could observe teachers, that would be helpful. Going into a confident teacher's room to see how they teach science would be really helpful in boosting confidence. It is hard when it is a whole unit, but I suppose teachers could be videotaped too. Teachers could watch different segments and learn from them. (PA10)

> I think that would have significant value for building teacher confidence because some things you don't think of until you see another teacher doing them. They always say we're going to take advantage of teacher observation, but there is never time. It just isn't a priority. (PA11)

The theme of team teaching emerged numerous times, in which grades would departmentalize some of the content areas so that one fourth grade teacher would teach science to multiple fourth grade classes. Eight of the teachers interviewed reported that such a model would result in content experts who would have a greater influence on student learning. Still others felt that buildings should have a science content specialist who could provide in-district professional development and improve teacher effectiveness in science. “It is really nice having someone in-house that can coordinate and just pop in on us, pull us together for PD, send out e-mails about common assessments, about common understandings.” (PA12)

Administrative support, opportunities for play, sensitivity to child development, and exploration were also discussed as potential paths to overcome the barriers associated with the teaching and learning of science. Table 10 on the following page depicts the suggested actions needed to overcome the identified barriers for teaching science and the percentage of teachers who independently made those assertions.

The teachers who took part in this study face similar challenges that have been described in the national literature. These barriers include an emphasis on reading and mathematics and limited time dedicated to science instruction in elementary classrooms (Berg & Mensah, 2014; Blank, 2012; Keeley, 2009; Milner et al., 2012). Teachers also believe that they require additional training to bolster science content knowledge and science pedagogy (Gunning & Mensah, 2011; Saçkes, 2014; Shen et al., 2010). Teachers felt that making science a greater district priority and investing in professional development and updated resources, that these barriers could be systematically overcome.

Table 10

Strategies Believed to Overcome Science Teaching Barriers

Strategy	Percentage of Teachers Who Identified this Strategy
Aligned, Hands-On Curriculum & Resources	87%
Professional Development	80%
More Flexible Instructional Schedule	73%
Make Science is a District Priority	67%
Mentorship & Collegial Planning	60%
Team Teaching/Departmentalized Instruction	53%
In-house Content Specialist	33%
Honest Dialogue About Challenges & Solutions	33%
Administrator Support	27%
Opportunities to Play/Explore with Science Materials	20%

Note. The strategies were independently identified in response to an open-ended question within the interview guide.

RQ 4: What are elementary teachers' self-efficacy beliefs for teaching science?

Teachers were asked to describe their level of confidence teaching science and compare that confidence to other subject areas they teach. Of the 15 teachers interviewed, eight of them described having high confidence in teaching science, five reported an average level of confidence and two described themselves as having lower confidence (Table 11).

Table 11

Teachers Reported Confidence Level for Teaching Science

Confidence Level	Percentage of Teachers Who Identified with Each Confidence Level
High Confidence	53%
Average Confidence	33%
Low Confidence	13%

Note. The teachers who elected to participate in the study consider themselves as science advocates and generally enjoy teaching science.

Eight of those who reported having high or average confidence further clarified that they were confident with the knowledge required for the concepts at their grade level.

> Teaching first grade science definitely I am comfortable with. I am confident because the level is very basic…I mean I always made good grades in science, but it was hard. I was that kid who ended up in the teacher's classroom everyday saying, "I don't get it. I just don't get it." I had great instructors who never made me feel stupid or a burden, but my confidence level from the get-go has never been really high in science. (PA9)

Nine of the teachers, who describe their confidence with the science content they teach in their grade, also expressed anxiety by the thought of teaching students above their grade level. "I feel confident at kindergarten and first grade content. If you were to put me in a fifth grade classroom, I would not feel confident at all." (PA8) These teachers attributed this lack of confidence to a lack of content knowledge and concern that they did not have enough training to make the science meaningful for students.

> I think it [confidence in science] is lower than my confidence teaching math. It's interesting because in my building I was for quite a while this science representative on the leadership team. But every time I had my principal observe me, it was always during a math lesson because the outcomes are more predictable, management is more predictable. I am very confident in my understanding of science or my ability to look up something that I don't know, but in terms of how to translate that into digestible chunks for kids and give them meaningful experiences that help them grow their knowledge, I don't know if I'm there yet. (PA12)

Although not asked, nearly all of the teachers referenced a similar mindset and described their level of comfort telling students they did not know the answer to a posed question. “To me confidence means not being afraid to say, ‘I don’t know.’ How many teachers that you know are going to stand up in front of their class and say I don’t know?” (PA4) Fourteen of the interviewed teachers found that admission exciting and used it as a motivating exercise to get students to conduct research and learn collectively.

> And I have no problem telling them in some cases, “This is the first time I've done this. Let's all figure it out together.”… So that's a comfort area I didn't have when I was brand new when I thought maybe I'll get fired if I don't do everything just right, like I have to know everything. I am much more likely now also to ask for help. (PA1)

> I know the content, and I know what they have to hit. But do I know all the answers to all the questions? No. That's fine, and that's what I like about science.

> Because then they are coming up with crazy questions and I say, “I don't know but let's figure it out,” or “Where can we go? How can we figure that out? Is there something we can do to test that?” Or, you know, I turn it back on them because they know I cannot know everything about science. I mean that is impossible, so how can we do this together? (PA3)

13 of the teachers believe that the students are not troubled when their teacher admits not knowing the answers to a posed question.

> I do know that when kids ask me a question I can’t answer, they know I'm going to say, “I'm not really sure. I am going to have to ask someone else.” My kids are flexible enough to go with that flow knowing that I don't know everything. (PA8)

The one exception was PA13, who stated the opposite believing she should possess the answers to student generated questions.

> I suppose the hardest thing for me is when kids ask a question because they are curious about something and I can't answer it. For me that is the hardest thing and when I feel the most amount of pressure. I may look at notes to see how something works, but then I worry that I may not be explaining it right so I have to go back and reread the explanation myself and I feel like a total idiot if I have to read from the notes. (PA13)

She was one of two teachers reporting low confidence and attributes her anxiety to her limited content knowledge.

Experiences that affected teachers’ level of confidence teaching science. The teachers were asked to consider what experiences impacted their level of confidence to teach science. Eight of the teachers shared university experiences that helped to inspire them, and these were most often traced to individual instructors who motivated them as learners and helped them connect to the content. Eight of the teachers also described how their confidence teaching science has grown over time and with additional professional experiences. Professional relationships were referenced as a contributing influence to their science confidence including support from colleagues, principals, mentors, and professional development opportunities. Over half of the teachers also shared stories about family members being an inspiring contributor in science confidence. Although these were most often referencing experiences with parents, like participant fifteen who described her father as “Mr. Wizard, and we did Mr. Wizard stuff in the basement”, but there were also references to spouses and the influence of having children and viewing the natural world with a new sense of wonder. Several referenced influential high school experiences, which might have been traced to a specific teacher, but just as often to the content itself. The opposite was also true with high school experiences.

> Yeah, I can't say that any of my high school teachers really had much of an influence. It's actually a wonder that some of them didn't have the opposite effect because some of them, we just did stuff straight out of the book with never a lab. (PA1)

Some of the teachers described a passion for the subject. “I love it. I have learned over the years it is not just the life sciences, I have developed a love for all of the sciences.” (PA2) The passion they have for science content positively influences their feelings about teaching it. “I think my passion for science really plays into it…So I think when you really like it, you like it, and you feel good about teaching it." (PA5) That personal interest motivates some of the respondents to initiate their own learning to be more effective science teacher.

> If I am teaching 5th grade science, I need to have a much higher level of understanding of those concepts because I need to know how to teach it in a way that it will grow and go forward…That is why I view my job as continually having to learn more in order to be a good fifth grade science teacher. (PA4)

Conversely, three others feel compelled to learn more because of the anxiety they have about teaching science, and the past experiences that led them to believe they have poor content knowledge. One of those participants feels challenged by her limited time to initiate that learning and boost her confidence teaching science.

> I am a perfectionist, and because I'm a perfectionist and know I should be doing something better, be doing something different, need to know more about a subject, I don't feel very good about the fact that I don't. I just wish I had more minutes in my day to remedy that…Even though I could do a science experiment with students, I only know the surface level of the information, but I don't have the deep understanding. Not having the time to go deep in that or brush up on it makes me nervous. (PA13)

Interestingly, two of the three teachers who feel driven to deepen their content knowledge to offset their anxiety have a science minor and the third had originally been a science major.

Science training and content knowledge description. The teachers were asked about their formal training in science education and its contribution to their resulting content knowledge. The responses could be sorted into one of three categories, university training, self-initiated learning, and district provided professional development opportunities. One third of the teachers interviewed have at least a minor in science and of those one not only has a major in science, but also a master's degree in fisheries and wildlife. The other 10 however, had few university science courses in their teacher preparation program. Eight had a single science methods course, one had two courses, and one had no science methods course, but a biology course to meet the graduation requirement. "So I did not have [a course on] how to teach elementary students science." (PA8) Many of the teachers commented that their university science methods course had little influence on their own content knowledge "Clearly it wasn't significant, I don't remember it," (PA3) or boost their confidence that they were prepared to teach elementary science.

> It has had almost zero impact. That being said, it has had an impact because that is what has motivated me to learn more to go above and beyond to say, "Jesus Christ, I am not prepared to teach this." I knew nothing and I said if I'm going to start teaching this, I got hired, and I need to learn it. (PA4)

Although two of the teachers described some hands-on activities as part of their science methods course, the general consensus was that the university courses had little effect on their content knowledge or pedagogical content knowledge to teach science.

> I don't think it was very impactful. I don't remember finding it useful… it was less about being a good science teacher and more about, “Here are some activities that you can do with the Moon.” It just seemed more activity-based and less about how to become an effective science teacher. (PA13)

Four of the teachers described their primary mode of science training to be self-initiated, and linked it to their own interest in the subject matter. “Well, (laughs) well the lack of training, I mean it’s a lot of muddling through, figuring out what to do, and collaborating with each other, but it’s had to come from me.” (PA3)

Participant three reported that any professional growth she sought out in science was self-initiated. The concern about the lack of district level professional development in science was shared among thirteen of the educators interviewed.

> Twelve years ago, we had some science professional development in the district, and the focus was to try to help teachers integrate more hands-on experiences with the students. But the district dropped the ball because it never went anywhere after that really good day of professional development. There was no follow-up, and there was no change to what we had or what we did…Aside from that one time, the district hasn't provided anything else in science. (PA10)

The most recent district-supported science training in any of the districts taking part in the study was four years ago. Some of the teachers reported not having any training since they were hired, “Zero in science,” (PA4) or recalled an experience 10 years prior, 12 years prior, and one teacher recounted that the last provided science training took place in her district in the late 1980s. “Since that experience in the late 1980s, I have had no other science trainings from the district that I can remember." (PA11) Lack of science training seemed to be a pattern among younger teachers, who were provided partial science kits, but received no training on how to use them. "I haven't ever been trained on how to use the district science kits. I was given the books and the kits, but I was on my own, which was daunting for someone who is new or inexperienced." (PA5) "I have taught science for eight years, but when it comes to our kits and curriculum, I have received zero training. Zero." (PA7)

Influence of science training. Teachers were asked to reflect on the influence that their training in college, self-initiated learning, and professional development had on their confidence to teach elementary science. Three of the teachers felt that their college learning directly affected their confidence to teach science, however that perspective was the minority. Most recounted that it had little to no influence and two teachers described feeling ill prepared to teach science. "Leaving college, no, I was not even equipped to teach." (PA7) The majority of the teachers interviewed felt compelled to initiate their own learning to become better science teachers because they enjoy the subject. "My confidence comes from the fact that science is my passion. I love it, and I want to learn more." (PA4) In some cases teachers credit this self-initiated learning leading to a significant shift in their science teaching methods and confidence.

Five of the teachers experienced influential science training in their careers that not only supported their own content knowledge, but also improved their pedagogical effectiveness in science teaching. They each described a similar paradigm in which they were immersed in content as adult learners actively engaging in the science content while their instructor modeled the teacher role acting as a facilitator of discovery. "Watching someone model teaching science would have been the best experience I had." (PA8) Teachers reported such experiences enhanced their content knowledge, confidence, and pedagogy.

> We were in the learner position, and a lot of us had background knowledge in a lot of this stuff, but we would go through the entire experience like what a student would do. You make your predictions and your observations, and when you are through, you thought, "This is exactly what I'll be doing with students and this is how I can help them." I knew I could replicate it and that helped build my confidence. (PA9)

Five of the teachers from two different participating districts had recently taken part in a national science training. The teachers had sought out the training on their own to better understand the newly adopted Michigan Science Standards. The training followed a similar model of teachers as learners and they reported significant benefit from the experience.

> I think that's what made the 5 days we spent at the training so different. Even though we were doing activities, and they weren't activities that I could easily take back to my classroom, but it helped me see the process that could be applied to any activity that we teach in science. I believe in our College of Education preparation, we are missing that element. They should be thinking in terms of application to every science lesson and what are the key elements that are included that make it applicable…. I am so grateful that I went. I feel so much

> better going into this year and I feel like I am ready to tackle Next Generation Science Standards. (PA13)

> I mean we copied one of the training experiments the other day in class and I had not ever had their attention like that in class. They were all actively involved and nobody even fought… The posters they came up with when they were developing models were just phenomenal. They all had different topics, pollinators or whatever, and this is the second to last week of school. The knowledge is there I just have to get it out. I can see how this training will do that. (PA11)

Knowing the relationship among teacher confidence, self-efficacy for science teaching, teaching practices and student achievement (Cakiroglu & Isiksal, 2009; Downing, 2011; Ucar & Sanalan, 2011), it is important to provide experiences in which teachers feel greater confidence teaching elementary science. Based upon the participants in this study, they are self-proclaimed "advocates" for science, yet 46% of them claim to have average or low confidence when teaching science. The majority of the teachers interviewed do not feel they have been adequately prepared to teach science from their university coursework or local district. This is also due to the limited professional learning opportunities districts have afforded teachers. With the newly adopted Next Generation Science Standards, teachers are feeling that professional development in which they can be immersed as science learners would not only improve their content knowledge, but also their pedagogy for teaching science and thereby improve their confidence to teach it.

Project Description

I predicted that the findings would lead to several project options, professional development, program evaluation, curricular plan or policy recommendations. Based upon the findings, there is a need to develop and provide professional development to Wise County elementary science teachers to improve content knowledge, pedagogical methods, and enhance teacher confidence. As a county we have determined that I will first provide training using the Next Generation Science Exemplar System, which begins with a 5-day training to introduce the connection of the science and engineering practices of modeling, explanation, and argumentation. However, there are key elements missing in the Next Generation Science Exemplar System that I will address in my original project during a follow-up 4-day training series. Teachers will require additional professional learning to improve teacher confidence, content knowledge, and pedagogical methods. These include learning how to teach core content integrating engineering and design strategies, how to emphasize the cross cutting concepts to help students make better science connections, and how to teach the newly assigned performance expectations in a three-dimensional way integrating the disciplinary core ideas, cross-cutting concepts, and the science and engineering practices. I will provide the professional development to area K-5 science teachers in which teachers will be immersed as science learners to improve their content knowledge and then work as collaborative educators to understand how to infuse three-dimensional science and engineering learning into their classrooms. Teachers who have participated in such study groups stated that it was most influential to improving their confidence, pedagogy, and content knowledge. The training series will target improved content knowledge within physical science and pedagogical methods applicable to each of the science domains. The intent will be to prepare teachers for teaching science that aligns with the newly adopted Michigan Science Standards and the K-12 Science Framework (Harris et.al, 2015). This would include a focus on integrating inquiry-based lesson designs and experiencing the value of a social constructivist model for science learning. Teachers will discover how to incorporate the science and engineering practices, and applying their knowledge of modeling, argumentation, and explanation through purposeful classroom discourse (Bybee, 2014; Christodoulou & Osborne, 2014; Schwarz, Passmore, & Reiser, 2017). The training model will provide ongoing support to the teachers (Pinner & Ray, 2015), as well as establish a county network of educators for ongoing collaborative learning, in-house modeling, and coaching. The intent of that work will be to collaboratively share practice, coordinate curricular unit development among similar grade colleagues, build individual capacity among the county's elementary science teachers, and improve teacher efficacy to improve student understanding of science material.

Section 3: The Project

Introduction

The results from the data indicated that Wise County elementary science teachers believed they would benefit from professional development to improve their instructional effectiveness, increase student achievement, and overcome some of the barriers associated with teaching science. Based upon participant responses, Wise County teachers require professional learning for several purposes. Professional development is needed to support teacher content knowledge, model effective science pedagogy, and clarify the instructional changes necessary to align to the Michigan Science Standards with the ultimate goal of improving student content knowledge in science.

After the elementary teachers in Wise County participate in a 5-day Next Generation Science Exemplar System (NGSX, 2015), they will take part in my 4-day training on three-dimensional learning with science and engineering practices. Participants will spend each of the training days working as both adult learner and reflective educator while exploring the principles in engineering and design, as well as how to use cross cutting concepts to help students build connections in science. Teachers will participate as adult learners working through content using engineering design projects in physical science to improve their understanding of three-dimensional learning and the science and engineering practices (Duschl & Bismack, 2016), as well as work as reflective educators to analyze modeled pedagogy and prepare for implementation in their own classrooms. Each of the training days will be spaced 3 to 4 weeks apart to allow teachers time to practice learned skills and return to collaboratively reflect on their experiences. Teachers will not only have classroom application homework, but also readings to complete.

The goals of the training will be to enhance teacher content knowledge in physical science and understanding of how to teach science in a manner that is aligned to the state standards and National Research Council (NRC) science framework, as well as establish a network of sustainable support.

Rationale

Professional development was the second most identified solution Wise County teachers believed would overcome the barriers to teaching science and enhance student content knowledge. This was second only to having access to aligned curricular resources and materials. However, teachers must first have a good understanding of the material and the methods for teaching it to students, then maximize the benefits that aligned resources can yield. As a result of this need, the Michigan Department of Education determined that a state focus on professional development would be the first state priority to prepare teachers for the adopted Michigan Science Standards (Ziker, 2014).

The data also revealed the large percentage of elementary teachers who lack confidence when teaching science. It was evident that many teachers opt out of teaching science due to their own anxiety and avoidance of the content. The majority of teachers referenced the difficulties they had teaching physical science due to their limited background. Lack of content knowledge was referenced by nearly half of the respondents as a primary barrier that teachers face in Wise County. Several teachers asserted that when pressed for time it was difficult to fit in all of their subjects, so they willingly gave up their science time. Omitting science may have alleviated teacher anxiety, but it did little to boost students learning in science. Providing sustained professional development would impact teacher confidence (Mintzes, Marcum, Messerschmidt-Yates, & Mark, 2013).

Teachers in the county also reported that due to limited pedagogical training experience, both in college and as in-service district teachers, they did not have a strong foundation for knowing how to teach science effectively. The majority found that physical science was especially perplexing to teach and difficult for students to master. There has been evidence that providing professional learning to elementary science teachers alters their instructional practices and effectiveness (Sandholtz & Ringstaff, 2014) as well as changes their attitude about the content (Van Aalderen-Smeets, Walma van der Molen, Van Hest, & Poortman, 2017).

It is evident Wise County teachers would benefit from science professional development. The initial NGSX (2015) training system would address some of the above concerns (Duschl & Bismack, 2016); however, it is not enough to provide teachers with a comprehensive understanding of the science and engineering practices and components of three-dimensional learning required in the Michigan Science Standards. After completing the project training, teachers will have improved content and pedagogical content knowledge, as well as greater confidence teaching science and engineering. Additionally, because the training is aligned to practices required in the Michigan Science Standards, the professional learning would also align with the goals from the Michigan Department of Education (Ziker, 2014). Finally, supporting professional learning for Wise County elementary science teachers could positively impact student achievement (Taylor, Roth, Wilson, Stuhlsatz, & Tipton, 2016). Based upon the identified problem in the county and data findings, a focus on professional development is appropriate.

Review of the Literature

To improve student achievement in Wise County area elementary schools, teachers require professional development to improve both their content and pedagogical content knowledge in science. According to the literature, targeted professional development will need to address several elements. Because Michigan has adopted a variation of the Next Generation Science Standards, the state has been prioritizing teacher professional development on the instructional shifts necessary to provide classroom experiences that are three-dimensional, align to the National Research Council science framework, and improve student learning (Dotger, 2015; Heitin, 2014; Quinn, Schweingruber, & Keller, 2012; Wilson, 2013; Ziker, 2014). The added element of engineering design is another area teachers have limited background knowledge about and necessitates professional learning support (Bybee, 2011; Capobianco, Yu, & French, 2015; Diefes-Dux, 2015; Schafer, Williams, Truscott, & Stenhouse, 2015). The science practice of argumentation embedded within the Michigan Science Standards is also a new element for teachers, so learning how to facilitate productive talk (Michaels & O'Connor, 2012) and argument from evidence in science discourse is another area of new learning (Choi, Klein, & Hershberger, 2015; Osborne, Donovan, Henderson, MacPherson, & Wild, 2016), as is the inquiry-based design for some teachers (Trna, Trnova, & Sibor, 2012). Due to the complexity associated with these shifts and the teachers' claim that professional training is in their students' best interest, elementary teachers require scaffolded professional learning (Kleickmann, Tröbst, Jonen, Vehmeyer, & Möller, 2016; Quinn et al., 2012). Consequently, selecting a genre focus on professional development is appropriate.

The literature review on professional development for elementary science teachers was framed around key terms including *elementary science, student achievement, Next Generation Science Standards, inquiry, three-dimensional learning, content knowledge, pedagogy*, and *professional development*. References were limited to those published in the last 5 years and drawn from scholarly peer-reviewed sources. Because there are numerous states that adopted the Next Generation Science Standards and there is greater attention to opportunities in the STEM fields, there is currently a growing body of research on science in the elementary grades (Reiser, Michaels, Dyer, Edwards, & McGill, 2016). Numerous studies in the literature provided evidence that professional development positively impacts elementary teacher content knowledge, can alter classroom practices and build teacher confidence, and improves student learning (Harlow, 2014; Heller, Daehler, Wong, Shinohara, & Miratrix, 2012; Jackson & Ash, 2012; Lumpe, Czerniak, Haney, & Beltyukova, 2012; Michaels & O'Connor, 2012; Sandholtz & Ringstaff, 2014; Van Aalderen-Smeets et al., 2017). A synopsis of these studies will be explored, as well as the professional learning methods recommended by science experts to be effective for science teachers, and how the selected project aligns with those recommendations.

There was evidence that professional learning can affect both teacher content knowledge and classroom practices (Harlow, 2014; Heller, Daehler, Wong, Shinohara, & Miratrix, 2012; Jackson & Ash, 2012; Lumpe, Czerniak, Haney, & Beltyukova, 2012; Michaels & O'Connor, 2012; Sandholtz & Ringstaff, 2014; Van Aalderen-Smeets et al., 2017). Jackson and Ash (2012) conducted a 3-year study with 24 Texas elementary teachers. During the treatment phase, the researchers met with teachers 1 hour per month to help them align their instruction to the state standards, model the inclusion of inquiry-based instruction, and provide teachers with planning tools. Participants met with researchers 10 times on average over the 2-year treatment period. The findings indicated improved content knowledge, a shift in classroom practice, an increase in confidence teaching science, as well as an increased time commitment for collegial lesson planning (Jackson & Ash, 2012). With respect to the classroom instructional shifts, teachers increased the amount of time dedicated to science instruction, as well as the number of opportunities to engage students in science and engineering practices.

Elementary science teachers often have limited content knowledge, which directly affects student learning. The participants in my study articulated that their science content knowledge was a barrier when teaching science, which aligned with the national literature (Diamond, Maerten-Rivera, Rohrer, & Lee, 2014; Fleer, 2009; Nowicki et al., 2014). Science content knowledge is often traced to the number of science courses teachers have taken in their teacher preparation programs, and there has been evidence of a relationship among the number of science courses teachers have taken, their teacher content knowledge, and science scores in their classrooms (Diamond, Maerten-Rivera, Rohrer, Lee, 2013; Lee & Maerten-Rivera, 2012). In a more recent study, however, Diamond et al. (2014) found that teacher science content knowledge was the most significant predictor of student learning. Although this has implications for preservice teachers, it is apparent that providing professional learning to in-service elementary teachers is beneficial for improving content knowledge and can also improve student learning (Desimone, 2009; Heller et al., 2012).

There has been further evidence that professional development can deepen both teacher content knowledge and student learning. Heller et al. (2012) conducted a randomized experimental study with 270 elementary teachers and 7,000 students in six states investigating the causal relationship that professional development had on content knowledge, instruction, and student learning. They found that improving content knowledge improved instruction and student achievement. However, they also discovered that when the professional development provided learning content in conjunction with analyzing instructional practices and student learning, student outcomes showed a deeper conceptual understanding of the material.

Another aspect of professional development for elementary science teachers that has been associated with improved student outcomes is when the training is scaffolded for teachers and sustained over time. Kleickmann et al. (2016) researched the effects of scaffolded professional development on 73 elementary teacher and 1,039 students. Through the experimental study, the authors had three treatment groups of teachers who were provided with different levels of expert guidance to explore curricular materials. The authors found that teachers receiving the greatest level of guided curricular training had the most significant gains in efficacy beliefs, quality of science instruction, and student learning.

Lumpe et al. (2012) also found that sustained professional learning positively impacted elementary teacher efficacy beliefs for science teaching. They discovered that teacher efficacy combined with the number of hours teachers took part in professional training were significant predictors of both student learning and the time devoted to science instruction. Miller, Curwen, White-Smith, and Calfee (2015) found similar results in their California study with primary teachers in an at-risk school. They found that through sustained support teachers were able to apply what they had learned, develop a culture of collegial learning, and provide active learning experiences to their students that stimulated science thinking.

Evidence has suggested that all elementary teachers could benefit from professional learning in science. Nadelson et al. (2013) found in their study that participating in 3-day summer institute training had significant effect on elementary teachers' content knowledge and affinity for the STEM content introduced. They also measured a significant increase in teacher efficacy beliefs about teaching science and that increased content knowledge directly impacted classroom instructional practice. Additionally, they noted that there was no correlation between the levels of confidence teachers had teaching the STEM content with the number of years teaching. The authors asserted that all elementary teachers benefitted from the professional learning in science regardless of their years of service.

Researchers have suggested several considerations when working toward the most influential professional learning experiences with elementary science teachers. Parker, Abel, and Denisova (2015) worked with an urban school district to establish a STEM program to align to the requirements of the Next Generation Science Standards. Based upon their findings, they made numerous recommendations for improved success with elementary teacher professional development. Teachers must be provided with ample experiences to improve content knowledge, so the training should integrate an explicit focus on content. Teachers should engage in active learning opportunities as both a learner of the content and as a teacher to reflect on the instructional practices. They found that building collective understanding with colleagues resulted in deeper content understanding and that the number of opportunities for collective professional learning increased the likelihood of changing practice.

Immersing teachers as adult learners and reflective practitioners in three-dimensional learning trainings has numerous benefits for teachers (Duschl & Bismack, 2016; Reiser, Michaels, Dyer, Edwards, & McGill, 2016). According to Reiser et al. (2016), there is evidence that such professional development has a positive influence supporting teacher content knowledge within the science domains. It can also improve teacher understanding of three-dimensional learning and classroom experiences that are aligned to the National Research Council framework (Duschl & Bismack, 2016). Participants have improved understanding and confidence using science and engineering practices, which is an important aspect of instruction required by the Michigan Science Standards and one that requires specific support (Osborne et al., 2016). It is evident that even a 3-day training series for teachers is sufficient to support STEM learning (Nadelson et al., 2013) and understand model-based reasoning exercises (Reiser et al., 2016) with science and engineering concepts (Capobianco et al., 2015). Immersing teachers in collaborative instructional analysis and collective knowledge building demonstrates how to incorporate productive talk in the classroom (Michaels & O'Connor, 2012).

The format of this project training series encompasses the evidence-based practices that Parker et al. (2015) identified. The training focuses on physical science content explored through an engineering design lens to deepen content knowledge through applied learning. The participants take part in a series of hands-on design challenges, which help them explore and apply science concepts. They learn how to collectively develop models to design solutions within constraints and engage in the work assuming both the learner and teacher perspective. Finally, the training is delivered over a period of time to provide scaffolded sustainable support. Professional development models such as this are effective in building teacher and student content knowledge, clarifying how to teach in a three-dimensional manner, providing clear pedagogical strategies, and boosting teacher confidence (Parker et al., 2015). Training Wise County elementary science teachers have the potential to positively influence science teaching and improve student achievement.

Project Description

The focus of my project will be to provide professional development to as many Wise County elementary teachers as possible in the next two years. Providing the training series to the Wise County teachers is an opportunity to improve elementary science teaching and learning; however, coordinating such an initiative requires explicit planning and addressing some of the barriers. The initial steps were to present preliminary findings of my study to my supervisors and describe the project training as a means to improve student achievement in the county. My supervisors supported this focus and granted me permission to move forward with the project. To prepare the training series, I had to attend a series of trainings to better understand the Michigan Science Standards, three-dimensional learning, and instruction that is aligned to the National Research Council framework. Such state level endorsements would have cost my agency $3,500. However, the Michigan Department of Education coordinated a grant through Teachers Engaged in Science Leadership Activities (TESLA) and the Michigan Mathematics and Science Centers Network (2017) and invited 80 science consultants including me to be trained. I participated in 12 full days of training completing the final day in January 2017. This provided ample background for me to design the training series for the Wise County teachers.

The next step in the implementation plan is to present my findings to the county superintendents and curriculum directors. I am scheduled to present to county leadership where I will provide a compelling reason for their elementary teachers inclusion in the training. We will examine their district science testing trend data, the teacher perceptions and findings around the four research questions in this study, and the potential for the project training to address those findings and positively impact student achievement in science.

There are potential barriers associated with the training project. Due to the nature of the training, it is difficult to manage more than 35 teachers at one time, so this will require multiple training cohorts to build district capacity within the county. Because the teachers will be engaging in science and engineering design activities, this focus will require access to one of my agency's larger training spaces throughout the year. The agency cost to train each of the county K-5 science teachers could be a deterrent to local districts. Finally, each participant will need a composition book, handout copies, and design supplies to work through the training tasks, so there will be additional agency costs associated with the training.

I do have a solution for each of these barriers. My agency has given me permission to open the training calendar early so that we can schedule eight to 10 cohorts in each of the next two years. This decision will enable me to reserve the training space far in advance, ensure that space is not an obstacle, and provide enough slots to accommodate the county K-5 teachers. My agency has approached district leadership to offer a block fee option in which districts can pay a nominal fee based upon the number of students they serve and send an unlimited number of their teachers to take part in agency provided professional learning in a given year. Therefore, districts will only have the cost of substitute teachers and would not have to pay the typical $200 registration fee. This cost savings could help motivate district leaders to take advantage of the training now so that their teachers could be ready for the newly aligned science assessments the state plans to have in place in the spring of 2020 (Michigan Department of Education, 2016). With respect to the expense of copies, composition books, and training materials, those funds will come from line items in our agency's budget, which is offset both by state funding and the district participation on our block fee grant. By taking advantage of the training local districts could maximize the benefit of their block fee payment. Finally, to further reduce costs and model the accessibility of such instruction, supplies used in the engineering tasks would largely rely on household materials.

My plan will be to run successive, yet overlapping cohorts and encourage districts to send teams of teachers to the same cohort. Teaming teachers would not only build capacity within the building, but also ensure that teachers have a collaborative network of support for implementation. I will begin the first cohort in September focusing on content knowledge development in the engineering design process and the elements of teaching physical science in a three-dimensional manner. We then will meet once each month over the next 2 months exploring the science and engineering practices, components of redesign, reengineering, reverse engineering, cross cutting concepts, productive talk and science discourse, the performance expectations within the Michigan Science Standards, and available resources to align their instruction and curriculum. The second cohort would start 2 weeks after the first and the pattern would be repeated through the 10 cohorts. Training days will be dedicated to Tuesdays and Thursdays so that I could be available for on-site coaching and support on alternate days. After completing the 10 cohorts, I will host grade banded follow up sessions for ongoing support, collaborative unit planning, and reviewing resources. The timeline goal will be to have the majority of elementary science teachers in Wise County trained by the spring of 2019.

Project Evaluation Plan

To evaluate the effectiveness of the professional development training, I intend to use a combination of formative, summative, and outcome measurements. I selected these options for several purposes. With respect to the formative data, my plan is to ensure that the teachers apply their new learning of the science and engineering content during the trainings series. Because they will be working as adult learners in the training, it is important that I verify their understanding of the content, confront misconceptions that arise, and model for teachers how to effectively gather formative assessment data when they are teaching in their own classrooms. These data will be collected during the training days through participant individual models and design plans and anecdotal implementation stories they share at the beginning of the second and third training sessions. At the beginning of each training session, teachers will share and reflect on application tasks they conducted in their classrooms and the student affect that it had.

The summative data will be from two perspectives, first that associated with the changes in teacher thinking and practices for teaching science and engineering, and second the impact of that instruction on student proficiency. Because the ultimate end goal is to improve student learning, measuring the training on student learning is a necessary focus. Summative data will be determined using a pre and post professional development self-assessment survey (see Appendix A). Each participant will take a preworkshop survey, in which they will rate their familiarity with the Michigan Science Standards using a likert scale. They will also complete a scale rating their content knowledge teaching physical science, their level of confidence teaching science, their level of confidence teaching engineering, and weekly time devoted to teaching science. Finally, they will have several constructed response questions. They will be asked to explain the importance of students modeling, to explain phenomena and design solutions, how prepared they feel they are to support students engaging in the science and engineering practices, and what they would like to learn more about with respect to the teaching and learning of science.

I have also designed the training with teacher-specific goals in mind: to increase teacher content knowledge in physical science, to help teachers understand three-dimensional learning and the Michigan Science Standards, to provide pedagogical strategies for teaching science effectively, to improve teacher confidence teaching science and engineering, and to motivate teachers to teach science more frequently to their students. By supporting teachers in their professional learning, it will be possible to positively impact student learning (Harlow, 2014; Heller et al., 2012; Jackson & Ash, 2012, Lumpe et al., 2012; Sandholtz & Ringstaff, 2014; Van Aalderen-Smeets et al., 2017).

The overall evaluation goal of the training is to improve elementary students' content knowledge in science as demonstrated on the fifth grade state science assessment. Although noting the ultimate impact of the professional development will take some time to measure, I assert that by increasing time dedicated to teaching science, and teaching it more effectively and in a manner that is aligned to the Michigan Science Standards, student achievement will improve.

There are many stakeholders that will be affected by this professional development project. The stakeholder groups include the 20,000 K-5 students within Wise County, the elementary science teachers in each of the 12 districts within the county, their building administrators, and the Central Office leadership teams. Additionally, because I will be providing the training as part of my duties as the county STEM Consultant, my agency will be an active stakeholder, as well as the partners through Michigan Department of Education, TESLA grant-provider, and the Michigan Mathematics and Science Centers Network.

Project Implications

At the classroom level, the professional learning has the potential to significantly impact the science experiences that elementary students are provided. Students are the primary beneficiary of the training and are the most significant stakeholder group. Next, the classroom teachers will learn to alter or refine their teaching practices through improved content and pedagogical content knowledge. Their students' performance correlates to their effectiveness on state required evaluations, so teachers have a professional interest in improving student learning. Building administrators are relevant stakeholders as the state science proficiency scores impact public school perception, and because the administrator is accountable for student progress and teacher effectiveness. This training will affect Central Office leadership, as there will be a cost for substitute teachers during release training days. At the same time, because the training will be provided at a significantly reduced cost, they can be mindful of their budget restrictions and invest in their teachers' professional growth. Such learning could support the goals in the curriculum department, as well as their school improvement and strategic plan initiatives to improve student learning.

The professional agencies involved in the project will take an interest in the project as well. First, the goal of my agency is to support county districts through education and professional development training as a means to improve student achievement. The professional learning opportunity aligns with the mission of our agency and will be useful for documenting the number of teachers we serve in a given year. The Michigan Department of Education will take an interest, as they have helped coordinate science leadership training so that I could develop a teacher learning opportunity that supports the transition to instruction aligned to the Michigan Science Standards. Any data I can provide to demonstrate its effectiveness would be relevant. The partnership between the TESLA grant-provider and the Michigan Mathematics and Science Centers Network will want to evaluate the affect the science leadership training has on teaching and learning to justify the financial investment in my training and its effect on teacher practices and student learning.

On a larger scale, society has a stake in such improvement as the training could result in introducing science and engineering content to students in a manner that fosters creativity and motivates them to follow an interest in science and the STEM fields. This emphasis has the potential to have long lasting social change implications.

Michigan and the United States have many concerns associated with science and STEM. There is concern about global competition in the STEM fields and the relationship about innovation and a country's economy (Hausman & Johnston, 2014).

There is a concern about the disproportionate number of women and minorities pursuing STEM careers (Sakulich & Peterson, 2017). Historically poor achievement results on international mathematics and science assessments rank the United States lower than would be expected for an innovative wealthy country (Martens & Niemann, 2013). There are many open STEM positions around the country that cannot be filled due to lack of qualified candidates (Lewin & Zhong, 2013). In light of the economic concerns, there is evidence that establishes the relationship among a nation's creativity, innovation, economic prosperity and its student achievement (Fang, Xu, Grant, Stronge, & Ward, 2016). With such a national emphasis on innovation, competition, and economic prosperity, it is evident that such national interests must first start with quality education and opportunities. Quality science education comes with investing in the time to teach it, and by presenting the material in a manner that stimulates curiosity, which has proven to be predictive of increased student achievement (Tatar, Tüysüz, Tosun, & İlhan, 2016). With local districts prioritizing a greater value for science education and investing in ample training for their teachers, the end result could be not only improved student achievement, but also investing in the next generation of innovative STEM problem solvers.

Section 4: Reflections and Conclusions

Project Strengths and Limitations

The primary goal associated with providing this professional development series is to improve teacher effectiveness and students learning, and trainings that emphasize teachers being immersed in three-dimensional learning themselves have proven to be effective (Duschl & Bismack, 2016; Reiser et al., 2016). Based upon the research on what training characteristics lead to more effective professional learning experiences (Parker et al., 2015), the format of this training is well aligned. Because the training focuses on content within physical science, a science domain Wise County teachers identified as being challenging due to their limited content knowledge, the numerous exploratory experiences will help to build teacher understanding. The opportunity for teachers to be active participants in the learning process as adult learners and reflective instructors is another strength and is an identified effective professional learning characteristic. The sustained work group format of the training series also aligns with literature recommendations for collective learning and its deeper content knowledge and could increase the likelihood that teachers will alter their classroom practice with their students.

There are potential limitations associated with the project as well. Although the training series has the potential to increase teacher content knowledge in physical science as other three-dimensional trainings have done (Duschl & Bismack, 2016; Reiser et al., 2016), elementary teachers may not feel equipped to transfer the pedagogical methods to life science or earth and space science. Teachers may still feel less equipped to teach those areas if they lack content knowledge and confidence within those domains.

Another limitation is that there is no guarantee that the teachers will transfer their knowledge from the training and alter their classroom practice or increase the instructional time dedicated to science. Although some will feel motivated to better prepare their students to meet the demands of the Michigan Science Standards in preparation for the fifth grade state assessment, it still requires the teachers to feel a sense of motivation to commit to that level of work. It is possible that teachers will not, particularly teachers in younger grades who feel less accountable to the fifth grade test and might prefer to dedicate instructional time to literacy and mathematics. Some teachers may also be required to attend the training from their administration, but not believe that the effort to change their current practice is worth the time and effort.

A third limitation is the risk of districts not making science a professional learning priority and sending their teachers for training. If districts elect not to participate in the training, there is little chance that they will see changes to their student achievement in science. At the same time, there is the concern of administrators sending selected teachers to reduce substitute teacher costs in hopes that the ones they send could train the remaining staff. This situation would be problematic for two reasons. First, if teachers are not sent with building colleagues, it is difficult to scale up building capacity, establishing too great a burden on a few teachers, making the work too demanding, and reducing the likelihood of long-term change. Second, teachers who engage in the training alone have no one accessible for collaborative planning and reflection, which could reduce their motivation to alter their practice.

A fourth limitation is whether or not the 3 training days will be sufficient to meet the intended goals of the project. Although the learning time may be ample for some teachers, particularly those who feel more confident teaching science, it may not be enough for those who avoid teaching science already. Those teachers may require additional support and training.

A final limitation of the project is that at the conclusion of the training, the teachers must still work with the curricular resources that their districts have. Most Wise County teachers were critical of their resources, asserting they were out of date, were not plentiful enough to have for any duration, and had many missing materials. Although the training equips teachers to use currently accessible resources in a three-dimensional manner, many teachers could still feel overwhelmed by that approach and prefer a comprehensively aligned curriculum be provided.

Recommendations for Alternative Approaches

Although this project focuses on the use of professional development for elementary science teachers to improve student achievement, an alternate approach could have been an evaluation study and curriculum plan. It is possible that the students underperform in science because of the content and curriculum. The materials may not be effective in improving student understanding, or the materials may not be useful to classroom teachers so science is not covered so completely. Knowing that the Wise County teachers were largely dissatisfied with the science curriculum and the science kits the districts currently use in the elementary grades, choosing a curricular focus might also improve student achievement and support teachers' professional growth and confidence.

In this regard, the project might begin with an evaluation study, reviewing K-5 science curriculum claiming to be aligned to the Next Generation Science Standards. Using the Next Generation Science Standards (2017) Equip 3.0 rubric tool, my agency could evaluate which science programs were most aligned and offer the most supports to classroom teachers to improve student learning in science.

The next step would be to take those findings to local district leadership and contact publishers for formal county presentations from the vendors. I would allow districts 1 to 2 months to review materials and reflect on the formal vendor presentations before reconvening county leadership and seeking their action plan. Those district personnel who want to move forward with a purchase would work to find consensus on the preferred series. Working through my education provider agency, we could leverage a collaborative purchase to lower the overall costs for the individual districts.

Those districts that elect to purchase and adopt the curriculum would then be invited to take part in countywide professional development focusing on the curriculum itself. Trainings would be conducted by grade level to help teachers become familiar with the units and lessons, understand the science progression, and build collaborative capacity. Teachers would be invited to take part in a formal kickoff training in the summer before school begins, then meet three times throughout the year to familiarize and prepare for the two upcoming science units. This would help with the fidelity of implementation, as well as give time for teachers to better understand the specific content that they will be teaching.

Although a project focus on curriculum could be a viable solution, I expect that I will initiate such work in my agency once publishing companies have more time to develop better aligned curriculum. When the Common Core was adopted in Michigan, many of our local districts purchased math programs that were labeled as being aligned to the Common Core. However, after making purchases, those districts in Wise County discovered there were many areas in the content that were not aligned and still required supplementation. That experience has made local superintendents more thoughtful and patient to ensure that curricular investments are well informed and collaborative.

Scholarship, Project Development and Evaluation, and Leadership and Change

When I first started envisioning the project study, I anticipated a completely different direction my project would take than where I landed. In that time, accountability requirements in science have increased in my state, Michigan has adopted new K-12 science standards, I have changed careers, and the science achievement scores in my county have remained flat. The findings in my study pointed to the need for targeted professional development to improve elementary teachers' content and pedagogical knowledge in science and engineering, enhancing their confidence, and prioritizing science so that dedicated instructional time could occur in the elementary grades. In my new position as the sole STEM consultant in the county, I have oversight of the science achievement and bear responsibility to support districts in systematic improvement and professional development for teachers. Not only are my findings of interest to the local stakeholders, but also they are now compelled to address the challenges they face in their elementary science programs. Consequently, I intend to fully implement my project to achieve those goals.

Additionally, with the adoption of the Michigan Science Standards, my state has also taken recent interest in a professional development model to better prepare teachers and students for the Michigan Science Standards. Serving as one of the state science leaders afforded me an opportunity to receive significant training in preparation for the Michigan Science Standards, which I concluded in January of 2017. It was evident that this background aligned with the needed professional development outcomes for the Wise County elementary science teachers. The intersection of my doctoral work with my personal professional goals was not originally anticipated but is of great benefit to the students and teachers in my region.

When planning the study itself, I recognized that I must start with a report for county superintendents to establish compelling reasons to dedicate more attention to science learning. By receiving a summary of my findings in conjunction with the historically flat achievement scores, recent adoption of the state standards, and the accountability and transition timeline defined by the Michigan Department of Education, superintendents would have to make science learning a higher priority. I also thought it best to then describe the training opportunity and provide them with cohort timelines and flyers for distribution to their building principals and teachers. Helping stakeholders become aware of their options requires facilitated conversation, so I elected to provide as much detail as possible that they could share.

As I considered the challenges that elementary science teachers face, I made the choice to focus on professional development in the project first rather than jumping to curriculum. Because the instructional shifts are so significant in the Michigan Science Standards, teachers must first focus on their own content knowledge and pedagogy. I decided to spread the series over 3 full days to reduce the number of days teachers will have to be out of their classrooms. The platform, however, is set up to support both a science focus and an engineering focus as they learn how to integrate the disciplinary core ideas, science and engineering practices, and cross cutting concepts within their respective grade bands. They will discover how to embellish their current science units so that they are fully three-dimensional and incorporate summary tables, phenomenon-based explanations, design solutions, and effective student discourse. Throughout the training teachers will have practice implementing their learning and be provided with collegial support and mentoring.

This project has profoundly affected me as a scholar practitioner. I feel equipped to analyze education data and engage in research to improve systems and student learning. When I first began this journey, I was a classroom teacher, then became a school administrator, and am now the sole science consultant in the county. The research and work that I conducted in this project study is now directly applicable to my work and will bring about social change in my region.

The experience has improved my confidence to establish a comprehensive professional development project. At the same time, I feel more prepared to anticipate implementation challenges and determine solutions while still in the preparation stage. A primary component in my current job description is providing science professional development to teachers and administrators to improve student achievement. It is exciting to consider that all of the energy invested in this project will be realized in its full implementation. I am already anticipating next steps of support, which will likely include on-site coaching, curricular review and recommendation, then unit-specific professional development. Although each of these future goals is extensive, I recognize my ability to implement them as well.

Reflection on Importance of the Work

As I reflect on this process, it is evident to me how one's observations when objectively informed, can lead to significant change. Wise County has not invested in science teaching and learning largely ignoring the subject matter for numerous years. I can only imagine how many students have missed learning opportunities, and in some cases, may have lost the inspiration to pursue a career in science or STEM. Helping districts recognize and acknowledge the deficiencies in their science programs is the first step in making science learning a higher priority. However, providing them with corroborated feedback from their own teachers and potential solutions to bring about systemic change, gives the districts a path to pursue. Rather than simply complaining about the issue or assigning blame, the discussion becomes more solution focused. With the help and guidance of my agency to provide training and sustainable support to county teachers, I believe we are poised to see significant change in student learning and teacher effectiveness in elementary science.

County leadership is well aware of my research and that alone is helping them to be more reflective on their K-12 science programs. Superintendents are already reaching out to me to help them define targeted action plans and suggest revisions to their school improvement goals to address the needs in science. Although this study has exclusively examined K-5, the training will affect the entire K-12 progression. In time, elementary students will enter middle school with deeper content knowledge in science and increased exposure. Secondary teachers will then provide even more sophisticated learning to their students. Not only will students be more science literate in the county, but also demonstrate that knowledge on the state's accountability assessments.

I believe we are at a crossroads in the state of Michigan with respect to science teaching and learning. Engaging in this research, particularly as it supports my current position, will have a profound effect on the science learners in my region. I feel fortunate to have engaged in this work and have a greater appreciation of how the efforts of an individual can lead to dramatic social change.

Implications, Applications, and Directions for Future Research

Wise County elementary science standards have a history of poor achievement. Implementing a targeted professional development to enhance teacher content and pedagogical content knowledge has the potential for positive social change at many levels. The ultimate intended outcome of the project is to improve student achievement in science. In doing so, student success could also influence their self-concept. Achieving greater success in science content could not only improve their science literacy, but also their interest in the subject matter, their perseverance, and their ability to solve novel problems. Students who are more interested in subject matter would be more likely to pursue careers in fields that engage in that subject matter.

Positive student feedback about district science learning would be highly influential on local families. Not only would they take pride in their children's success, but hold higher regard for their local schools and their commitment to improving student learning. Establishing support among local families could lead to the passing of local millage initiatives, greater parent involvement in the schools, and public celebratory communication about the schools.

Elementary science teachers have the potential to experience significant changes as well. The training has the potential to improve their content understanding and boost confidence teaching science. If a teacher feels confident teaching content, they are less likely to avoid that material, choosing instead to provide additional learning opportunities for their students. Additionally, as students begin to perform better on state standardized assessments, those results will yield positive reflections on the reputations of the teachers both within the community and among district administration.

District administration would benefit from improved science achievement among the elementary student body. Because student achievement is publicly reported and closely monitored within communities, any success catches media attention and leads to community pride. Improving district reputations could lead to a bigger influx of students choosing to attend the district and increase revenue into general funds. At the same time, local science industry might take an interest in positive trends in student learning and be more eager to further student learning opportunities through community partnerships.

On a broader scale, by improving student science learning and increasing the number of students who are fond of the content, it is more likely that the number of students pursuing science and STEM professions would also increase. This increase would benefit society with a supply of ingenuity and innovation to support the economy while protecting the natural world.

The project could have methodological implications as well, relating to the practicing pedagogy of science teaching. Within the new vision of the Michigan Science Standards, students are expected to routinely engage in the active application of the science and engineering practices. This paradigm is uniquely different from how students have traditionally been taught science. One of the outcomes of the project is to help teachers recognize how this model of science and engineering teaching is different from traditional instruction and how it can be incorporated into their instructional practice. Because the students are required to think much more deeply about content, provide reasoning for their thinking, evidence for their claims, and novel solutions to problems within defined constraints, they are incorporating the same skills that field scientists and engineers engage. This model not only has the potential to improve teacher effectiveness, but also instills habits of thinking among our students that are much more sophisticated than what we have been able to elicit from students with traditional science teaching.

There is potential for future research as a result of this project. It would be advisable to continue to follow the teachers who have completed the training to monitor any measurable changes in content knowledge, time devoted to teaching science, efficacy beliefs, and their students' achievement. It would also be interesting to conduct a correlational study to determine whether or not teachers who participate in the training with grade level building colleagues are more likely to implement instructional changes than those who attend the trainings independently. Most importantly, it is necessary to follow the county student achievement scores to determine if the teacher training has a measurable impact on student content knowledge. An additional study for six to 12 teachers would be useful to determine if the program has similar teacher outcomes, and if so are they transferable into improved student achievement for older students. Finally, there is a potential for a long-term study following elementary students who report an increased affinity for science content as they mature. It would be worthwhile to follow students over time to see if their science interest sustains through their high school years and into adulthood possibly leading to a STEM degree and eventual career.

Conclusion

During the research for this study, it became evident me that elementary students in Wise County, as well as in the state of Michigan and entire United States, are demonstrating limited science content knowledge and that elementary teachers are faced with numerous challenges associated with science teaching and learning. At the same time there are demands for a growing technologically equipped workforce in the STEM fields, shifts in national educational science standards, and accountability measures for school effectiveness and student proficiency. These conflicting situations warrant greater attention to science education and points for increased support for elementary science teachers. By providing targeted professional development, it is possible to boost teacher science content knowledge, improve pedagogical methods, and enhance science teachers' confidence. Consequently, it is also possible to improve student learning, bolster societal perceptions of schools, and inspire more students to gravitate to STEM fields and serve as the next generation of innovative visionaries.

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Appendix A: Preparing for the Michigan Science Standards Training Project

The purpose of the professional development project in Wise County is to increase elementary teacher content knowledge in physical science, to help them understand three-dimensional learning and the Michigan Science Standards, to provide pedagogical strategies for teaching science and engineering effectively, to improve teacher confidence teaching science, to motivate teachers to teach science more frequently to their students, and to ultimately improve elementary students' content knowledge as measured by the state summative science assessment. By supporting teachers in their professional learning, it will be possible to positively impact student learning.

The training is targeting K-5 teachers in Wise County who teach science, and districts will be encouraged to send teams of teachers to attend the same cohort in order to build capacity within the building and district. Teachers will attend four days of training over a period of three months. Prior to beginning the training, teachers will complete a survey in order to evaluate their learning over time. This program focuses on the integration of phenomenon explanations and design solutions within physical science disciplinary core ideas. Participants will unpack the elements of three-dimensional learning and the Michigan Science Standards. The training will allow K-5 teachers to engage as adult learners with science content and engineering content, and provide practical implementation strategies to support pedagogy aligned to the vision of the National Research Council's Framework for K-12 Science Education. The four-day training series is designed to engage teacher learners in a study group format in the three major dimensions of the Michigan Science Standards- core ideas of science, scientific and engineering practices, and the crosscutting concepts. Training days will include science and engineering content exploration, on-site coaching and modeling, group science modeling and discourse, reflection time for analysis and problem-solving, collaborative unit planning, and the reviewing resources. Teachers will complete a post-training survey to measure the effectiveness of the training, which will also be measured through formative means throughout the training.

The following includes the pre and post survey documents, the daily training agendas and training details, as well as the training slides for each session.

Pre-Project Training Teacher Survey

For each of the following statements, please circle the number that best characterizes how you feel about the statement where 1 = Strongly Disagree and 10 = Strongly Agree.

	Strongly Disagree									Strongly Agree
I am familiar with the Michigan Science Standards.	1	2	3	4	5	6	7	8	9	10
I understand physical science content.	1	2	3	4	5	6	7	8	9	10
I am confident teaching science.	1	2	3	4	5	6	7	8	9	10
I am confident teaching engineering.	1	2	3	4	5	6	7	8	9	10
I spend at least 90 minutes teaching science each week.	1	2	3	4	5	6	7	8	9	10

Please answer the following questions in detail.
What is the importance of students engaging in modeling to explain phenomena and design solutions?

Do you feel prepared to support students engaging in the science and engineering practices? Why or why not?

What would you like to learn more about with respect to the teaching and learning of science?

Post-Project Training Teacher Survey

For each of the following statements, please circle the number that best characterizes how you feel about the statement where 1 = Strongly Disagree and 10 = Strongly Agree.

	Strongly Disagree									Strongly Agree
I am familiar with the Michigan Science Standards.	1	2	3	4	5	6	7	8	9	10
I understand physical science content.	1	2	3	4	5	6	7	8	9	10
I am confident teaching science.	1	2	3	4	5	6	7	8	9	10
I am confident teaching engineering.	1	2	3	4	5	6	7	8	9	10
I spend at least 90 minutes teaching science each week.	1	2	3	4	5	6	7	8	9	10

Please answer the following questions in detail.

What is the importance of students engaging in modeling to explain phenomena and design solutions?

Do you feel prepared to support students engaging in the science and engineering practices? Why or why not?

What would you like to learn more about with respect to the teaching and learning of science?

Implementation Timeline

Spring 2017: Present to county superintendents and curriculum directors establishing the rationale for the training and the timeline.

Training Dates for 2017-2018

Cohort 1: Day 1- September 5, 2017
Day 2- October 3, 2017
Day 3- October 24, 2017
Day 4- November 14, 2017

Cohort 2: Day 1- September 12, 2017
Day 2 - October 5, 2017
Day 3- October 26, 2017
Day 4- November 16, 2017

Cohort 3: Day 1- September 19, 2017
Day 2 - October 17, 2017
Day 3- November 7, 2017
Day 4- November 30, 2017

Cohort 4: Day 1- September 26, 2017
Day 2- October 19, 2017
Day 3- November 9, 2017
Day 4- November 28, 2017

Cohort 5: Day 1- October 10, 2017
Day 2- November 2, 2017
Day 3- November 15, 2017
Day 4- December 5, 2017

Cohort 6: Day 1- January 9, 2018
Day 2- January 30, 2018
Day 2- February 20, 2018
Day 4- March 13, 2018

Cohort 7: Day 1- January 16, 2018
Day 2- February 8, 2018
Day 3- March 1, 2018
Day 4- March 22, 2018

Cohort 8: Day 1- January 23, 2018
Day 2- February 22, 2018

Day 3- March 15, 2018
Day 4- April 5, 2018

Cohort 9: Day 1- February 1, 2018
Day 2- February 27, 2018
Day 3- March 20, 2018
Day 4- April 10, 2015

Cohort 10: Day 1- February 13, 2018
Day 2- March 8, 2018
Day 3- March 29, 2018
Day 4- April 19, 2018

Training Dates for 2018-2019

Cohort 11: Day 1- September 4, 2018
Day 2- October 2, 2018
Day 3- October 23, 2018
Day 4- November 13, 2018

Cohort 12: Day 1- September 11, 2018
Day 2- October 4, 2018
Day 3- October 25, 2018
Day 4- November 15, 2018

Cohort 13: Day 1- September 18, 2018
Day 2- October 16, 2018
Day 3- November 6, 2018
Day 4- November 29, 2018

Cohort 14: Day 1- September 25, 2018
Day 2- October 18, 2018
Day 3- November 8, 2018
Day 4- November 27, 2018

Cohort 15: Day 1- October 9, 2018
Day 2- November 1, 2018
Day 3- November 14, 2018
Day 4- December 4, 2018

Cohort 16: Day 1- January 8, 2019
Day 2- January 29, 2018
Day 3- February 19, 2019

Day 4- March 12, 2019

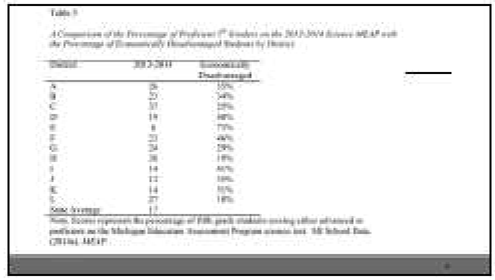
Cohort 17: Day 1- January 15, 2019
Day 2- February 7, 2019
Day 3- February 28, 2019
Day 4- March 21, 2019

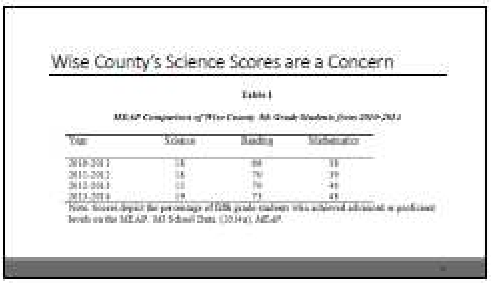
Cohort 18: Day 1- January 22, 2019
Day 2- February 21, 2019
Day 3- March 14, 2019
Day 4- April 4, 2019

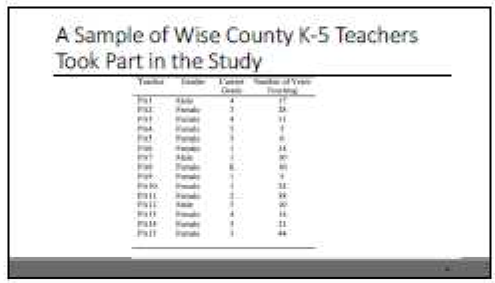
Cohort 19: Day 1- January 31, 2019
Day 2- February 26, 2019
Day 3- March 19, 2019
Day 4- April 9, 2019

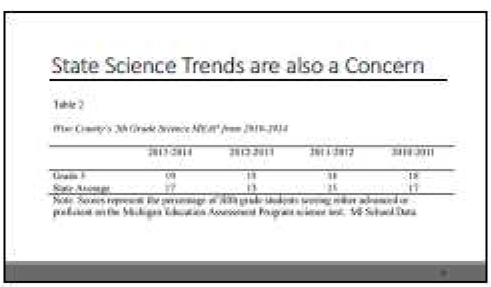
Cohort 20: Day 1- February 12, 2019
Day 2- March 7, 2019
Day 3- March 28, 2019
Day 4- April 18, 2019

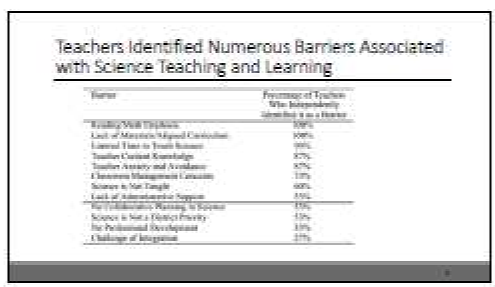
Project Study Slide Show Report to Wise County Superintendents











Primary Identified Barriers

Barrier	Percentage of Teachers Who Identified it as a Primary Barrier
Limited Time to Teach Science	80%
Teacher Content Knowledge	46%
Science is Not a District Priority	33%
Lack of Materials/Aligned Curriculum	33%
Reading/Math Emphasis	26%

Please recognize the need for district conversations to address the time devoted to science instruction. Prioritizing the content is a necessity.

Michigan Science Standards Adoption

The Michigan Science Standard were adopted in November 2015. This adds to the need for professional development in science. Teachers must first understand the instructional shifts before we look at curriculum.

MICHIGAN Department of Education

These standards mirror the Next Generation Science Standards (with a few Michigan specific references).

Teacher Confidence is Another Challenge

Confidence Level	Percentage of Teachers Who Identified with Each Confidence Level
High Confidence	53%
Average Confidence	33%
Low Confidence	13%

Note. The teachers who elected to participate in the study consider themselves as science advocates and generally enjoy teaching science.

NGSS States

Numerous states, like Massachusetts and Utah, have adopted a variation of NGSS.

Strategies Teachers Believe will Overcome Barriers and Improve Student Learning

Strategy	Percentage of Teachers Who Identified the Strategy
Aligned, Hands-On Curriculum & Resources	87%
Professional Development	80%
More Flexible Instructional Schedule	73%
Make Science a District Priority	67%
Mentorship & Collegial Planning	60%
Team Teaching Departmentalized Instruction	53%
In-house Content Specialist	53%
Honest Dialogue About Challenges & Solutions	37%
Administrator Support	27%
Opportunities to Play/Explore with Science Materials	20%

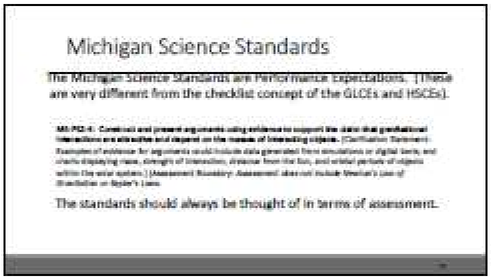
Note. The strategies were independently identified in response to an open-ended question within the interview guide.

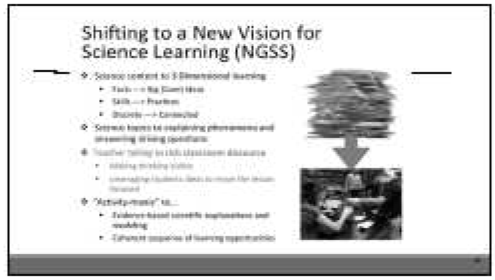
MDE's Transition Priorities

Professional Development:
- First, NGSX Trainers train 80,000 Teachers
- Second, support teachers in learning how to integrate Engineering Technology within the three dimensions

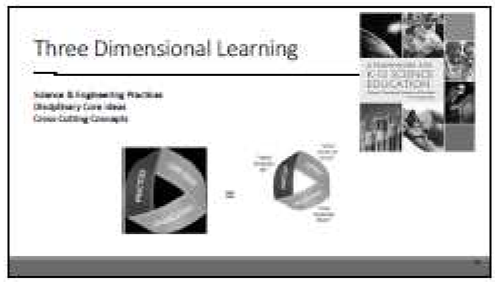
Shift Classroom Instruction:
- Trained teachers "NGSSify their Current Content"
- Three-dimensional learning

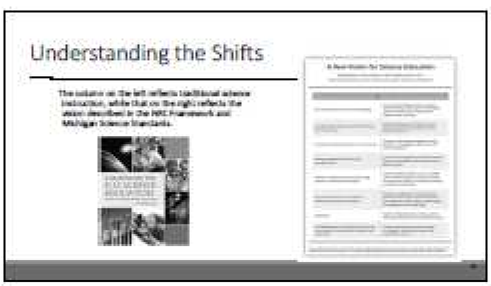
Develop and Pilot Assessments

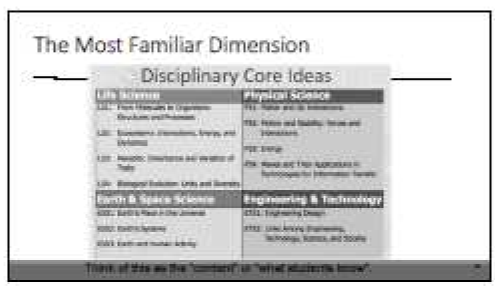

Michigan Science Standards
The Michigan Science Standards are Performance Expectations. (These are very different from the checklist concept of the GLCEs and HSCEs).
The standards should always be thought of in terms of assessment.

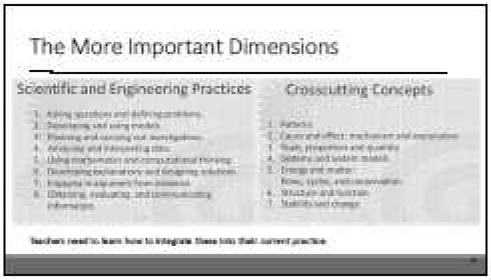

Shifting to a New Vision for Science Learning (NGSS)

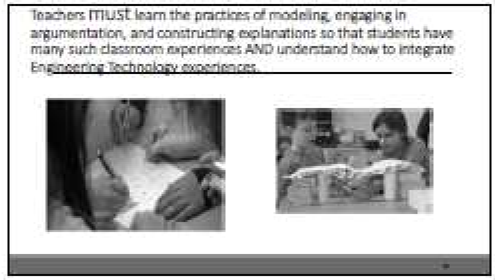

To prepare students for the performance expectations, students will need coherent, consistent, high quality three dimensional science learning experiences.
The Next Generation Science Standards are written as performance expectations
Science and Engineering Practices

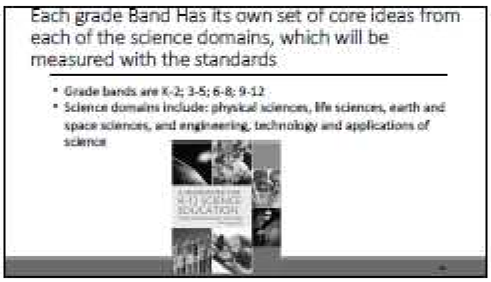

Three Dimensional Learning
Science & Engineering Practices
Disciplinary Core Ideas
Cross Cutting Concepts
K-12 SCIENCE EDUCATION


Understanding the Shifts
The column on the left reflects traditional science instruction, while that on the right reflects the vision described in the NRC Framework and Michigan Science Standards.


The Most Familiar Dimension
Disciplinary Core Ideas
Life Science
Physical Science
Earth & Space Science
Engineering & Technology
Think of this as the "content" or "what students know".

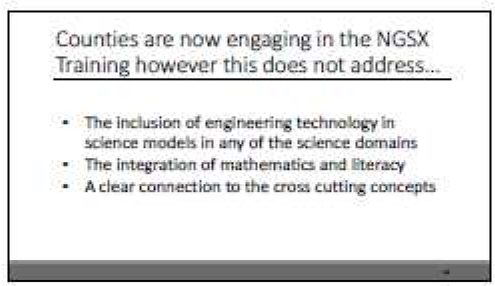

The More Important Dimensions
Scientific and Engineering Practices
Crosscutting Concepts
Teachers need to learn how to integrate these into their current practice


Teachers must learn the practices of modeling, engaging in argumentation, and constructing explanations so that students have many such classroom experiences AND understand how to integrate Engineering Technology experiences.


Each grade Band Has its own set of core ideas from each of the science domains, which will be measured with the standards
• Grade bands are K-2; 3-5; 6-8; 9-12
• Science domains include: physical sciences, life sciences, earth and space sciences, and engineering, technology and applications of science


Michigan has a group of facilitators who have recently been trained to lead this work—me being one.


Michigan Science Standards: How does this change instruction?

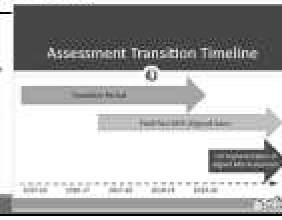

Counties are now engaging in the NGSX Training however this does not address...
• The inclusion of engineering technology in science models in any of the science domains
• The integration of mathematics and literacy
• A clear connection to the cross cutting concepts

Introducing Level 2: Preparing for the Michigan Science Standards

The four-day training series is designed to engage teacher learners in a study group format in the three major dimensions of the Michigan Science Standards: core ideas of science, scientific and engineering practices, and the crosscutting concepts.

MSS Assessment Timeline

- Initial field test item clusters written to the new MSS will be available this spring (either through traditional or stand alone field tests).
- MDE anticipates that a complete transition to a new MSS aligned test may occur in the Spring of 2020.



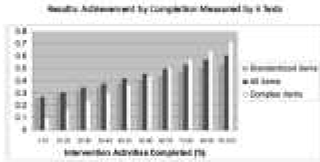
Training Goals

- Improve teacher content knowledge in physical science
- Establish better pedagogy and instruction
- Help teachers prepare for the Michigan Science Standards
- Improve teacher confidence
- ****Improve student learning

Tentative Assessment Timeline

- The No Child Left Behind Act (NCLB) and state law require that we give a state science exam once each in elementary, middle, and high school. The Every Student Succeeds Act (ESSA) continues these same requirements.
- MDE will continue to give the SAT and the M-STEP Science and Social Studies for 11th Grade
- The timeline for the New Michigan Science Standard assessment is:
  - Spring 2017 - Field Test New MSS aligned item clusters (Grades 5, 8, 11)
  - Spring 2018 - Field Test New MSS aligned item clusters (Grades 5, 8, 11)
  - Spring 2019 - Aligned MSS M-STEP assessment (No High Stakes accountability) (Grades 5, 8, 11)
  - Spring 2020 - Fully operational MSS assessment (Grades 5, 8, 11)

The Power in Three-Dimensional Learning



Where are we as a county?

We currently have 400 teachers now getting trained in Level 1, so it's time to plan ahead.

Preparing for the Michigan Science StandardsTraining begins September 5, 2017.

This program focuses on the integration of phenomenon explanations and design solutions within physical science disciplinary core ideas. Participants will unpack the elements of three-dimensional learning and the Michigan Science Standards. The training will allow K-5 teachers to engage as adult learners with science content and engineering content, and provide practical implementation strategies to support pedagogy aligned to the vision of the National Research Council's Framework for K-12 Science Education.

Next Steps

Next Steps in Transitioning to MSS

1) Preparing for the Michigan Science Standards Training
2) Administrator Trainings
3) Division of Performance Expectations/ Course Mapping
4) Curricular Exploration or working to NGSSify current curriculum (i.e. TCI Science Alive)

Preparing for the Michigan Science Standards, a Project Study Report to Wise County Superintendents

THANKS FOR LETTING ME JOIN YOU TODAY!

[illegible]

MSS Level 2 Trainings in 2017-2018

There are 10 Preparing for the MSS cohorts scheduled in [illegible]
- Maximum of 32 per cohort
- Training is intended for all K-5 science teachers.
- Each series is four (non consecutive) full days of training.
- The study group format is most beneficial during the year so teachers can integrate three-dimensional learning while they learn it.

Advertising Flyer

Preparing for the Michigan Science Standards

STARTS

SEPTEMBER 5, 2017

(10 COHORTS THROUGHOUT 2017-2018)

This program focuses on the integration of phenomenon explanations and design solutions within physical science disciplinary core ideas. Participants will unpack the elements of three-dimensional learning and the Michigan Science Standards. The training will allow K-5 teachers to engage as adult learners with science content and engineering content, and provide practical implementation strategies to support pedagogy aligned to the vision of the National Research Council's Framework for K-12 Science Education.

The four-day training series is designed to engage teacher learners in a study group format in the three major dimensions of the Michigan Science Standards- core ideas of science, scientific and engineering practices, and the crosscutting concepts.

Training Goals:
Improve elementary science teacher content and pedagogical content knowledge, boost teacher confidence, and improve student learning in science.

Open to all
K-5 Teachers

Facilitated by Robert Stephenson

Wise County Education Service Provider

Day 1- Preparing for the Michigan Science Standards: Integrating Engineering Technology in Three-Dimensional Learning

8:00: Introductions and Agenda

8:15: Why is there such an emphasis on Engineering Technology in the MSS?

8:35: Engineering Technology in the MSS: A Design Challenge to Get Us Started

9:15: Modeling within Engineering Technology

9:35: Gallery Walk and STEAM Meetings

10:00: Connecting Mathematics and Research, in the Science and Engineering Practices

10:30: Break

10:40: Engineering Design in a K-3 Classroom- a Second Challenge

11:15: NGSS Instructional Shifts and Analysis

11:30: Lunch

12:10: Research Findings in Elementary Classrooms

12:30: Reengineering: Application with the SCAMPER Strategy

1:20: Going Public in Scientific Modeling

1:30: Break

1:40: Math Connections- Determining Cost Factors and Developing a Marketing Plan

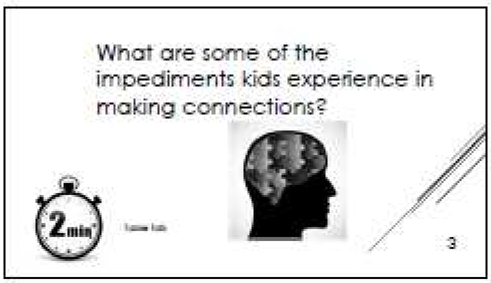
2:15: Coding as a Part of the Science Classroom

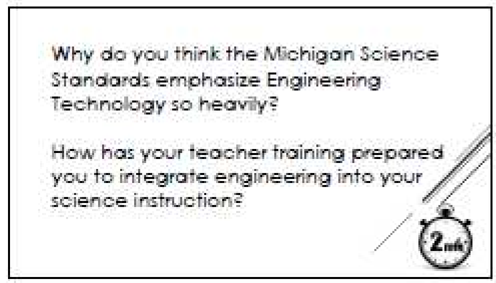
2:30: Coding: the Student Perspective & Teacher Perspective

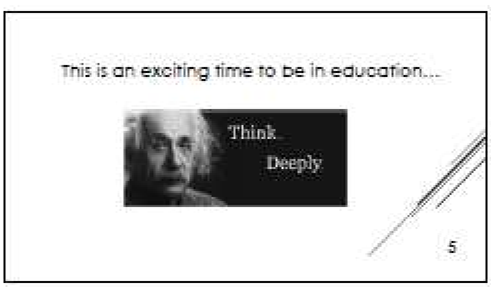
3:20: Reflection, Goal-Setting, and Discussion

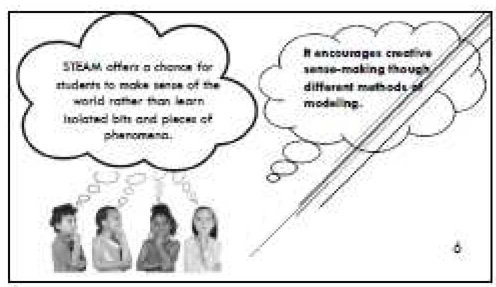
3:30: Adjourn

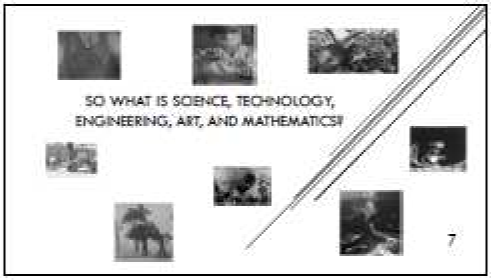
Day 1 Training Slides

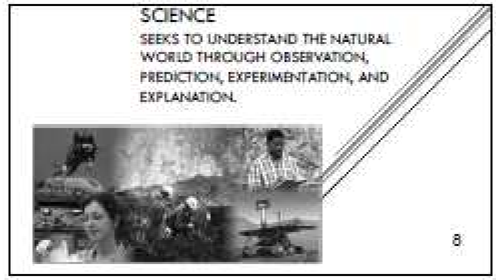


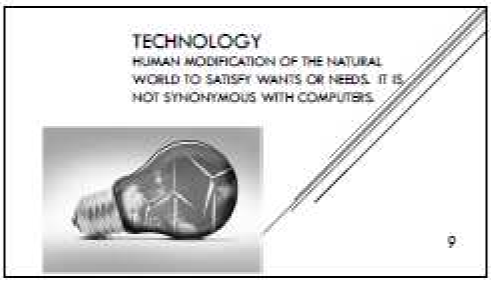


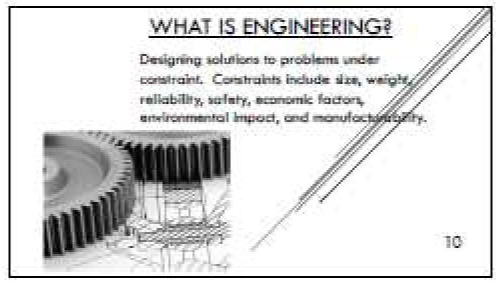


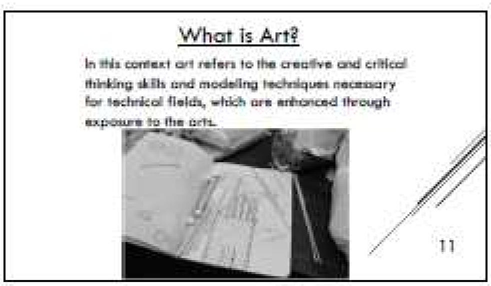


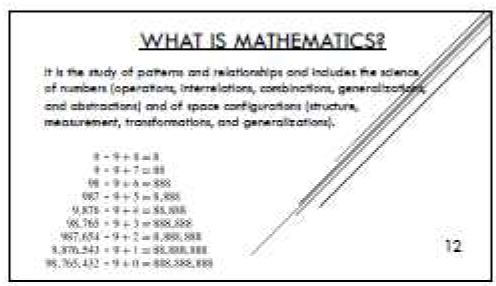

SO WHAT IS SCIENCE, TECHNOLOGY, ENGINEERING, ART, AND MATHEMATICS?
7


SCIENCE
SEEKS TO UNDERSTAND THE NATURAL WORLD THROUGH OBSERVATION, PREDICTION, EXPERIMENTATION, AND EXPLANATION.
8


TECHNOLOGY
HUMAN MODIFICATION OF THE NATURAL WORLD TO SATISFY WANTS OR NEEDS. IT IS NOT SYNONYMOUS WITH COMPUTERS.
9


WHAT IS ENGINEERING?
Designing solutions to problems under constraint. Constraints include size, weight, reliability, safety, economic factors, environmental impact, and manufacturability.
10


What is Art?
In this context art refers to the creative and critical thinking skills and modeling techniques necessary for technical fields, which are enhanced through exposure to the arts.
11


WHAT IS MATHEMATICS?
It is the study of patterns and relationships and includes the science of numbers (operations, interrelations, combinations, generalizations, and abstractions) and of space configurations (structure, measurement, transformations, and generalizations).
12

INTEGRATED OR SEPARATED?

Integrated STEAM: The principles of science and the application of mathematics are interpreted with the arts through the design process of technology and engineering in the classroom.

13

INTEGRATED OR SEPARATED?

Separated S.T.E.A.M.: each subject is taught separately with the hope that the synthesis of disciplinary knowledge will be applied. This may be referred to as STEAM being taught in "Silos".

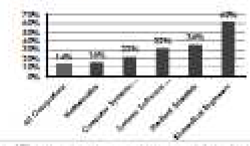
14

WHY IS STEAM EDUCATION GETTING SO MUCH ATTENTION?

15

Projected Percentage Increase in STEM Jobs: 2010-2020

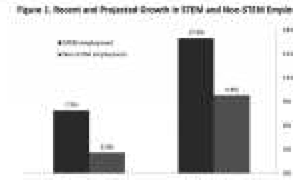
STEM EDUCATION



As this graph shows, STEM occupations are projected to grow much faster than others. In fact, 15 of the 20 fastest growing jobs require a strong background in mathematics and science.

16

Figure 1. Recent and Projected Growth in STEM and Non-STEM Employment

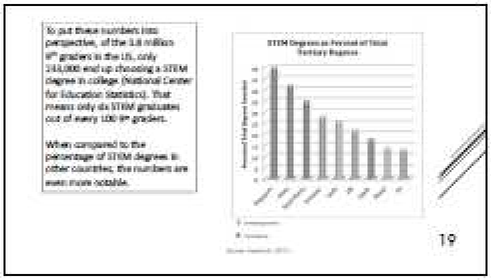


We have already seen this shift in occupations in recent years. In addition, 80% of jobs in the next decade will require technical skills.

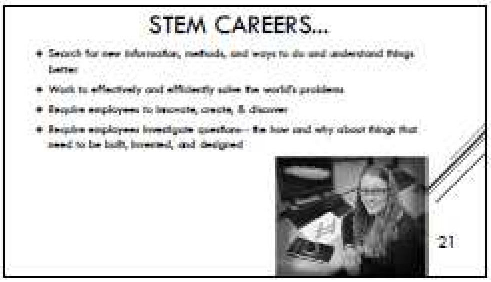
17

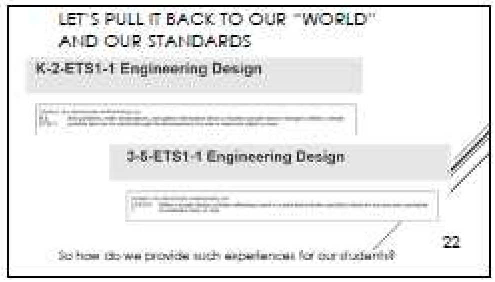
By 2018 the U.S. will have over 1 million job openings in STEM-related fields, but according to the U.S. Bureau of Statistics, only 16% of U.S. bachelor's degrees will specialize in STEM. As a nation, we are not graduating nearly enough STEM majors to supply the demand.

18


To put these numbers into perspective, of the 3.8 million 9th graders in the US, only 233,000 end up choosing a STEM degree in college (National Center for Education Statistics). That means only six STEM graduates out of every 100 9th graders.
When compared to the percentage of STEM degrees in other countries, the numbers are even more notable.
STEM Degrees as Percent of Total Tertiary Degrees
19

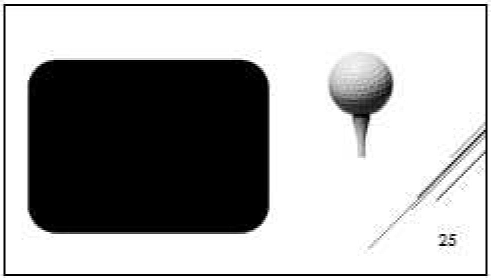

"Educate to innovate." --President Obama
20

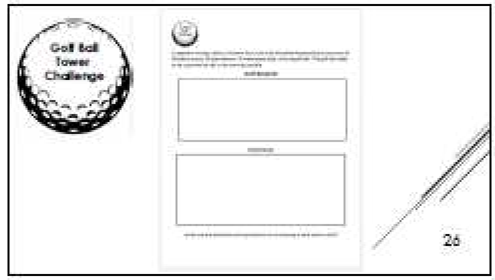

STEM CAREERS...
Search for new information, methods, and ways to do and understand things better
Work to effectively and efficiently solve the world's problems
Require employees to innovate, create, & discover
Require employees investigate questions-- the how and why about things that need to be built, invented, and designed
21

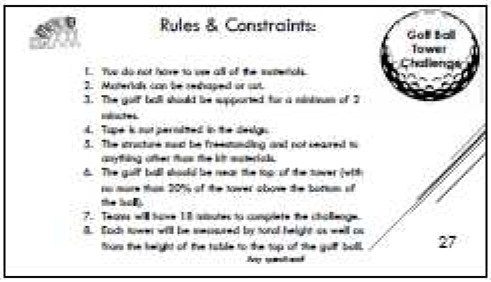

LET'S PULL IT BACK TO OUR "WORLD" AND OUR STANDARDS
K-2-ETS1-1 Engineering Design
3-5-ETS1-1 Engineering Design
22
So how do we provide such experiences for our students?

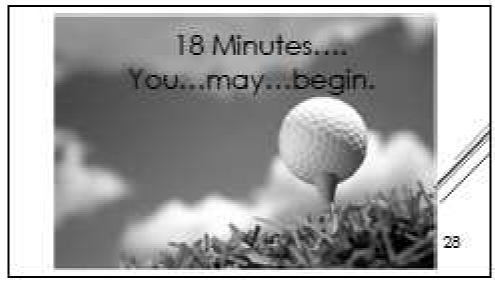

Let's begin with a little challenge..........
23


The Golf Ball Tower Challenge
24


25


Golf Ball
Tower
Challenge
26


Rules & Constraints:
Golf Ball
Tower
Challenge
1. You do not have to use all of the materials.
2. Materials can be reshaped or cut.
3. The golf ball should be supported for a minimum of 2 minutes.
4. Tape is not permitted in the design.
5. The structure must be freestanding and not secured to anything other than the kit materials.
6. The golf ball should be near the top of the tower (with no more than 20% of the tower above the bottom of the ball).
7. Teams will have 18 minutes to complete the challenge.
8. Each tower will be measured by total height as well as from the height of the table to the top of the golf ball.
Any questions?
27


18 Minutes....
You...may...begin.
28


Time's up—let's take
some measurements!
29


Let's do some comparisons!
30

Questions to consider:

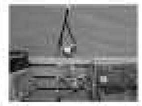
1. How similar was your design to the actual tower you built.
2. If you found you needed to make changes during the construction phase, describe why your team decided to make revisions.
3. Did you use all the parts provided to you? Were any of the parts used only to increase the height of the tower?

Keep in mind that the ball must be supported near the top of the tower, with the bottom of the ball no more than 20% below the upper height of the tower. If the bottom of the ball is more than 20% below the top, your tower will be disqualified. Complete the box below for your tower.

Overall height of the bottom of the ball on/to tower	Distance from bottom of golf ball to top of tower	Percentage of tower supporting golf ball.

31

What are the educational implications from doing this challenge?



On your sheet, compare your original design with your final tower, jot down your thoughts to the final question, and then begin a 5 minute discussion on the question above. (Think, Ink, and Link)

32

What are the educational implications from doing this challenge?

(Think, Ink, and Link)

33

HANOVER RESEARCH

2014 Synthesis of Research on 21[st] Century Skills

Drawn from:

- Partnership for 21st Century Skills
- Tony Wagner's Seven Survival Skills
- Metiri Group's enGauge framework
- Iowa Core 21st Century Skills (Iowa Department of Education)
- Connecticut State Department of Education and the Assessment and Teaching of 21st Century Skills (ATC21S)

34

Four Major Focus Areas

- Collaboration and Teamwork
- Creativity and Imagination
- Critical Thinking
- Problem Solving

35

Let's ratchet it up a bit….

Draw a large scale picture of your tower.

Include details and your rationale for the design changes you made.

In your diagram communicate what forces are acting on the tower.

36

STEAM Meeting Time

Teams will place their diagrams on the floor.

Take a few minutes to gallery walk around the diagrams.

We'll sit in a circle and discuss what we observed.

37

What would be the logical next step?

Redesign.

Use this experience as a launch to exploring science phenomenon. (such as balance, stability, gravity, center of mass, etc.)

Begin to research structural architecture.

38

Thoughts?

Reactions?

Questions?

39

How did we integrate mathematics in this challenge?

40

According to the Michigan Science Standards students need experience

- Designing solutions (prototypes)
- Developing explanations based on observed evidence
- Engage in argumentation to generate collective understanding
- Conduct research to deepen understanding

** Explanation involves looking for cause/effect relationships (a cross cutting concept) and then comparing and critiquing those explanations with the intent of refining them.

41

The process of **build, test, evaluate, and refine** is integral in developing knowledge.

Students must collaboratively evaluate their prototypes, interpret other teams' designs, and chronicle the evolution of their thinking.

Tip: capture every iteration of design so students can explain the evolution of their thinking.

42

Science & Engineering Practices
A Framework for K-12 Science Education

1) Asking questions (Science) & Defining problems (Engineering)
2) Developing and using models
3) Planning & carrying out investigations
4) Analyzing & interpreting data
5) Using mathematics & computational thinking
6) Constructing explanations (Science) & Designing solutions (Engineering)
7) Engaging in argument from evidence
8) Obtaining, evaluating, and communicating information

43

Science & Engineering Practices
A Framework for K-12 Science Education

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8) Obtaining, evaluating, and communicating information

Which practices did you engage in during our Golf Ball Challenge?

44

Incorporating research is an important aspect of engineering design in the classroom.

Take the time to investigate structural engineering as part of the project.

45

The CN Tower (picture to the left), located in Toronto, Ontario, Canada, is a communications and observation tower standing 553.3 meters tall. It was recognized as the tallest free-standing structure on land in the world for 31 years until it was surpassed in height by the Burj Khalifa in Dubai in the United Arab Emirates.

46

What forces are acting on this tower and how did the architect design the building to deal with it?

TABLE TALK

47

The Burj Khalifa was built in 2009 and is 828 meters high.

The ascent to the 124th floor is by a double-deck elevator, each deck carrying up to 14 people and traveling at 10 meters per second, in less than a minute. The elevator reaches the observation deck, the world's only public observatory at this height with an outdoor terrace.

48

TryEngineering

The golf ball tower challenge was inspired by a task from TryEngineering (tryengineering.org).

- 116 searchable STEM projects
- Searchable by keyword or category
- Aligned to national standards
- Each task comes with resources, student pages, and real world connections.

49

EiE Engineering is Elementary | Engineering Everywhere

- 10 free units for the upper grades
- Each has printable student notebook
- Designed fro grades 6-8 (but many can be used for upper elementary)

50

Let's take a few minutes to explore these two resources:

TryEngineering

EiE Engineering is Elementary | Engineering Everywhere

51

Let's take 10 minutes.

52

Curriculum is becoming more readily available.

The Tech
Design Lesson Challenges

PLTW
Engineering Courses

Engineering Everywhere Curriculum

TryEngineering

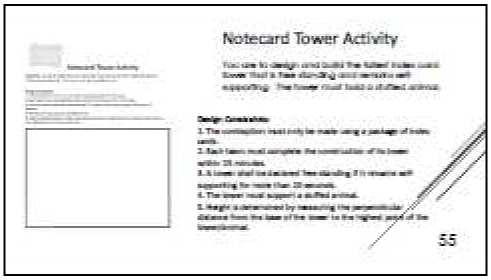
Spark101.org

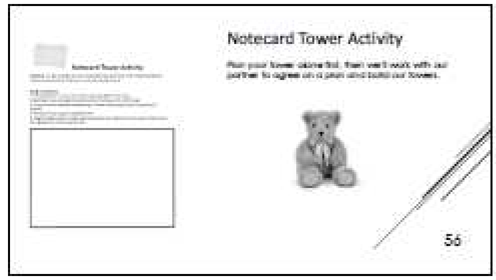
Google: "The Ultimate STEM Guide for Kids: 239 Cool Sites About Science, Technology, Engineering and Math"

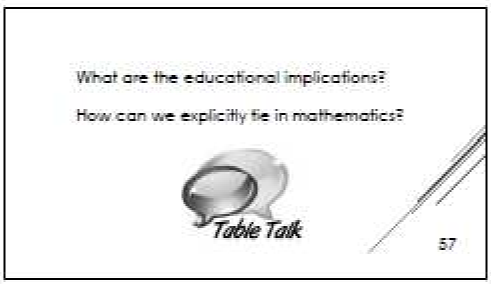
53

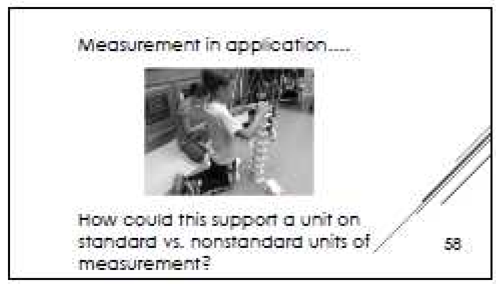
The Golf Ball Tower task may seem too complex for K-2 students, so let's explore another design challenge that is even appropriate for kindergarten students.

54

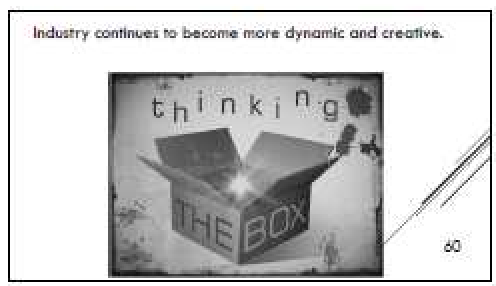

Notecard Tower Activity
You are to design and build the tallest index card tower that is free standing and remains self supporting. The tower must hold a stuffed animal.
55

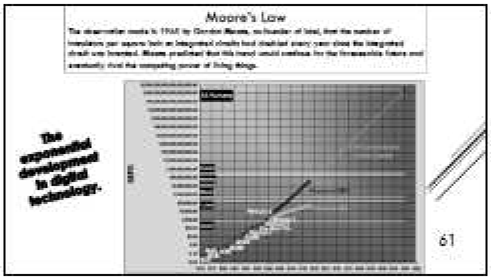

Notecard Tower Activity
Plan your tower alone first, then we'll work with our partner to agree on a plan and build our towers.
56


What are the educational implications?
How can we explicitly tie in mathematics?
Table Talk
57

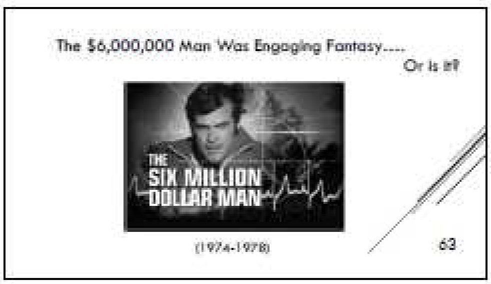

Measurement in application.....
How could this support a unit on standard vs. nonstandard units of measurement?
58

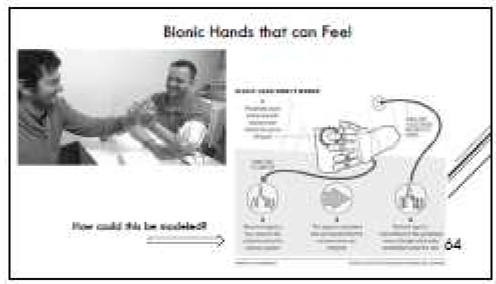

Innovation
Students need opportunities to foster their innovation.
59


Industry continues to become more dynamic and creative.
thinking
THE BOX
60

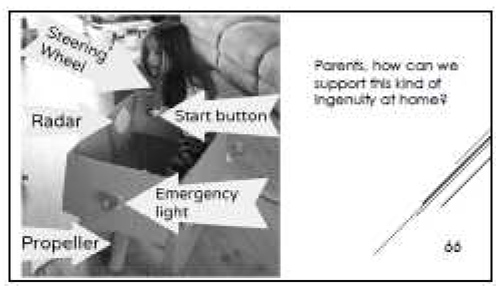

Moore's Law
The exponential development in digital technology.
61


And on it goes….
MOORE'S LAW
• Infinite Computing
• Sensor & Networks
• Robotics
• 3D Printing
• Synthetic Biology
• Digital Medicine
• Nanomaterials
• Artificial Intelligence
62

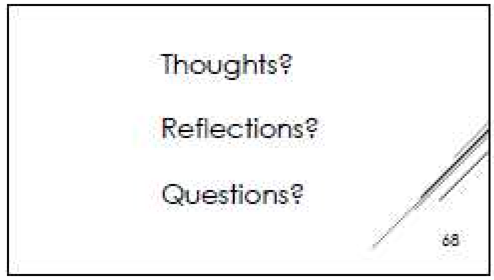

The $6,000,000 Man Was Engaging Fantasy….
Or is it?
THE SIX MILLION DOLLAR MAN
(1974-1978)
63

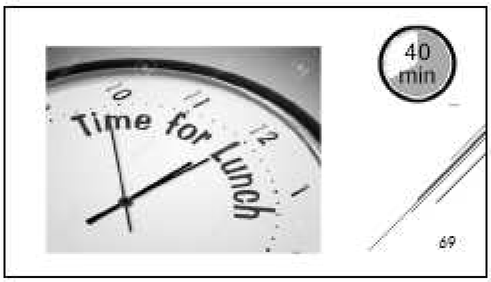

Bionic Hands that can Feel
How could this be modeled?
64

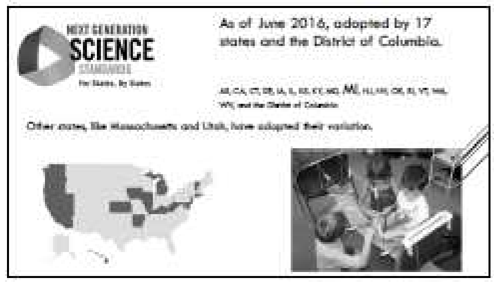

Autonomous Vehicles
It is estimated that by 2020, there will be 10,000,000 cars with self-driving features on U.S. roads.
65

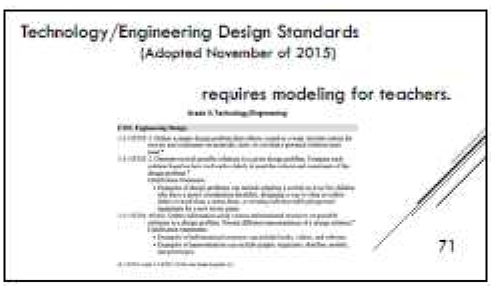

Steering Wheel
Radar
Start button
Emergency light
Propeller
Parents, how can we support this kind of ingenuity at home?
66

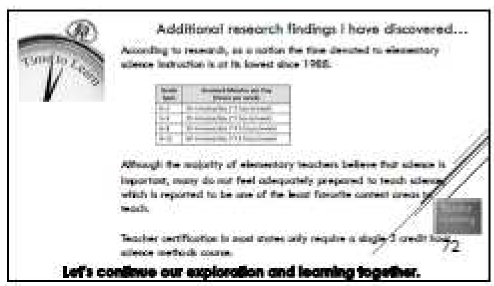

Teachers, how can we ensure students have STEAM experiences at school?
This expectation is becoming a reality.
67


Thoughts?
Reflections?
Questions?
68


Time for Lunch
40 min
69


NEXT GENERATION SCIENCE STANDARDS
As of June 2016, adopted by 17 states and the District of Columbia.
Other states, like Massachusetts and Utah, have adopted their variation.


Technology/Engineering Design Standards
(Adopted November of 2015)
requires modeling for teachers.
71


Additional research findings I have discovered…
According to research, as a nation the time devoted to elementary science instruction is at its lowest since 1988.
Although the majority of elementary teachers believe that science is important, many do not feel adequately prepared to teach science which is reported to be one of the least favorite content areas to teach.
Teacher certification in most states only require a single 3 credit hour science methods course.
Let's continue our exploration and learning together.
72

The concept of reengineering is an important inclusion for the Michigan Science Standards.

Intel Education Design and Discovery Curriculum

73

The SCAMPER Strategy to Improve Design of Everyday Objects

Substitute
Combine
Adapt
Minimize/Magnify
Put to other Uses
Eliminate/Elaborate
Reverse/Rearrange

74

Let's discuss an example.

SCAMPER	Questions to Ask	Water bottle improvement	Benefit
Substitute	What could be used instead? What kind of alternate material can I use?	Different bottle material	Plastic bottle is unbreakable unlike glass
Combine	What could be added? How can I combine purposes?	Add straw in to top	Straw allows access to bottom of water bottle without lifting and tilting bottle
Adapt	How can it be adjusted to fit another purpose? What else is like this?	Use squirt top for watering plants	Directed stream gets water to the plant roots
Magnify	What happens if I exaggerate a component? How can it be made larger or stronger?	Larger bottle	More water for better hydration
Minimize	How can it be made smaller or shorter?	Smaller bottom of bottle	Can store in car's cup holder easily
Put to other uses			
Eliminate			
Elaborate			
Rearrange			
Reverse			

75

SCAMPER	Questions to Ask	Water bottle improvement	Benefit
Substitute			
Combine			
Adapt			
Magnify			
Minimize			
Put to other uses	Who else might be able to use it? What else can it be used for other than its original purpose?	Turn upside down	Hand washing station
Eliminate	What can be removed or taken away from it?	Eliminate the handle	More volume for water storage
Elaborate	What can be expanded or developed more?	Larger base	Lower center of gravity helps keep water bottle from tipping
Rearrange	Can I interchange any components? How can the layout or pattern be changed?	Move handle from side to top	Better ergonomics for hauling large amounts of water
Reverse	What can be turned around or placed in an opposite direction?	Water spout at bottom	Easier to dispense water into cups

76

Let's try the SCAMPER Strategy to redesign a backpack

Substitute
Combine
Adapt
Minimize/Magnify
Put to other Uses
Eliminate/Elaborate
Reverse/Rearrange

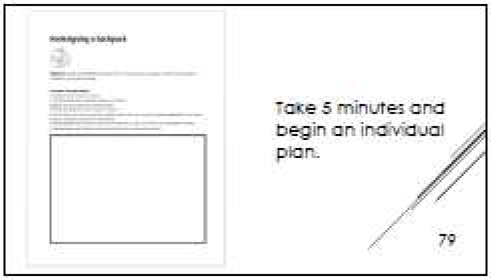
77

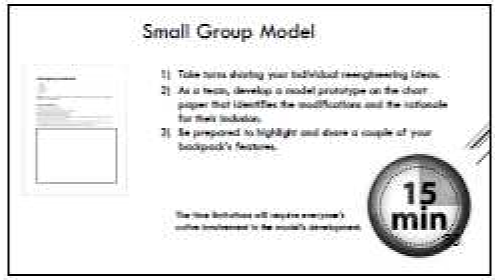
Use the sheet to plan with colleagues.

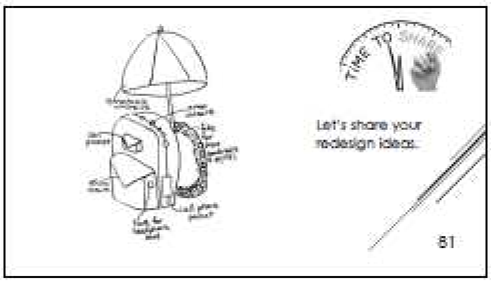
You will have 15 minutes to generate your redesign in your teams.

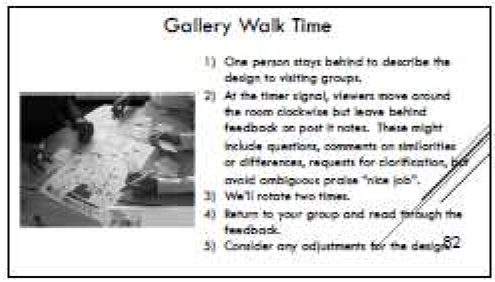
Be sure to note the potential benefits of your redesign on page 3.

78

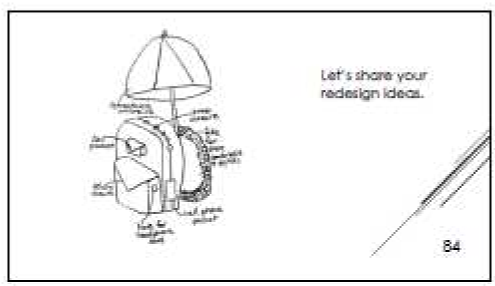

Take 5 minutes and begin an individual plan.
79


Small Group Model
1) Take turns sharing your individual reengineering ideas.
2) As a team, develop a model prototype on the chart paper that identifies the modifications and the rationale for their inclusion.
3) Be prepared to highlight and share a couple of your backpack's features.
The time limitations will require everyone's active involvement in the model's development.
15 min


TIME TO SHARE
Let's share your redesign ideas.
81


Gallery Walk Time
1) One person stays behind to describe the design to visiting groups.
2) At the timer signal, viewers move around the room clockwise but leave behind feedback on post it notes. These might include questions, comments on similarities or differences, requests for clarification, but avoid ambiguous praise "nice job".
3) We'll rotate two times.
4) Return to your group and read through the feedback.
5) Consider any adjustments for the design.
82


Return to your group and reflect on the feedback and discuss the following questions.
• What design alterations might you consider?
• Have you justified your design plan?
• What might be the next steps in your prototype development?
83


Let's share your redesign ideas.
84

Why is it important for students to "go public" with their thinking?

85

Research has shown us that unless a student makes their thinking public (in some fashion) they will not refine their thinking.

This has powerful implications when it comes to student misconceptions.

86

Let's take 10 minutes.

87

Math Connections

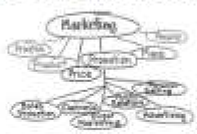
One of the constraints defined within the Michigan Science Standards is the economic considerations of prototype design and development.

The solution.... Have students work with material costs to determine the cost of development, the price at which the product could sell, and then develop a marketing plan.

Now you try it!

88

Time to Share Your Marketing Plan and the Price Point for Your Backpack.



89

How could this project support learning in math and in literacy?

90

What other objects could be redesigned using the SCAMPER strategy?

91

How many of you have had your students engage in computer coding?

Why might that be something to add to your science classroom?

How does it connect to the Michigan Science Standards?

92

CODE.ORG

The idea of coding involves computer programming within the area of computer science.

93

94

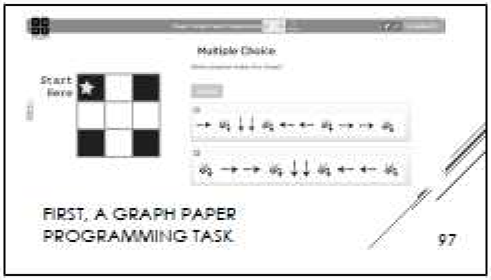
HOW MANY OF YOU HAVE DONE THE "HOUR OF CODE" WITH YOUR STUDENTS?

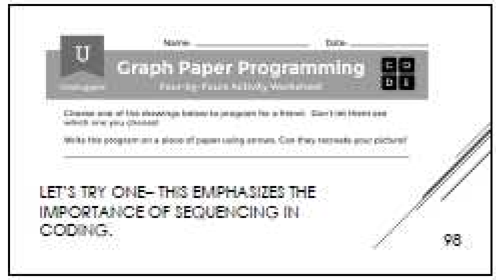
THIS IS HOW MANY TEACHERS FIRST EXPOSE THEIR STUDENTS TO COMPUTER PROGRAMMING.

95

FIRST WE WILL EXPLORE CODE.ORG AS A STUDENT, AND THEN ESTABLISH OUR CLASSES AND COURSES AS INSTRUCTORS.

96

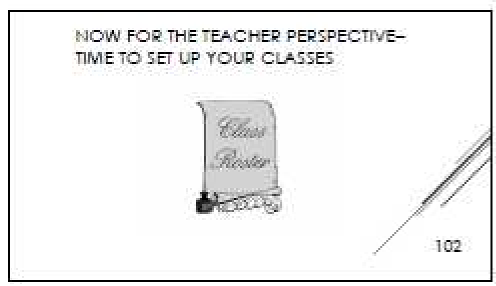

Start Here
Multiple Choice
FIRST, A GRAPH PAPER PROGRAMMING TASK.
97


Graph Paper Programming
LET'S TRY ONE– THIS EMPHASIZES THE IMPORTANCE OF SEQUENCING IN CODING.
98


BASIC PROGRAMMING AND INTRODUCTION TO BLOCKLY LANGUAGE
99

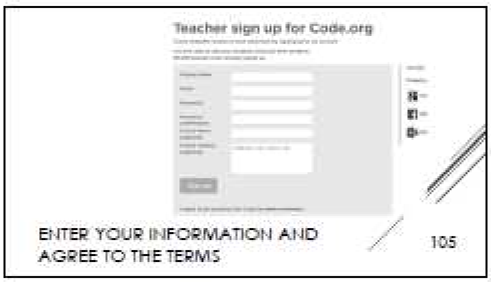

YOU WILL EACH LOG INTO MY CLASS USING YOUR CARD.
100


BEGIN WORKING THROUGH THE ASSIGNMENT TO GET A FEEL FOR HOW IT WORKS.
Explore
101

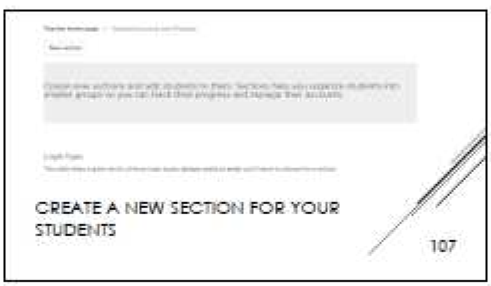

NOW FOR THE TEACHER PERSPECTIVE– TIME TO SET UP YOUR CLASSES
Class Roster
102

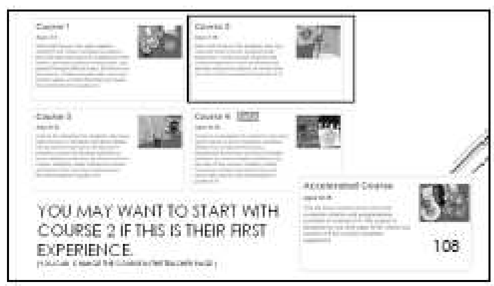

Have an account already? Sign in
Let's sign up as a teacher
SIGNING UP FOR CODE.ORG
103


All Ages
TEACHER SIGN UP
104


Teacher sign up for Code.org
ENTER YOUR INFORMATION AND
AGREE TO THE TERMS
105

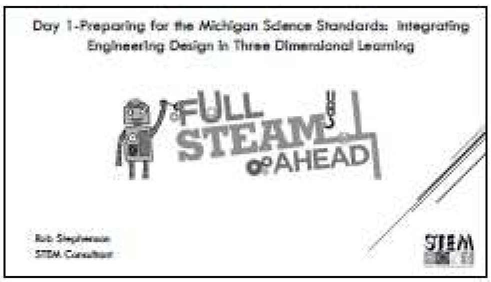

Teacher Home Page
LAUNCH THE TEACHER HOMEPAGE
106


CREATE A NEW SECTION FOR YOUR
STUDENTS
107


Course 1
Course 2
Course 3
Course 4
Accelerated Course
YOU MAY WANT TO START WITH
COURSE 2 IF THIS IS THEIR FIRST
EXPERIENCE.
108


SKYPE GUEST SPEAKER OPTIONS
THIS IS A GREAT CONNECTION TO SCIENCE AND ENGINEERING PRACTICE # 8.
Computer Science Guest Speakers
Guest Speakers in Computer Science


SET A GOAL FOR YOURSELF. WHAT WILL YOU TRY WITH YOUR STUDENTS BEFORE WE SEE EACH OTHER AGAIN?
GOAL SETTING
Let's take 2 minutes to write and 5 minutes to share.
110


Day 1-Preparing for the Michigan Science Standards: Integrating Engineering Design in Three Dimensional Learning
FULL STEAM AHEAD
Rob Stephenson
STEM Consultant
STEM

Day 1 Handouts

Golf Ball Tower Challenge

In eighteen minutes, teams of three to four must build the tallest freestanding structure out of 50 plastic straws, 50 pipe cleaners, 25 metal paper clips, and one golf ball. The golf ball needs to be supported as high in the tower as possible.

Draft Blueprint

Final Tower

Questions to consider:

1. How similar was your design to the actual tower you built?

2. If you found you needed to make changes during the construction phase, describe why your team decided to make revisions.

3. Did you use all the parts provided to you? Were any of the parts used only to increase the height of the tower?

Present your tower to the class and have your teacher measure the height of the tower. Bear in mind that the golf ball must be supported near the top of the tower, with the bottom of the ball no more than 20% below the upper height of the tower. If the bottom of the ball is more than 20% below the top, your tower will be disqualified. Complete the box below for your tower:

Overall height of the bottom of the ball on/in tower	**Distance from bottom of golf ball to top of tower**	**Percentage of tower supporting golf ball.**

Notecard Tower Activity

Objective: You are to design and build the tallest index card tower that is free standing and remains self-supporting. The tower must hold a stuffed animal.

Design Constraints:

1. The contraption must only be made using a package of index cards.
2. Each team must complete the construction of its tower within 15 minutes.
3. A tower shall be declared free-standing if it remains self-supporting for more than 10 seconds.
4. The tower must support a stuffed animal.
5. Height is determined by measuring the perpendicular distance from the base of the tower to the highest point of the tower/animal.

Redesigning a backpack

Objective: Apply the SCAMPER technique to the components of a backpack and draft the redesigned backpack in the space provided.

Scamper Considerations:
S Substitute one thing for another.
C Combine with other materials, things, or functions.
A Adapt: Can it be used for something else?
M Minimize/Magnify: Make it larger or smaller.
P Put to other uses: Can you put it to another use? In this case, could it be used to carry vegetables or some other food?
E Eliminate/Elaborate: Remove some part or material, or make one section more detailed or refined.
R Reverse/Rearrange: Flip-flop some section of the item, move parts around.

SCAMPER	Questions to Ask	Backpack improvement	Benefit
Substitute	What could be used instead? What kind of alternate material can I use?		
Combine	What could be added? How can I combine purposes?		
Adapt	How can it be adjusted to fit another purpose? What else is like this?		
Magnify	What happens if I exaggerate a component? How can it be made larger or stronger?		
Minimize	How can it be made smaller or shorter?		
Put to other uses	Who else might be able to use it? What else can it be used for other than its original purpose?		
Eliminate	What can be removed or taken away from it?		
Elaborate	What can be expanded or developed more?		
Rearrange	Can I interchange any components? How can the layout or pattern be changed?		
Reverse	What can be turned around or placed in an opposite direction?		

Additional Materials for Day 1 Training

Golf Ball Tower Challenge-- Per Group (teams of 3-4):

50 pipe cleaners
50 plastic straws
25 metal paper clips
1 golf ball
Tape Measure

Notecard Tower Activity

1 package of notecards per pair
1 heavy stuffed bear
Several heavy books
Tape Measure
Ruler for standard measurement
Snap Cubes for nonstandard measurement

Backpack Redesign

1 empty backpack per group (any kind will work).

Day 2- Preparing for the Michigan Science- Integrating Literacy, Redesign, and Reverse Engineering in the Three Dimensional Classroom

8:00: Welcome and Implementation Update

8:20: Cross Cutting Concepts and Video Analysis

9:10: Using Children's Literature to Inspire Science and Engineering Technology Tasks

9:40: Cantilever Challenge

10:10: Break

10:20: Redesigning, Peer Feedback, and Conceptual Extensions

11:05: Resource Exploration

11:30: Lunch

12:10: SCAMPER revisited

12:25: Reengineering: Cain's Arcade & the Cardboard Challenge

12:50: Rube Goldberg: Another Reengineering Process

1:30: Break

1:40: Modeling with Simple Machines

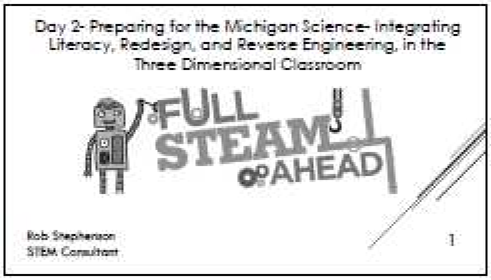
2:10: Reverse Engineering with the Stick Contraption

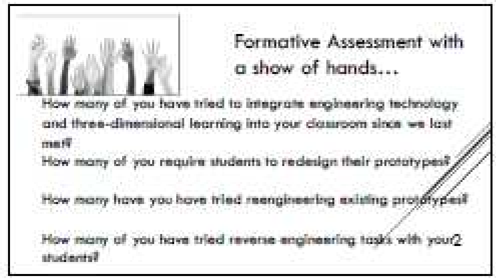
3:00: Internet Resources to Explore after the Session

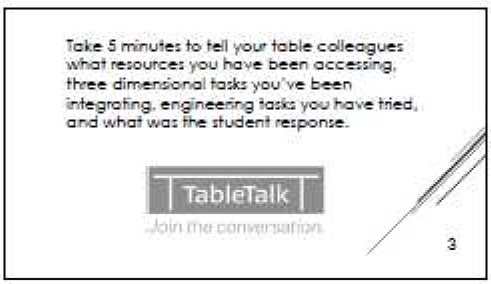
3:20: Reflection, Goal-Setting, and Discussion

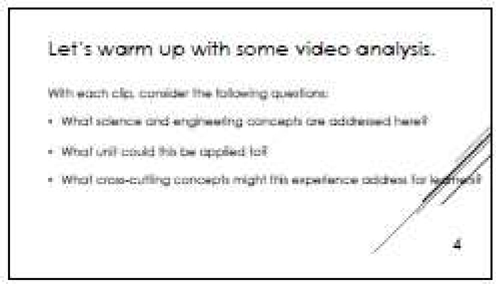
3:30: Adjourn

Day 2 Training Slides

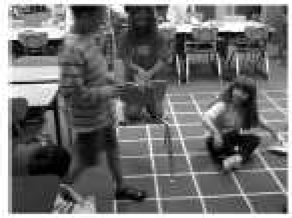








7



8

- What science and engineering concepts are addressed here?
- What unit could this be applied to?
- What cross-cutting concepts might this experience address for learners?

table talk

9

Design a Paddlewheel Boat

10

- What science and engineering concepts are addressed here?
- What unit could this be applied to?
- What cross-cutting concepts might this experience address for learners?

table talk

11

Design and Build a Marble Rollercoaster

12

- What science and engineering concepts are addressed here?
- What unit could this be applied to?
- What cross-cutting concepts might this experience address for learners?

table talk

13

Electrical Engineered Houses

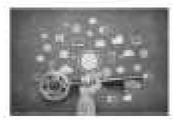
14

- What science and engineering concepts are addressed here?
- What unit could this be applied to?
- What cross-cutting concepts might this experience address for learners?

table talk

15

What are some key takeaways?



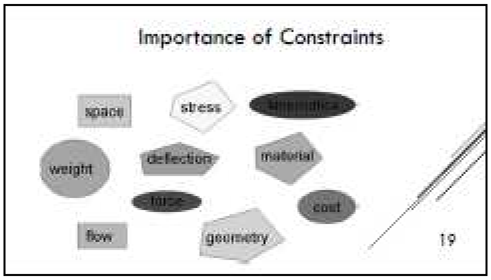
16

Require multiple blueprints with explanations and rationale– i.e. Modeling

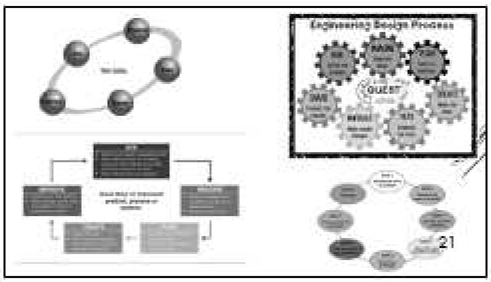
17

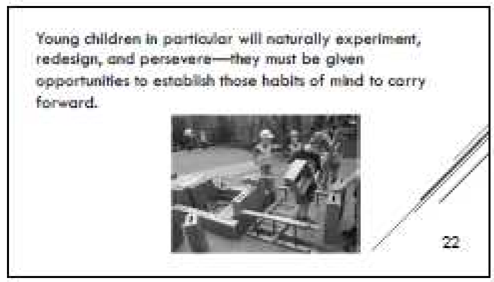
Add the cost constraint for prototype development and a Marketing Plan to advertise and produce the design.

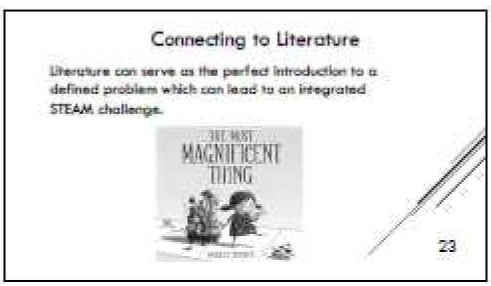
18

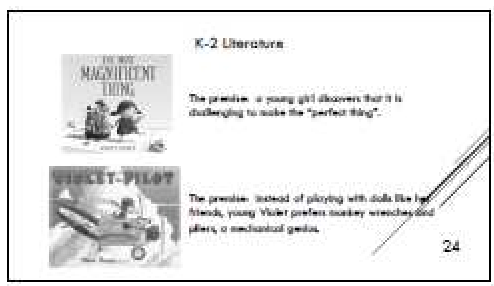

Importance of Constraints
space
stress
weight
deflection
material
force
cost
flow
geometry
19

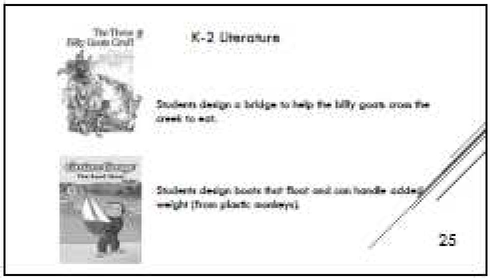

The opportunity to redesign is an integral component in STEAM education.
[re]
DESIGN
It is also the first element that gets dropped.
20

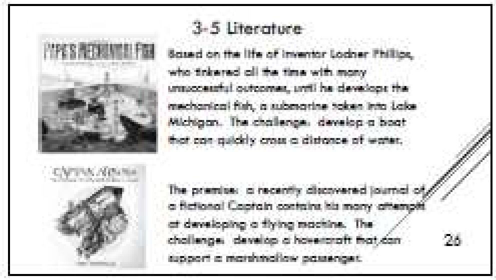

Engineering Design Process
QUEST
21

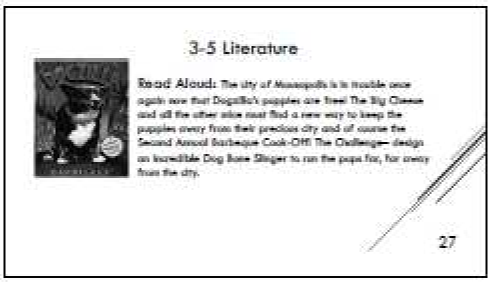

Young children in particular will naturally experiment, redesign, and persevere—they must be given opportunities to establish those habits of mind to carry forward.
22


Connecting to Literature
Literature can serve as the perfect introduction to a defined problem which can lead to an integrated STEAM challenge.
THE MOST
MAGNIFICENT
THING
23


K-2 Literature
The premise: a young girl discovers that it is challenging to make the "perfect thing".
The premise: Instead of playing with dolls like her friends, young Violet prefers monkey wrenches and pliers, a mechanical genius.
24

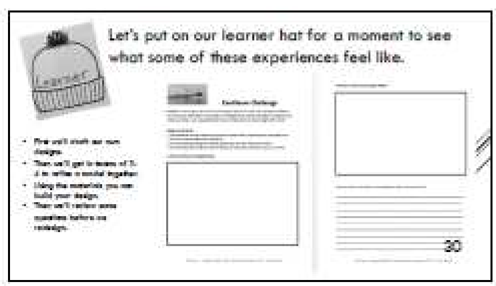

K-2 Literature
Students design a bridge to help the billy goats cross the creek to eat.
Students design boats that float and can handle added weight (from plastic monkeys).
25


3-5 Literature
Based on the life of inventor Lodner Phillips, who tinkered all the time with many unsuccessful outcomes, until he develops the mechanical fish, a submarine taken into Lake Michigan. The challenge: develop a boat that can quickly cross a distance of water.
The premise: a recently discovered journal of a fictional Captain contains his many attempts at developing a flying machine. The challenge: develop a hovercraft that can support a marshmallow passenger.
26

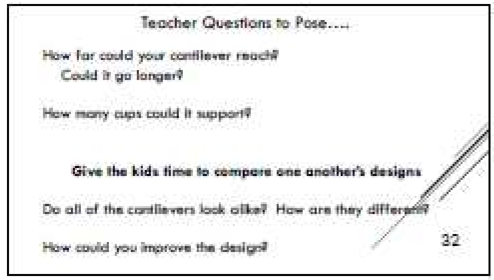

3-5 Literature
Read Aloud: The city of Mousopolis is in trouble once again now that Dogzilla's puppies are free! The Big Cheese and all the other mice must find a new way to keep the puppies away from their precious city and of course the Second Annual Barbeque Cook-Off! The Challenge-- design an Incredible Dog Bone Slinger to run the pups far, far away from the city.
27

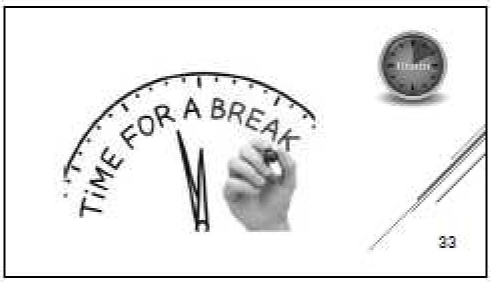

Other Great Titles to Connect to Engineering
(and underrepresented groups)
ROSIE REVERE ENGINEER
Rosie invents, solves problems, and dreams of being an engineer.
An African girl designs and redesigns ways to keep a bee hive vibrant despite skepticism from the men in the village.
UP
Diverse children build model structures while the book travels through Malaysia, China, and Egypt.
28

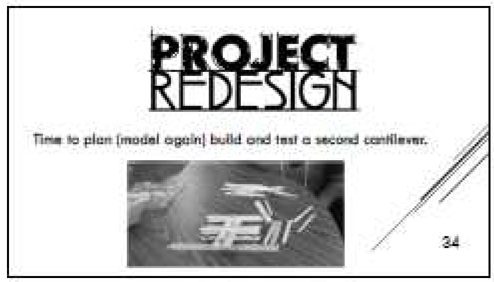

A Literacy Launch
IGGY PECK ARCHITECT
29


Let's put on our learner hat for a moment to see what some of these experiences feel like.
Learner
30

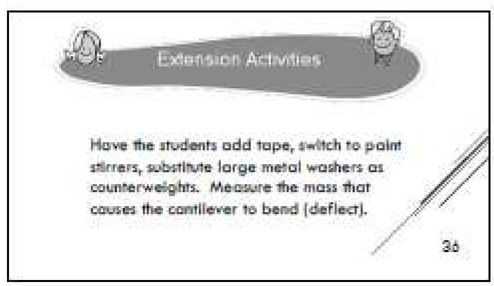

Instructional Video Clip on Cantilevers
North
31


Teacher Questions to Pose….
How far could your cantilever reach?
Could it go longer?
How many cups could it support?
Give the kids time to compare one another's designs
Do all of the cantilevers look alike? How are they different?
How could you improve the design?
32


TiME FOR A BREAK
33


PROJECT REDESIGN
Time to plan (model again) build and test a second cantilever.
34


STEAM Meeting
I used to think....
but now I think....
Share and give feedback on the updated models.
Discuss:
How did your team improve the design?
Which of your cantilevers was better? How do you know?
35


Extension Activities
Have the students add tape, switch to paint stirrers, substitute large metal washers as counterweights. Measure the mass that causes the cantilever to bend (deflect).
36

The Benefits of Redesign

- Students get practice persevering with challenging tasks.
- It emphasizes the development process rather than the product, which is captured in their iterative modeling.
- Students can synthesize and apply their evolving learning.
- Students engage in "failure" analysis.
- Students gain experience engaging in collaborative problem-solving.
- Students recognize that there are multiple avenues to achieve an intended outcome.

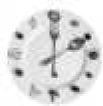
37

Let's Check out a couple resources for a moment…
University of Arkansas Literacy-Launch Challenges

City Technology Energy Systems Units (citytechnology.org)

38

Enjoy your lunch!



Have any of you tried a SCAMPER Strategy to Improve Design of Everyday Objects?

Substitute
Combine
Adapt
Minimize/Magnify
Put to other Uses
Eliminate/Elaborate
Reverse/Rearrange

40

Remember the GEM paperclip…..

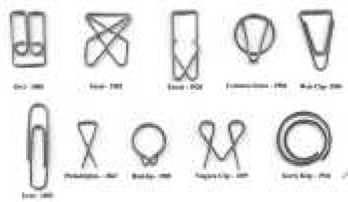
41

The Gem paper clip was invented in 1892– an excellent design.

Imagine giving this task to students: Your challenge is to design the Perfect Paper Clip an then "go public" with team prototypes.

42

Redesign is an integral part of industry.



43

What is the purpose of using the SCAMPER strategy?

In a word.....

Reengineering!

44

Can 1 boy reinvigorate the value of creativity and play?

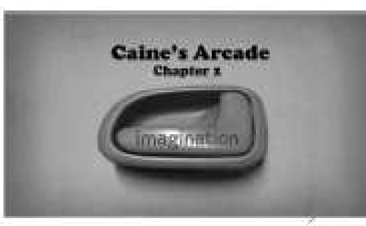
This is a wonderful example of reengineering a household object (a cardboard box) and invites redesign at the same time.

45

Caine's Arcade

Students are always inspired by this story.

46



47

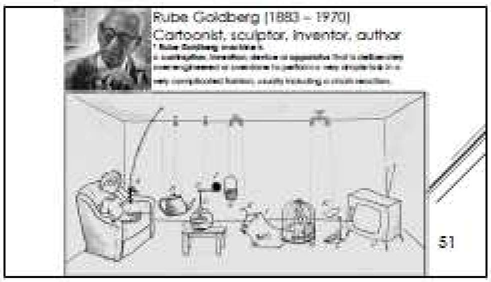
[illegible] global participants from [illegible] countries....so far.....

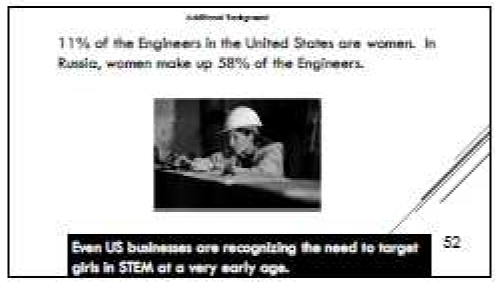
The Global Cardboard Challenge is an opportunity for children to play and learn by using simple materials to build the things they imagine.

48

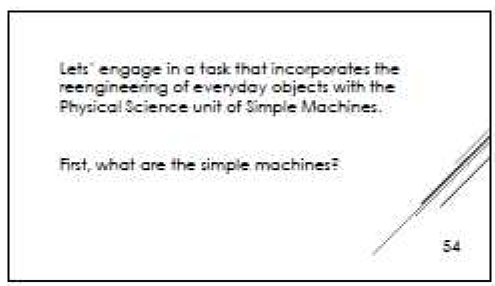

GLOBAL
DAY of
PLAY
49

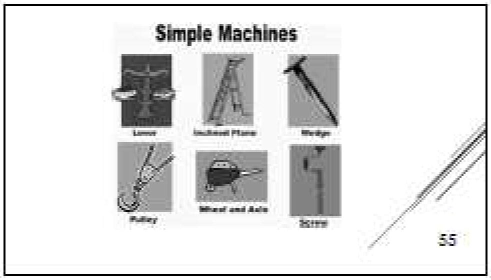

Everyone has a little
engineer inside!
50

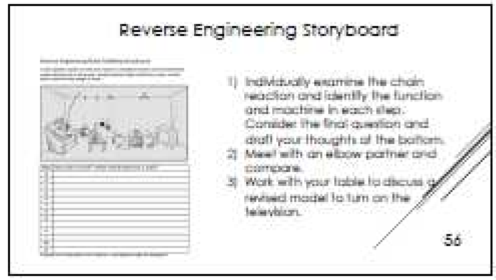

Rube Goldberg (1883 – 1970)
Cartoonist, sculptor, inventor, author
51


11% of the Engineers in the United States are women. In Russia, women make up 58% of the Engineers.
Even US businesses are recognizing the need to target girls in STEM at a very early age.
52


Goldie Blox commercial. A Rube Goldgerg chain reaction machine designed to change the channel on the TV. Target audience: young girls.
53


Lets' engage in a task that incorporates the reengineering of everyday objects with the Physical Science unit of Simple Machines.
First, what are the simple machines?
54

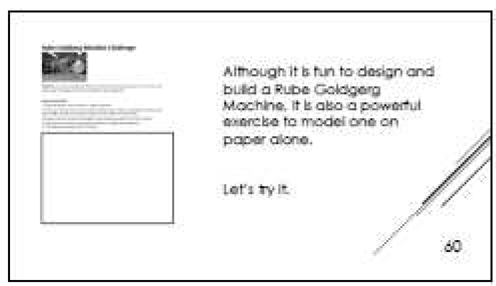

Simple Machines
Lever
Inclined Plane
Wedge
Pulley
Wheel and Axle
Screw
55

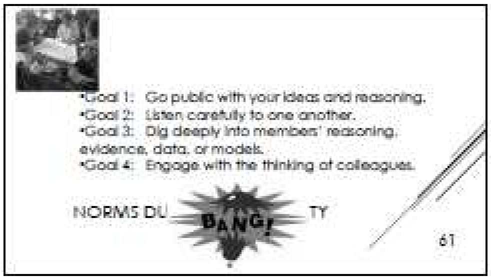

Reverse Engineering Storyboard
1) Individually examine the chain reaction and identify the function and machine in each step. Consider the final question and draft your thoughts at the bottom.
2) Meet with an elbow partner and compare.
3) Work with your table to discuss a revised model to turn on the television.
56


RUBE GOLDBERG
57
2016 Contest Task: Design a System That Can Open An Umbrella


My daughter and her friend made a contraption to put their dance shoes in a bag.
58

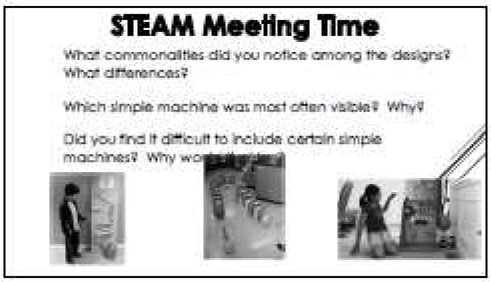

Not to be outdone: My Son's Put Put Chain Reaction
59


Although it is fun to design and build a Rube Goldgerg Machine, it is also a powerful exercise to model one on paper alone.
Let's try it.
60

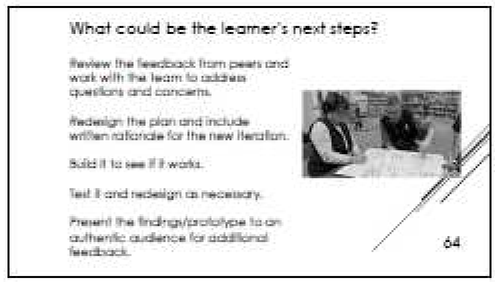


•Goal 1: Go public with your ideas and reasoning.
•Goal 2: Listen carefully to one another.
•Goal 3: Dig deeply into members' reasoning, evidence, data, or models.
•Goal 4: Engage with the thinking of colleagues.
NORMS DU
BANG!
TY
61

STEAM Meeting Time
Teams will place their charts on the floor.
Take a few minutes to gallery walk around the diagrams.
Leave sticky notes behind with questions, comments, or considerations the for each team. Do they have each simple machine in the system?
We'll sit in a circle and have a whole group discussion.
62

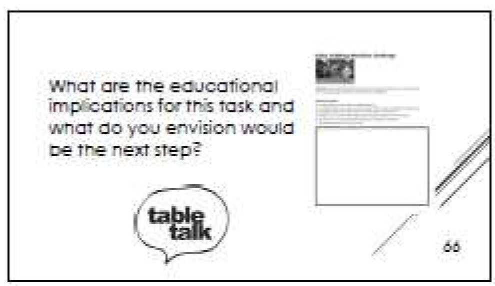


STEAM Meeting Time
What commonalities did you notice among the designs? What differences?
Which simple machine was most often visible? Why?
Did you find it difficult to include certain simple machines? Why wo
63



What could be the learner's next steps?
Review the feedback from peers and work with the team to address questions and concerns.
Redesign the plan and include written rationale for the new iteration.
Build it to see if it works.
Test it and redesign as necessary.
Present the findings/prototype to an authentic audience for additional feedback.
64

Let's See a Similar Rube Goldberg Challenge in Action
65



What are the educational implications for this task and what do you envision would be the next step?
table talk
66

Questions?

Thoughts?

Reflections?

67

Everyone has a little engineer inside.

table talk

Can you reverse engineer this contraption? How does it work?

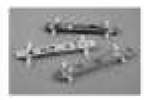
68

Reverse Engineering

By examining the structure and function of an object, students understand how it works. They then can improve on the design.

Let's try a couple of examples. The first is a Stick Contraption.

69



Take two minutes to jot down the purpose of the contraption and how the different parts work.

- Draw the contraption.
- Label the parts.
- Explain the function of each part.

70

After the demonstration:

- Draw the contraption.
- Label the parts.
- Explain the function of each part. Try to include the science principles in your explanation.

71

Small Group Modeling

Work with your colleagues to come up with an agreed explanation on how it works and diagram it.

72

This task can be extended:

- Group models before disassembly
- Redesign opportunities

What else could you reverse engineer?

73

Reflection:

What science concepts can this help students explore and explain?

What science unit could this be added to?

74

Let's explore some other resources.

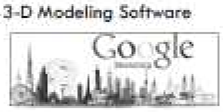
75

How many of you engage your students in 3-D Modeling?

Resources that are student friendly are becoming much more accessible.

76

Free 3-D Modeling Software

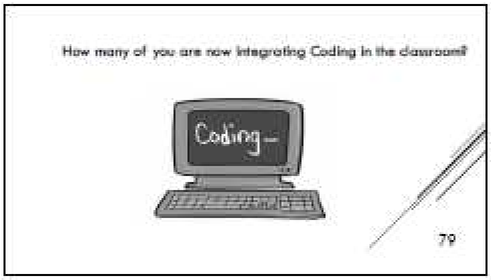


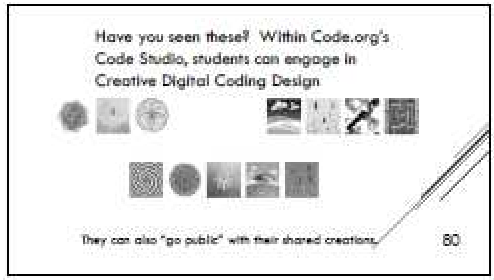
77

3-D Modeling Software

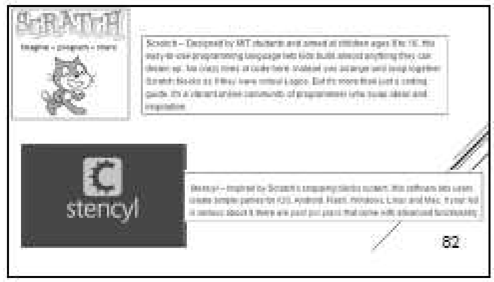
- Practice prototype designs
- Engage in reverse engineering
- Reengineer existing designs
- Send creations to a 3-D printer

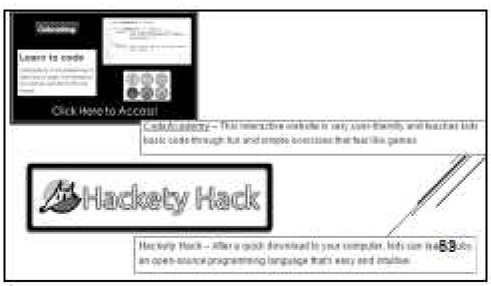
78

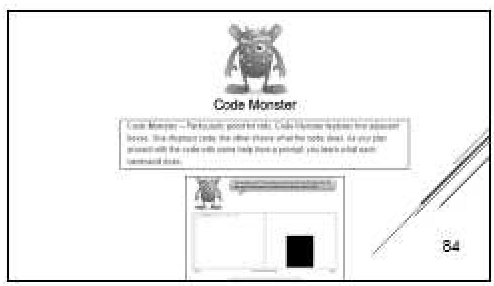

How many of you are now integrating Coding in the classroom?
Coding...
79

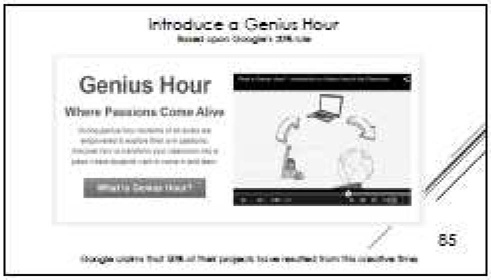

Have you seen these? Within Code.org's Code Studio, students can engage in Creative Digital Coding Design
They can also "go public" with their shared creations.
80


Other Coding Resources
81

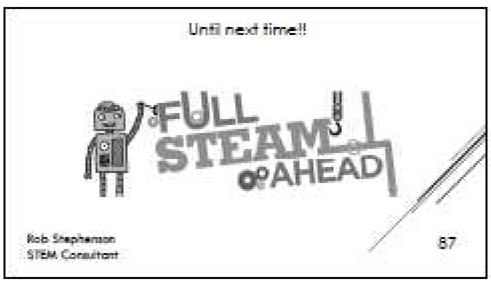

SCRATCH
stencyl
82


Learn to code
Click Here to Access!
Hackety Hack
83


Code Monster
84


Introduce a Genius Hour
Based upon Google's 20% rule
Genius Hour
Where Passions Come Alive
What is Genius Hour?
85


Take 2 minutes to reflect on the day, setting goals for yourself before the next session.
We'll share in a moment!
86


Until next time!!
FULL
STEAM
AHEAD
Rob Stephenson
STEM Consultant
87

Day 2 Handouts

Cantilever Challenge

Problem: What if Iggy Peck did not have enough materials to make the suspension bridge all the way across the stream? Fortunately, he thought about making a cantilever instead, but he needs your help. How long a cantilever can you make, and how much weight can it hold?

Design Constraints:
1. The cantilever will be made from one inch wooden cubes, Popsicle sticks, and paper cups.
2. We won't use any tape in the cantilever….yet.
3. It must be sturdy enough to hold the paper cups, but how many can it hold?
4. We will measure the reach of the cantilever, as well as the number of cups in can hold.

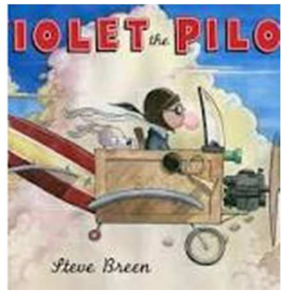
A Picture of My First Design Model:

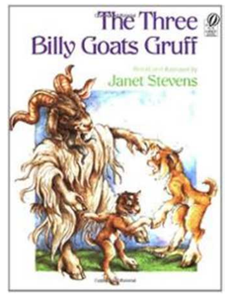
A Picture of My Second Design Model:

Which of your cantilevers was better? How do you know?

Children's Literature Mentioned in Rob's MSS Training

Violet the Pilot
Book by Steve Breen

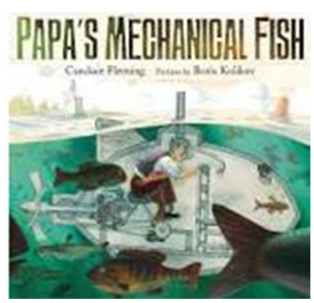




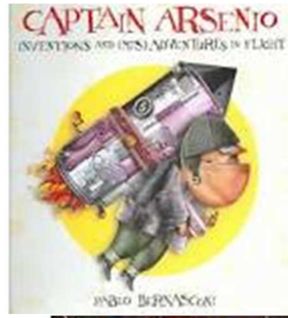
Three Billy Goats Gruff
By Janet Stevens

Curious George
Book by H. A. Rey and Margret Rey

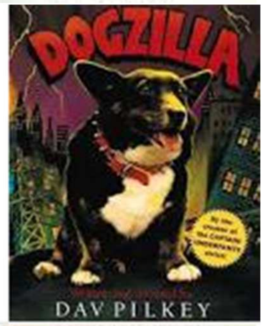
Papa's Mechanical Fish
Book by Candace Fleming



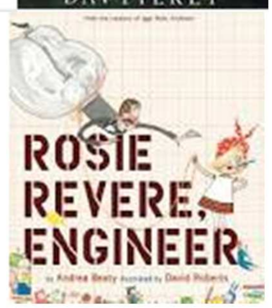
Captain Arsenio: Inventions and (Mis)adventures in Flight
Book by Pablo Bernasconi



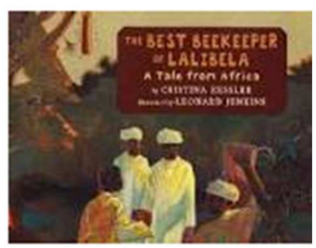
Dogzilla
Book by Dav Pilkey



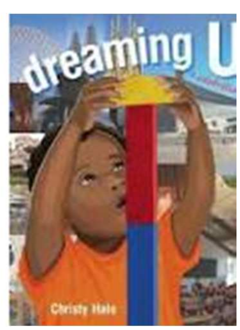
Rosie Revere, Engineer
Book by Andrea Beaty



The best beekeeper of Lalibela
Book by Cristina Kessler

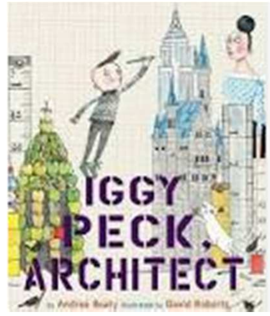


Dreaming Up: A Celebration of Building
Book by Christy Hale



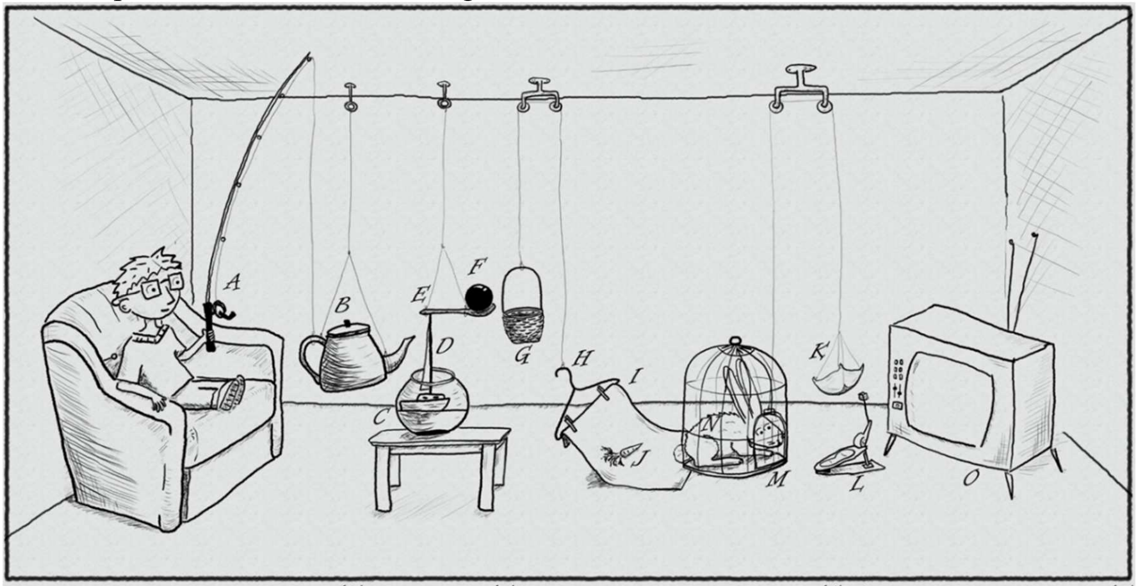
Iggy Peck, Architect

Book



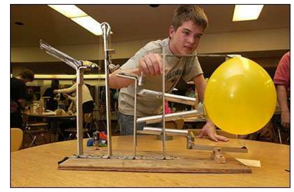
Reverse Engineering Rube Goldberg Storyboard

In each segment, explain how the chain reaction is intended to function and the role that the simple machines play in the process. Simple machines might include lever, pulley, inclined plane, wheel and axle, wedge, or screw.



Step	How does it work? What simple machine is used?
A	
B	
C	
D	
E	
F	
G	
H	
I	
K	
L	
M	
N	
O	

Compare your interpretation with a partner. What segment might be redesigned?



Rube Goldberg Machine Challenge

Objective: You are to design and draft a machine that will pop a balloon in a minimum of 8 steps using the design restrictions outlined on this assignment.

Design Constraints:

1. The contraption must fit within a single classroom.
2. The chain reaction must use 6 simple machines: Lever, Pulley, Inclined Plane, Wheel and Axle, Wedge, and Screw (simple machines can be used more than once).
3. Energy must be transferred through at least 8 separate steps from start to finish.
4. The only time a human may touch the device is to begin the apparatus.
5. The balloon must pop within 5 minutes.

Stick Contraption -- Reverse Engineering Task

In the box below, complete a ***detailed*** drawing predicting the function of this device and how the parts work.

- Draw the contraption.
- Label the parts.
- Explain the function of each part.

Before Demonstration

Share your prediction with an elbow partner. In a moment the teacher will demonstrate how the contraption can be used.

After Demonstration

How could the contraption be redesigned?

Additional Materials for Day 2 Training

Cantilever Challenge-- Per group (Teams of 3-4)
30 one-inch wooden cubes
20 Popsicle sticks
20 small paper cups
Measuring tape

Stick Contraption-- Per person
2 large Popsicle sticks
3 rubber bands
1 straw
Scissors

Day 3- Preparing for the Michigan Science- Cross Cutting Concepts, Engineering Technology, and Discourse in the Three Dimensional Classroom

8:00: Welcome and Implementation Update

8:20: Science Models and Creativity

8:45: Model-Based Reasoning with the Cup Contraption

9:30: Energy at Play Modeling and Design

10:10: Break

10:20: Revising Models and Peer Review

11:10: Resource Exploration

11:30: Lunch

12:10: Setting Norms and Supporting "First Draft Talk"

12:20: Definition and Role of Productive Talk in the Michigan Science Standards

1:00: Setting Norms to Ensure Productive Talk

1:45: Break

1:55: Developing Sentence Stems to Support Science Talk

2:40: Science Talk Configurations

3:10: Sharing Internet Resources

3:20: Reflection, Goal-Setting, and a Challenge to Go

3:30: Adjourn

Day 3 Training Slides

Day 3- Preparing for the Michigan Science- Cross Cutting Concepts, Engineering Technology, and Discourse in the Three Dimensional Classroom

Rob Stephenson
STEM Consultant

1

Take 5 minutes to tell your table colleagues what resources you have been accessing, three dimensional tasks you've been integrating, engineering tasks you have tried, and what was the student response.

TableTalk
Join the conversation

2

Last time we talked about several important considerations.

PROJECT REDESIGN

reverse engineering

3

Let's consider the concept of Science and Engineering Models, what might they include?

table talk

4

Modeling Could Include….

Design solutions can be modeled through…
- Diagrams
- Drawings
- Physical replicas or prototypes
- Dioramas
- Dramatizations
- Storyboards
- Analogies
- Abstract representations

- Models should include information about observable and unobservable mechanisms, and they include the idea of creativity.

5

The Significance of Creativity

2010 Research out of the College of William and Mary
- Found that creativity, and the ability to generate new ideas and persevere, has decreased every year since 1990.
- Students need opportunities to do just that.

6

Walking And Creativity

Stanford University published a study (confirmed by the University of Michigan), an 8 minute walk outdoors stimulates creativity.

How might these findings impact education?

7

Let's try another reverse engineering experience modeling exercise....

Using my Coffee Cup Contraption.

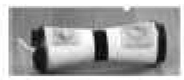
8

Reverse Engineering

By examining the structure and function of an object, students understand how it works. They then can improve on the design.

Let's try an example with my cup contraption.

9



1) First, take two minutes to jot down what the purpose of the Cup Contraption is.

2) I will demonstrate what it can do, then you will write down how you believe it works. Try to include the science principles in your explanation.
3) Talk with your table mates to come up with an agreed explanation on how it works.

10

Remember your process....

- Individual prediction
- Share your predictions at your table
- Observe the demonstrated function
- Individual model explaining how the device works and the science concepts involved
- Develop a small group/diagram with an agreed upon explanation of how it works and the science ideas behind it

11

This task can be extended:

- Group models before disassembly
- Redesign opportunities

What else have you tried to reverse engineer since we last saw one another?

12

Thoughts?

Questions?

Reflections?

13

Recall the Rube Goldberg challenges we had last time. How did those tasks integrate simple machines and science concepts on energy and motion?

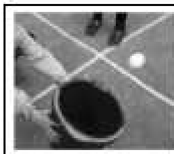
14

In the last couple of activities, we have explored:

- Simple machines
- Elastic Potential Energy
- Kinetic Energy
- Mechanical Energy
- Newton's Third Law of Motion

Let's apply our knowledge in another application task.

15



Energy at Play Challenge

You will have 20 minutes.

16

Time to share our initial launching devices.

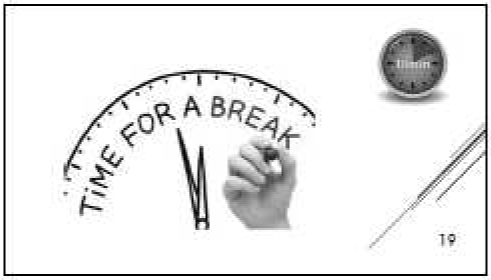
17

Communicate the Process of Struggle

Recent Study—Teachers College at Columbia University

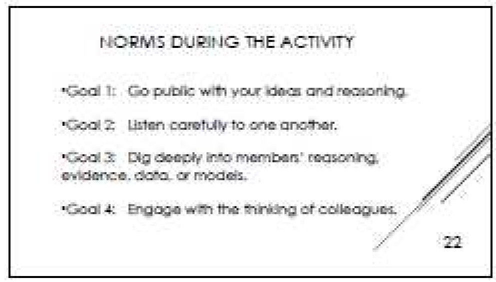
- Students routinely describe scientists as "geniuses". They believe that such accomplishments are unattainable (and actually perform worse on science assessments).
- When students are introduced to historical scientists and are exposed to the struggle they encountered, students see them as "human", people to emulate, and perform better on post assessments.

18


TIME FOR A BREAK
19


Let's publicly reflect on some of the science concepts and design solutions.
20


Let's ratchet it up a bit....
Draw a large scale picture of your design.
This time, show it in steps to demonstrate how the device functions.
Include details and your rationale for the design changes you made.
In your diagram communicate what forces are acting on your device in each step.
21


NORMS DURING THE ACTIVITY
•Goal 1: Go public with your ideas and reasoning.
•Goal 2: Listen carefully to one another.
•Goal 3: Dig deeply into members' reasoning, evidence, data, or models.
•Goal 4: Engage with the thinking of colleagues.
22


Science Meeting Time
Teams will place their diagrams on the floor.
Take a few minutes to gallery walk around the diagrams.
Leave sticky note feedback for teams giving advice or considerations, leaving questions or wonderings, but do not leave compliments.
We'll sit in a circle and discuss what we observed.
23


What might be the next step?
NEXT STEPS
24

- What science and engineering concepts are addressed here?
- What unit could this be applied to?
- What cross-cutting concepts might this experience address for learners?

table talk

25

Crosscutting Concepts

1 Patterns
2 Cause and effect
3 Scale, proportion, and quantity
4 Systems and system models
5 Energy and matter
6 Structure and function
7 Stability and change

26

TIED TOGETHER

Modeling Ties It All Together

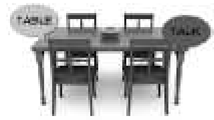
Design solutions can be modeled through…

- Diagrams
- Drawings
- Physical replicas or prototypes
- Dioramas
- Dramatizations
- Storyboards
- Analogies
- Abstract representations

- [illegible]

27

How are your students engaging in Design Modeling?



28

The Tech
Museum of Innovation

The Energy at Play Challenge was adapted from The Tech.

- Project ideas for under an hour
- One-two hour projects
- Multiple session lessons

DESIGN SQUAD

Some classroom examples mentioned last time were inspired by Design Squad on PBS.

29

CURIOUS CREW

Goals

1) To engage and inspire students to explore science principles through hands on investigations
2) To serve as a resource for classroom teachers and parents who are trying to promote critical thinking, persistent problem-solving, and innovation

30

Let's take a few minutes to explore these resources:

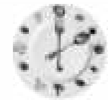
The Tech
Museum of Innovation

DESIGN SQUAD

CURIOUS CREW

31

Enjoy your lunch!



STEM

What is the role of talk in science instruction aligned to the Michigan Science Standards and how can you support it?

Tabletalk

33

NORMS FOR THIS PART OF THE TRAINING:

- Listen to others and show that you are listening.
- Speak to one another (not just the facilitator).
- Connect your ideas to others' (explain, add to, respectfully disagree).
- Participate.
- Ask questions when you are confused or you don't hear something.
- Explain with evidence or examples.

34

BENEFITS OF STUDENTS ENGAGED IN TALKING…

- Teachers get a glimpse of student thinking revealing misconceptions (a great formative assessment tool).
- It gives students practice speaking and supports their language development.
- They need to attend to and understand another person's perspective.
- Students understand concepts more deeply when they have opportunities to reason with evidence.
- It gives students practice learning to build collective understanding.
- Students improve their social skills, self-confidence, and are willing to take greater learning risks.

35

MICHIGAN SCIENCE AND ENGINEERING PRACTICES

- Asking Questions (Science) and Defining Problems (Engineering)
- Developing and Using Models
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
- Using Mathematical and Computational Thinking
- Constructing Explanations (Science) and Designing Solutions (Engineering)
- Engaging in Argument from Evidence
- Obtaining, Evaluating, and Communicating Information

Which practices require students to talk?

36

SUCCESSFUL SCIENCE INSTRUCTION INTEGRATE PRODUCTIVE TALK.....BUT HOW?

37

WHAT IS PRODUCTIVE TALK?

- It involves all students.
- It goes beyond surface thinking so students work deep understanding.
- Students feel obliged to go public with their thinking to help make the group smarter.
- The teacher ensures talk that is equitable, respectful, and based on reasoning.

38

HOW IS IT DIFFERENT FROM TRADITIONAL CLASSROOM QUESTIONING?

- IRE (Initiate, Respond, Evaluate)– In this model, teachers pose questions, elicit student responses, then provide feedback.
  - Teachers could affirm: "Yes, that's correct."
  - Or correct: "No, not quite."
  - It is more like the students are Game Show Contestants.

WHAT'S WRONG WITH IRE?

Tabletalk

40

IRE CHALLENGES….

It insinuates a "correct" answer or solution.

Few students actually participate in the learning while they wait for the "smart kid" to respond.

It does not require higher order thinking, as it is generally "recall" kinds of questions.

41

HOW IS PRODUCTIVE TALK DIFFERENT FROM TYPICAL CLASSROOM DISCUSSIONS?

- In classroom discussions, students generally offer opinions on a given topic.

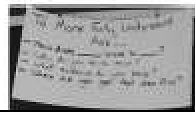
So how is productive talk different?

42

HOW IS PRODUCTIVE TALK DIFFERENT FROM TRADITIONAL CLASSROOM DISCUSSIONS?

Students may provide an opinion, but may not support their thinking with evidence or reasoning.

Students might not connect their thinking to the thoughts of others.



43

CHARACTERISTICS OF PRODUCTIVE TALK

44

CHARACTERISTICS OF PRODUCTIVE TALK

According to the video.....

- Students listen to one another
- Students go public, explaining their ideas
- Students connect their ideas to others'
- Students participate (actively and equitably)
- Students question and clarify ideas
- Students revise their thinking

45

Why is it important for students to "go public" with their thinking?

46

Research has shown us that unless a student makes their thinking public (in some fashion) they will not refine their thinking.

This has powerful implications when it comes to student misconceptions.

47

When we talk in terms of "scientific models" and "design prototypes", they must be public. They have to be reviewed and critiqued to see if they hold up.

WHAT MIGHT PREVENT A STUDENT FROM PARTICIPATING IN CLASSROOM TALK?

49

IMPORTANCE OF A SAFE CULTURE

- It is critical students feel secure enough that their ideas will be respected and taken seriously.

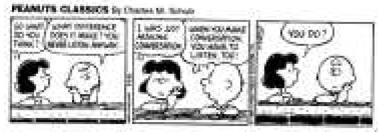
50

TEACHERS MUST BELIEVE IN THEIR STUDENTS

- We must truly believe that all students are capable of deep thinking and are capable of explaining their reasoning with evidence.
- We must communicate to students that everyone has something worthwhile to contribute.

51

ESTABLISHING A CLASSROOM THAT SUPPORTS PRODUCTIVE TALK REQUIRES NORMS



Our aim is for equitable talk. This means welcoming and requiring participation. Everyone has the right to be heard and are obliged to contribute.

52

DISCUSSION NORMS SHOULD ENSURE TALK THAT IS.....

- Respectful
- Equitable
- Based on Reasoning

RESPECTFUL TALK

Hold classroom discussions in which students identify why classmates might not speak up, how they can respectfully disagree, and how they can invite others to participate.

54

EQUITABLE TALK

Hold conversations with students describing the importance of wide participation: avoid the hogs and logs syndrome!

55

TALK BASED ON REASONING

Explain to students that they can anticipate hearing others ask "why" or "how" questions as an opportunity to <u>explain their thinking</u>. Helping students value the importance of revealed misconceptions and wrong answers as an opportunity to deepen understanding.

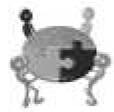
56

ESTABLISHING A CULTURE OF PRODUCTIVE TALK REQUIRES SCAFFOLDING

Hold classroom meetings to generate both norms and sentence stems that students can rely on and practice with.

57

Group Activity



1) Take a moment to individually draft at least 2 classroom norms that will support talk **that is respectful, equitable, or based on reasoning.**
2) As a table, share your statements.
3) Draft a consensus poster that captures norms that meet these talk elements.

15 min

Gallery Walk

1) Leave your posters on the table.
2) Circulate the room looking at 3 other table's posters.
3) Return to your seats.

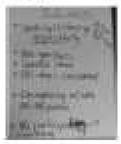
59

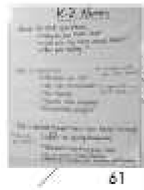
Were your norms similar?
Did you notice how expectations might be communicated differently depending on the grade level taught?

60

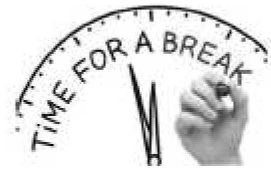
DISCUSSION NORM EXAMPLES

- 1. Everyone participates
- 2. Support claims with evidence
- 3. Challenge ideas, but respect the person
- 4. Revise and rethink often





61



62

Establish Talk Norms Early

Then model and teach students how to perpetuate good classroom discourse.

Sentence Stems Are Useful!

How might they be?

63

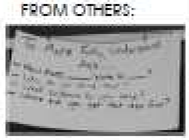
At your table groups, brainstorm different ways to ask a clarifying question.

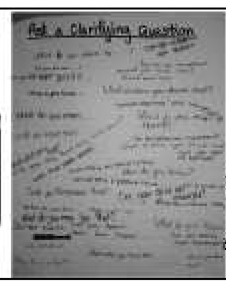
We'll share your ideas in five minutes and collect a master list.

Then we'll try another.

64

EXAMPLE SENTENCE STEMS ON SEEKING CLARIFICATION FROM OTHERS:





65

Now we'll divide the task by table.

Your table will be assigned one of the ideas below to brainstorm sentence stem samples for:

- Respectfully disagreeing
- Ways to ask for more evidence
- Ways to add on or agree with a statement

66

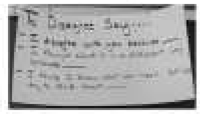
Let's gallery walk and review the posted ideas.

Take sticky notes with you, and if you are inspired to add another stem to the list, please do so.

7 min

67

SAMPLES OF RESPECTFULLY DISAGREEING:

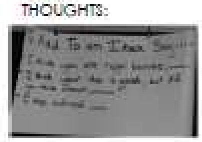


68

SAMPLES OF PROBING FOR EVIDENCE:

69

SAMPLES OF SENTENCE STEMS THAT CONNECT PEERS' THOUGHTS:



70

WHAT WOULD DEDICATED TALK TIME LOOK LIKE IN THE CLASSROOM?

table talk

71

ESTABLISHING A CULTURE OF PRODUCTIVE TALK REQUIRES PRACTICE IN DIFFERENT FORMATS

- Partners
- Small group
- Whole group

Within these structures students should spend dedicated time discussing, grappling with, reasoning, and asking the "how and why" questions associated with science phenomena and engineering designs.

72

PARTNER TALK IN PAIRS

- The teacher pauses briefly so partners can consider a posed question.
- This should take only 1-2 minutes.
- This enables students to safely go public with their "first draft" thinking.
- The teacher eavesdrops for formative purposes.
- Everyone is involved.
- Partner talks are great to throw in if something is so puzzling no one knows what to say or to elicit a number of perspectives or solutions to a task.

73

SMALL GROUP PRODUCTIVE TALK

- Students talk in teams of 3-4.
- The teacher circulates, eavesdrops, and occasionally supports or pushes small group thinking.
- The teacher revisits talk norms, defines the objective for the short discussion, and limits the time (visual timers are useful).
- The format encourages more "air time" in the classroom and gives students practice with their thinking in a less intimidating setting before going to the whole group. This makes the whole group discussion more productive.

74

WHOLE GROUP PRODUCTIVE TALK

- Students should circle up so they can see one another (STEAM Meeting) and the purpose is to make sense on a common task.
- They have generally had "practice" grappling with the task in partner and small group talk.
- The intent is collective knowledge building.
- The teacher facilitates the discussion, makes sure the norms are honored, and presses the students to fully explain their thinking.

75

TEACHERS NEED TO HELP STUDENTS ON THE FOLLOWING GOALS:

1)Sharing, expanding, and clarifying their thoughts
2)Listening carefully to their peers
3)Deepening their reasoning
4)Considering and responding to others' ideas

Don't forget the Talk Moves you have in your teacher Toolbox…

76

YOUR TURN—WHAT WOULD YOU SAY?

A student says to the class, "I think my team needs to redesign."

1) Turn and Talk
2) Say more
3) Who can say that? (Who can repeat or rephrase?)
4) So, let me see if I have your idea right. Are you saying…?
5) Why do you think that?
6) What do others think? (Agree or disagree, and why?)
7) Other

YOUR TURN—WHAT WOULD YOU SAY?

A student says, "I think the potential energy in the twisted rubber band will make the paddle unwind with kinetic energy and could push the boat through the water."

1) Turn and Talk
2) Say more
3) Who can say that? (Who can repeat or rephrase?)
4) So, let me see if I have your idea right. Are you saying…?
5) Why do you think that?
6) What do others think? (Agree or disagree, and why?)
7) Other

YOUR TURN—WHAT WOULD YOU SAY?

A student comments on another group's drawn model during a Science Meeting, "I don't get how their tower could balance with such a small base."

1) Turn and Talk
2) Say more
3) Who can say that? (Who can repeat or rephrase?)
4) So... let me see if I have your idea right. Are you saying...?
5) Why do you think that?
6) What do others think? (Agree or disagree, and why?)
7) Other

"Every time I am tempted to tell students something, I try to ask a question instead."

Steven C. Reinhardt, in his article "**Never Say Anything a Kid Can Say!**", asserts that questioning sends the message to students that their participation is essential.

80

The power of "Explain".

SO WHICH OF THE SCIENCE & ENGINEERING PRACTICES REQUIRE PRODUCTIVE TALK?

1. Asking Questions (Science) and Defining Problems (Engineering)
2. Developing and Using Models
3. Planning and Carrying Out Investigations
4. Analyzing and Interpreting Data
5. Using Mathematical and Computational Thinking
6. Constructing Explanations (Science) and Designing Solutions (Engineering)
7. Engaging in Argument from Evidence
8. Obtaining, Evaluating, and Communicating Information

81

HOW IS PRODUCTIVE TALK DEMONSTRATED IN THE PRACTICES?

- Asking Questions & Define Problems = Students will probe others for clarification and feedback
- Developing and using models = students need to express their sense making on the phenomena and figure out where they agree or disagree
- Planning and Carrying Out Investigations = Requires student collaboration to establish a common vision for fair test trials
- Analyzing and Interpreting Data = This is seldom done in isolation but instead requires group "think"
- Constructing Explanations & Designing Solutions = Students will have to negotiate different ideas to develop explanations and solutions
- Argumentation from Evidence = Students present ideas and back up their thinking with reasoning in order to generate collective knowledge building
- Obtaining, Evaluating, and Communicating Information = Student teams will present their findings, prototypes, creations to a broader audience by integrating the "expert knowledge"

82

Curriculum is becoming more readily available.

The Tech Design Lesson Challenges

PLTW — Launch, Gateway, Engineering Courses

Engineering Everywhere Curriculum

TryEngineering

Spark101.org

Google: "The Ultimate STEM Guide for Kids: 239 Cool Sites About Science, Technology, Engineering and Math"

83

WHAT OTHER RESOURCES DO YOU HAVE TO SHARE WITH THE GROUP?

84

Spark101.org

SPARK 101
ENGAGE. CONNECT. INSPIRE.

85

Here's a fun challenge to consider —Making a Paper Table

Summary: With your team in 20 minutes, construct a table using provided materials that will support a heavy dictionary at least 6 inches off the table for at least 60 seconds.
Materials:
1. 20 pieces of newspaper
2. 3 feet of masking tape
3. 1 8.5 x 11 inch piece of cardboard
4. 1 heavy dictionary

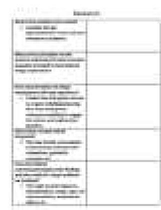
86

.....until we meet again.

Take 2 minutes to reflect on the day, setting goals for yourself before the next session.

We'll share in a moment!

87



Here is a great planning tool you may want to think about for some of your Engineering Technology modeling tasks.

88

Next time we meet, we will have a bit of time for applying what we have learned in our instructional plans, so be sure to bring a unit you will be working on.

Rob Stephenson
STEM Consultant

89

Day 3 Handouts

Drag Racing Cups -- Reverse Engineering Task

In the box below, complete a ***detailed*** prediction drawing of the internal and external components of the drag racer. **Do not open the cup.**

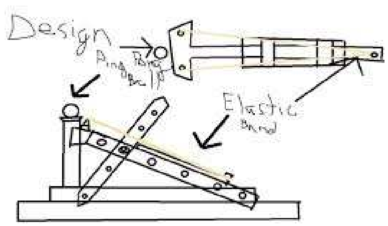
- Label the parts
- Explain the function of each part in making the cup drive.

Before Disassembly

Carefully open one end of the cup and examine the internal workings of the racer. Redraft the racer again labeling the parts and functions of each component.

After Disassembly

How could the dragster be redesigned?



Energy at Play Activity

Objective: You are to design and build a device that uses potential and kinetic energy to launch a ping pong ball at a target.

Design Constraints:

1. The device must have its own propulsion system and move a ping pong ball at least 5 inches.
2. Your device must store energy in some way to be released causing the ball to move.
3. You can only use the materials provided.
4. You may test and redesign your device at any time.
5. You will have 20 minutes to design and build your device.

Engineering Technology Planning Form

What is the problem to be solved? • **Consider the age appropriateness of the task and relevance to students.**	
What science principles are the students exploring and what concepts should be included in their finished design explanation?	
How many iterations of design development will they experience? • **If older than first grade, be sure to require individual planning first, then small group consensus modeling to engage the science and engineering practices.**	
What math concepts will be integrated? • **This may include cost analysis, measurement collection and comparison, geometric concepts, etc.**	
How will students communicate/explain their findings and who could be a target audience for feedback? • **This might include diagrams, dramatizations, songs, raps, 3-D representations, storyboards, videos, etc.**	

Additional Materials for Day 3 Training

Energy at Play Materials -- Per Group (teams of 4)

- Balloons (3 deflated 9-inch round)
- 10 Rubber Bands (any size)
- 5 Paper Cups (small Dixie style)
- 6 Tongue Depressors
- 1 meter String
- 1 Roll Masking Tape
- 5 Drinking Straws (any size)
- 4 Pipe Cleaners (can be reused)
- 8 1/2 x 11 Cardboard
- Cardstock (2 sheets)
- 3 Plastic Spoons
- 4 Medium Sized Binder Clips
- 6 Slender Craft Sticks
- 1 Ping pong ball

**Hand drawn paper target 24” in diameter (or an empty bucket) and scissors per group

Day 4 - Preparing for the MSS Grade Level Implementation Planning

8:00: Introductions, Michigan Science Standards Transition Update

8:15: Where are you now?

8:35: Modeling Exercise

10:05: Break

10:15: Three Dimensional Learning Components

10:50: NGSS Instructional Shifts and Analysis

11:30: Lunch

12:10: Digging In: Performance Expectations by Grade

1:10: NGSS Resources: Developing Curriculum, Frameworks, & PD Resources

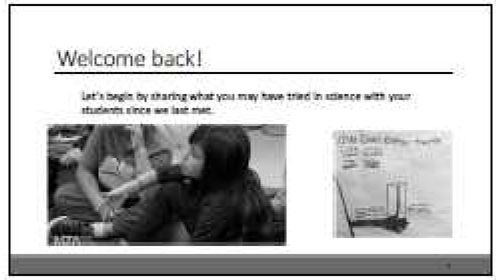
2:10: Break

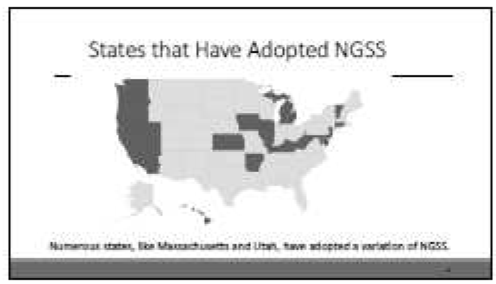
2:20: Exploring Phenomenal Science Curriculum

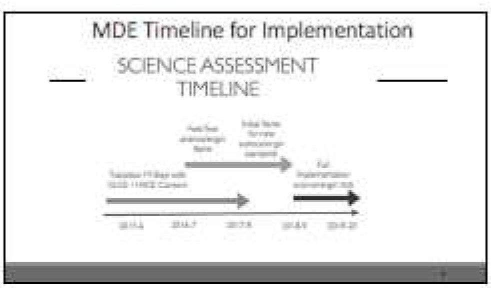
3:20: Complete final survey

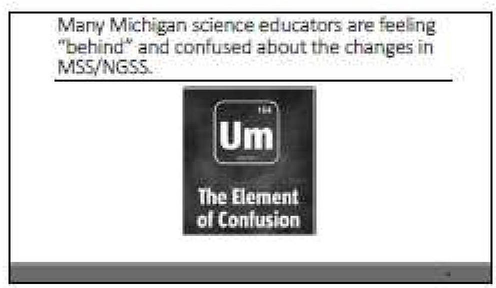
3:30: Adjourn

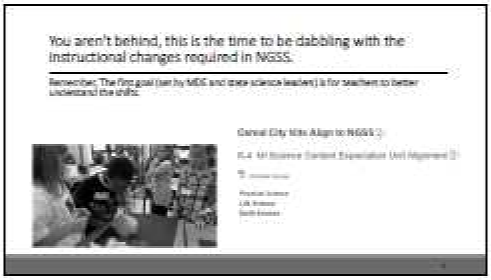
Day 4 Training Slides





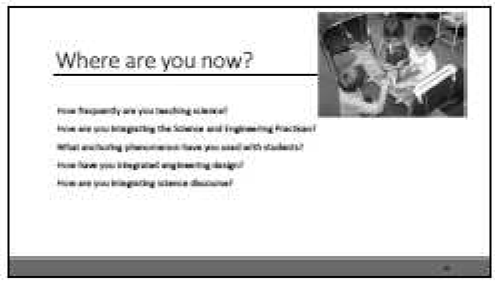


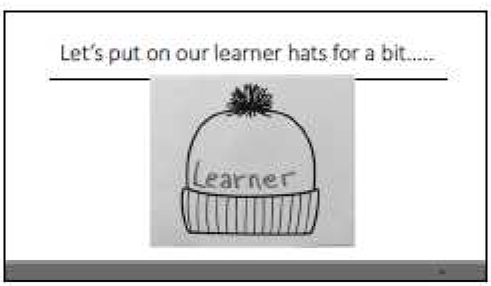


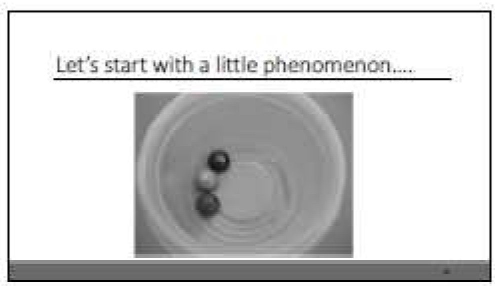

You aren't behind, this is the time to be dabbling with the instructional changes required in NGSS.
Remember, The first goal (set by MDE and state science leaders) is for teachers to better understand the shifts.
Cereal City Kits Align to NGSS


This is a very exciting time to be a science teacher in Michigan.....
because we are poised to guide students into doing science and understanding concepts at a deeper level.


Where are you now?
What have you done to "NGSSify" your current instruction?
What successes have you had?
What challenges are you facing?


Where are you now?
How frequently are you teaching science?
How are you integrating the Science and Engineering Practices?
What anchoring phenomenon have you used with students?
How have you integrated engineering design?
How are you integrating science discourse?


Let's put on our learner hats for a bit.....
Learner


Let's start with a little phenomenon....

Question(s)

Predictions

If we add warm water to the cup with 5 skittles, what will happen?

Why does this happen?

Individually write down your predictions for 2 minutes.

Investigate

With your group, pour the warm water into the cup with the skittles.

Use the spoon to turn the candies face up.

Watch what happens over the next several minutes.

Take pictures and notes.

Phenomenon

Explanation of the phenomenon

Individually, after completing the activity, take a few minutes to answer the following two questions.

How would you **describe** what you observed? (What was the behavior?)

How would you **explain** what you observed? (What caused the behavior?

Small Group Discussion & Construct a diagram to explain the phenomenon

Compare your initial explanations for the phenomenon.

Discuss your reasoning in your group.

Draw a diagram that represents your group's thinking (there may be more than one explanation in the group).

The diagram should describe what happened and explain why this happened in a step by step format.

Gallery Walk

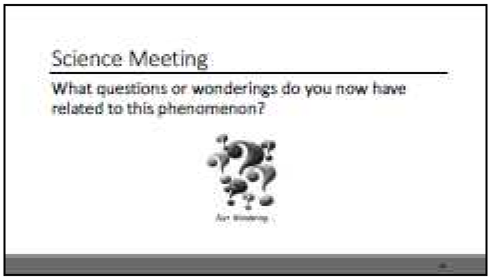
Place the drawings on the floor and circulate to compare explanations in our initial models.

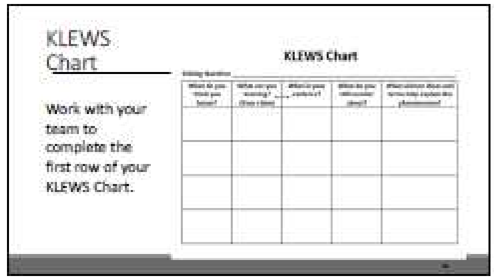
Use a post-it note to leave comments or questions, but avoid making statements like "Good work."

Science Meeting & Consensus Discussion

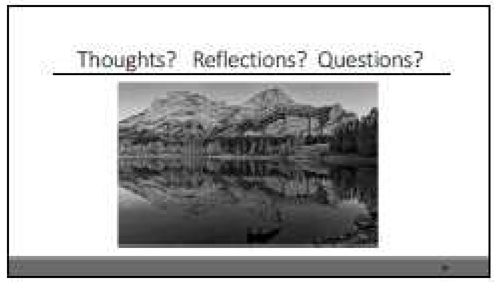
What commonalities do you notice in the explanations?

What We Figure Out

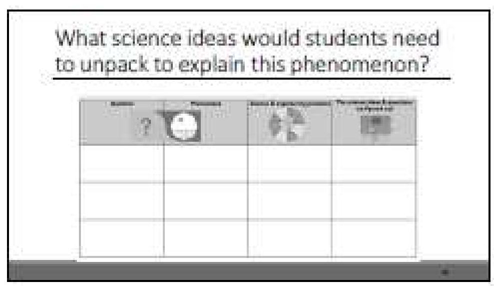

Science Meeting
What questions or wonderings do you now have related to this phenomenon?

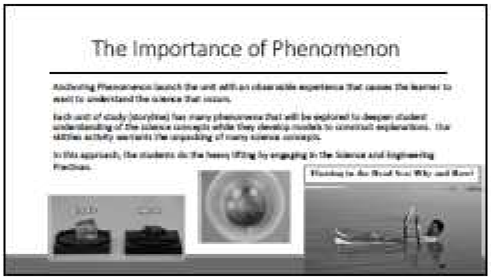

KLEWS Chart
Work with your team to complete the first row of your KLEWS Chart.
KLEWS Chart

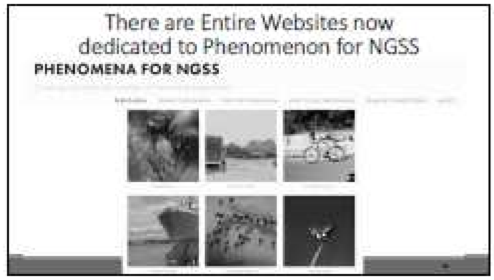

Let's put our teacher hats back on.......
Teacher
And analyze this experience, and get a reminder on three-dimensional learning

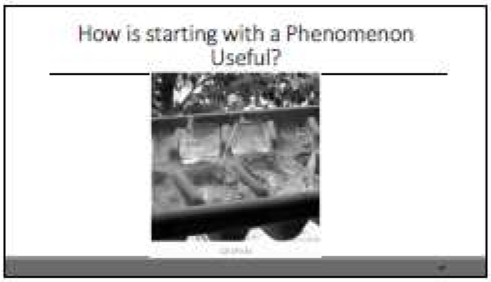

Thoughts? Reflections? Questions?

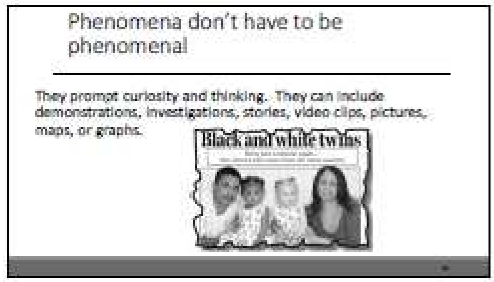

Time for a break
It's Time For A Break

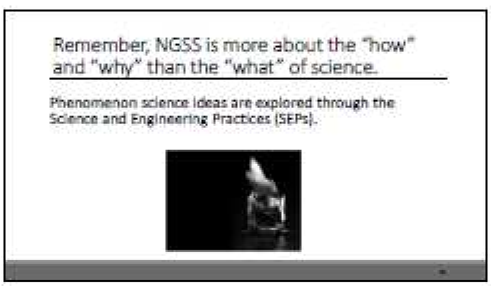

What science ideas would students need to unpack to explain this phenomenon?

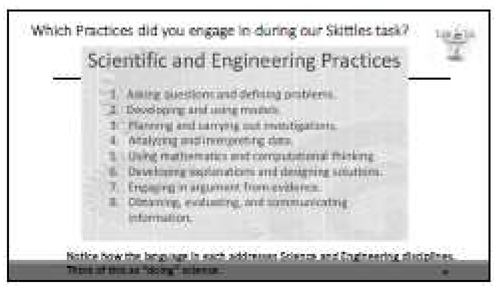

The Importance of Phenomenon

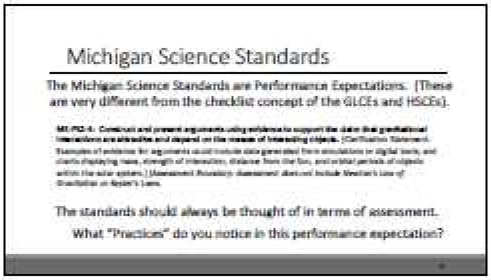

There are Entire Websites now dedicated to Phenomenon for NGSS
PHENOMENA FOR NGSS

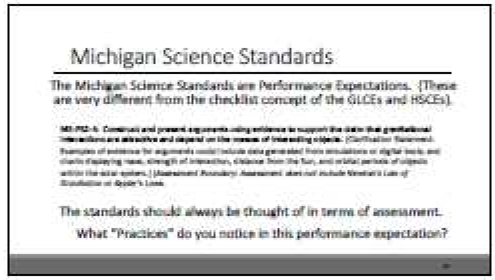

How is starting with a Phenomenon Useful?


Phenomena don't have to be phenomenal
They prompt curiosity and thinking. They can include demonstrations, investigations, stories, video clips, pictures, maps, or graphs.
Black and white twins


Remember, NGSS is more about the "how" and "why" than the "what" of science.
Phenomenon science ideas are explored through the Science and Engineering Practices (SEPs).


Which Practices did you engage in during our Skittles task?
Scientific and Engineering Practices
1. Asking questions and defining problems.
2. Developing and using models.
3. Planning and carrying out investigations.
4. Analyzing and interpreting data.
5. Using mathematics and computational thinking.
6. Developing explanations and designing solutions.
7. Engaging in argument from evidence.
8. Obtaining, evaluating, and communicating information.
Notice how the language in each addresses Science and Engineering disciplines.
Think of this as "doing" science.


Michigan Science Standards
The Michigan Science Standards are Performance Expectations. (These are very different from the checklist concept of the GLCEs and HSCEs).
The standards should always be thought of in terms of assessment.
What "Practices" do you notice in this performance expectation?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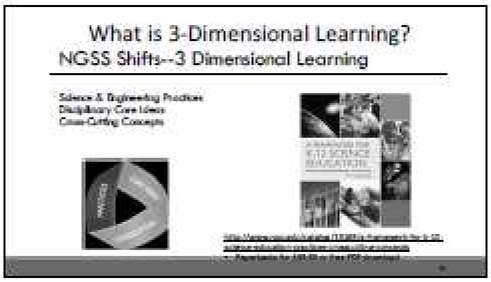
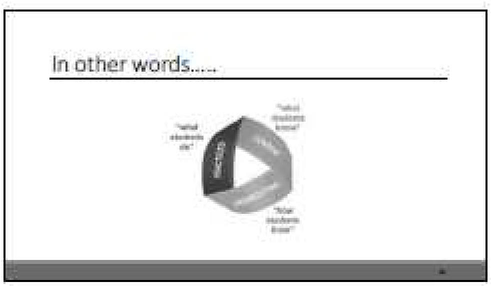
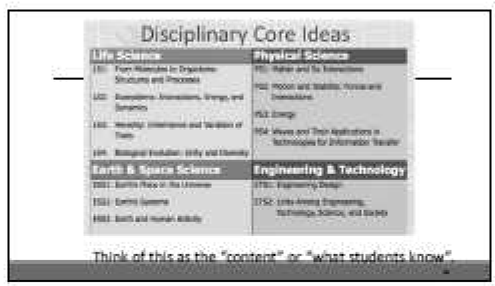

What is 3-Dimensional Learning?
NGSS Shifts--3 Dimensional Learning
Science & Engineering Practices
Disciplinary Core Ideas
Cross-Cutting Concepts


To prepare students for the performance expectations, students will need coherent, consistent, high quality three dimensional science learning experiences.
In fact, these three elements are a part of EVERY performance expectation.


In other words.....


Disciplinary Core Ideas
Life Science
Physical Science
Earth & Space Science
Engineering & Technology
Think of this as the "content" or "what students know".

Each grade Band Has its own set of core ideas from each of the science domains, which will be measured with the standards

- Grade bands are K-2; 3-5; 6-8; 9-12
- Science domains include: physical sciences, life sciences, earth and space sciences, and engineering, technology and applications of science.

Crosscutting Concepts

1. Patterns
2. Cause and effect: mechanism and explanation
3. Scale, proportion and quantity
4. Systems and system models
5. Energy and matter: flows, cycles, and conservation
6. Structure and function
7. Stability and change

Consider the CCCs as "connections" or "how students think".

What Crosscutting Concepts did you engage in during the Glitter task?

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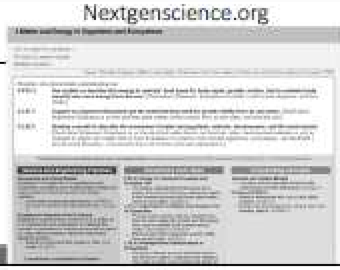
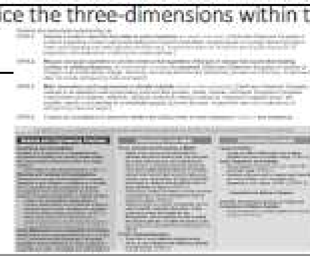
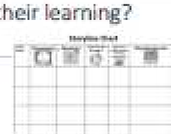


Notice the three-dimensions within the PE.



How can students track their learning?

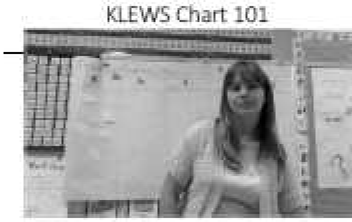
Here are a few options to help students make connections within a science unit.

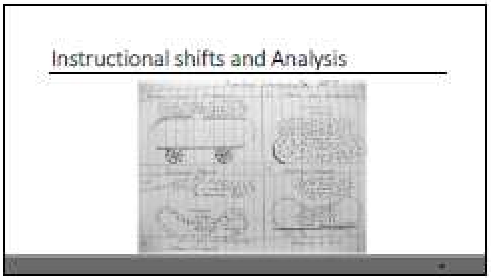


Please review these with your colleague and discuss how you might use these with your students?

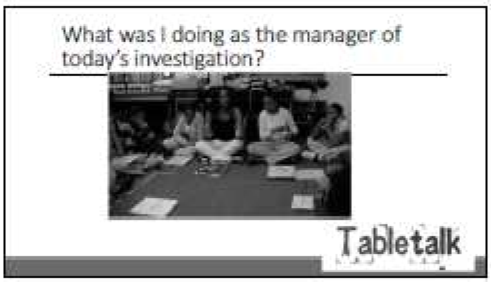
Is there one document you prefer?

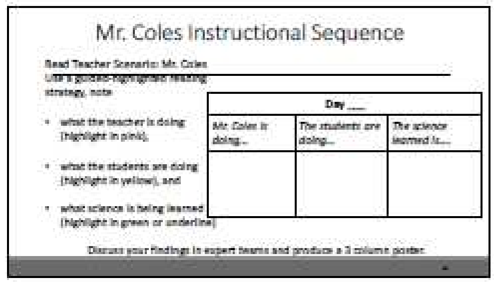
KLEWS Chart 101

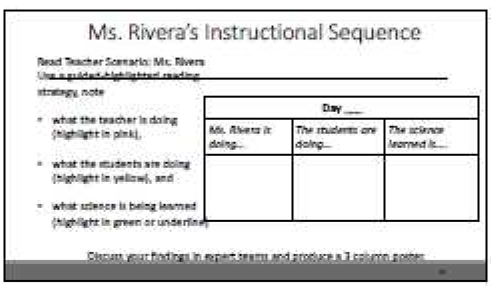


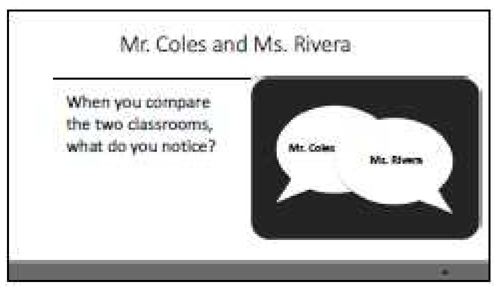

Instructional shifts and Analysis

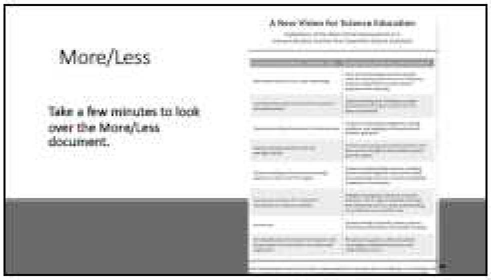

Michigan Science Standards: How does this change instruction?

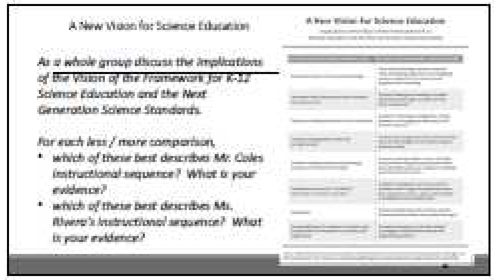

What was I doing as the manager of today's investigation?
Tabletalk

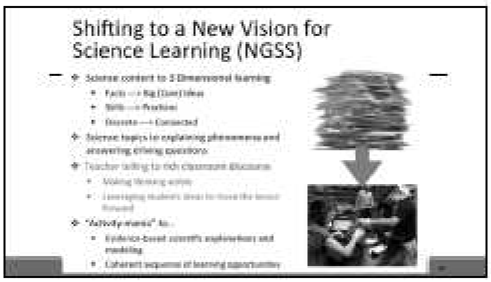

Mr. Coles Instructional Sequence
Read Teacher Scenario: Mr. Coles
Use a guided-highlighted reading strategy, note
• what the teacher is doing (highlight in pink),
• what the students are doing (highlight in yellow), and
• what science is being learned (highlight in green or underline)
Day ___
Mr. Coles is doing...
The students are doing...
The science learned is....
Discuss your findings in expert teams and produce a 3 column poster.

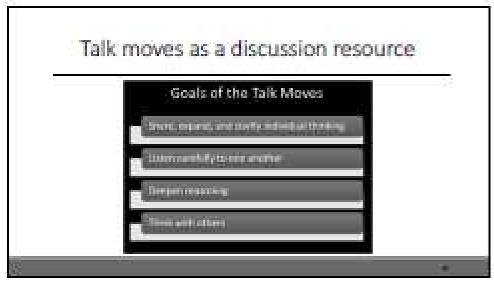

Ms. Rivera's Instructional Sequence
Read Teacher Scenario: Ms. Rivera
Use a guided-highlighted reading strategy, note
• what the teacher is doing (highlight in pink),
• what the students are doing (highlight in yellow), and
• what science is being learned (highlight in green or underline)
Day ___
Ms. Rivera is doing...
The students are doing...
The science learned is....
Discuss your findings in expert teams and produce a 3 column poster.

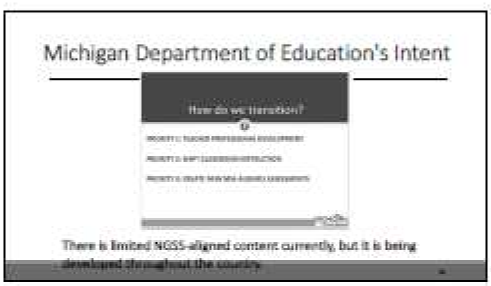

Mr. Coles and Ms. Rivera
When you compare the two classrooms, what do you notice?
Mr. Coles
Ms. Rivera

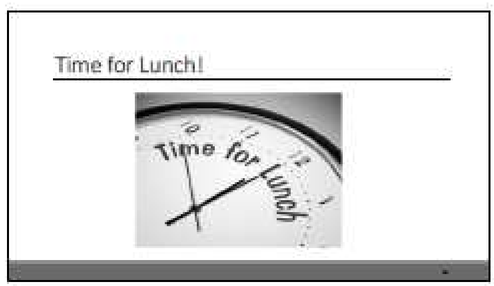

More/Less
Take a few minutes to look over the More/Less document.
A New Vision for Science Education


A New Vision for Science Education
As a whole group discuss the implications of the Vision of the Framework for K-12 Science Education and the Next Generation Science Standards.
For each less / more comparison,
which of these best describes Mr. Coles instructional sequence? What is your evidence?
which of these best describes Ms. Rivera's instructional sequence? What is your evidence?
A New Vision for Science Education


Shifting to a New Vision for Science Learning (NGSS)


Talk moves as a discussion resource
Goals of the Talk Moves


Michigan Department of Education's Intent
How do we transition?
There is limited NGSS-aligned content currently, but it is being developed throughout the country.


Time for Lunch!
Time for Lunch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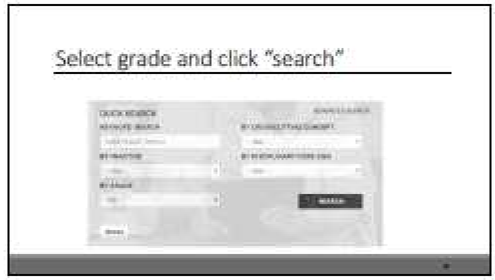
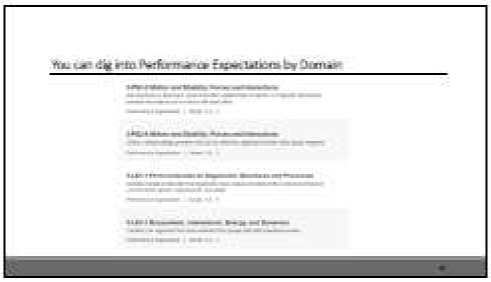
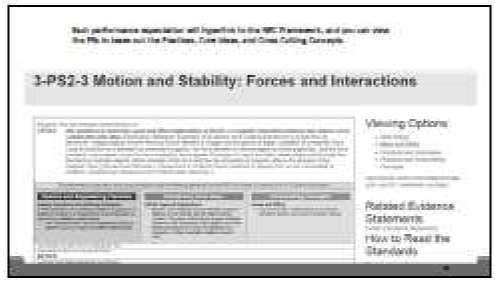
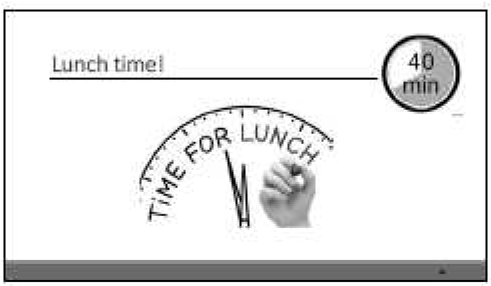
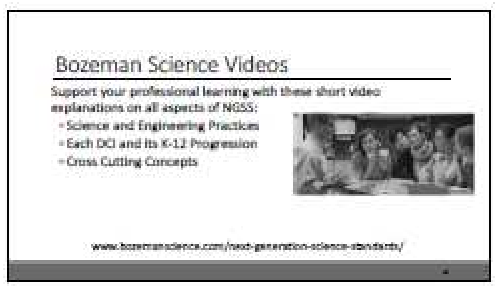

Select grade and click "search"


You can dig into Performance Expectations by Domain


3-PS2-3 Motion and Stability: Forces and Interactions
Viewing Options
Related Evidence Statements
How to Read the Standards


Lunch time!
40 min
TIME FOR LUNCH

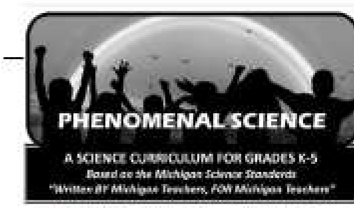

Bozeman Science Videos
Support your professional learning with these short video explanations on all aspects of NGSS:
Science and Engineering Practices
Each DCI and its K-12 Progression
Cross Cutting Concepts
www.bozemanscience.com/next-generation-science-standards/

New Jersey Framework

http://www.state.nj.us/education/modelcurriculum/sci/mo.shtml

New Jersey has developed a complete curricular framework for each grade. As you navigate the site, notice the suggested resources, but lack of explicit curriculum. New Jersey is a local control state, so the department has offered what it can to support the implementation of NGSS.

Time for a break



http://lor.mivu.org/phenomenal-science

Phenomenal Science

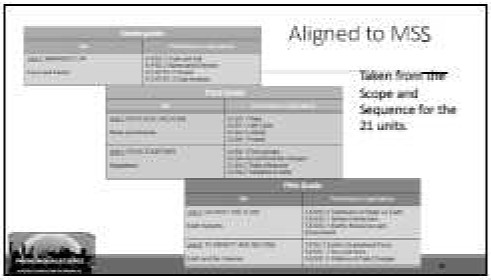
An Open Source K-5 Curriculum created by Michigan Educators for Michigan Educators.

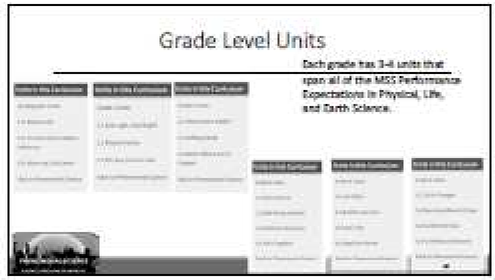
Phenomenal Science is a regional collaboration between the Science, Mathematics, Technology center at CMU and the Great Lakes Bay ISDs to develop K-5 Science Units through professional learning. Phenomenal Science is sponsored by Michigan Virtual University®, Michigan STEM Partnership and is supported by the Great Lakes Bay ISDs.

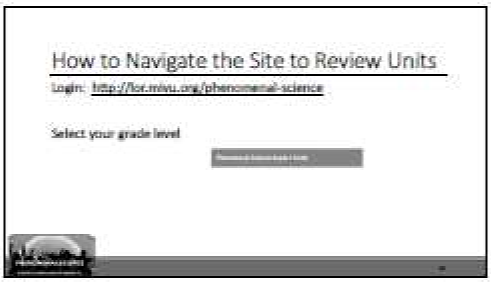
Grade Specific Units

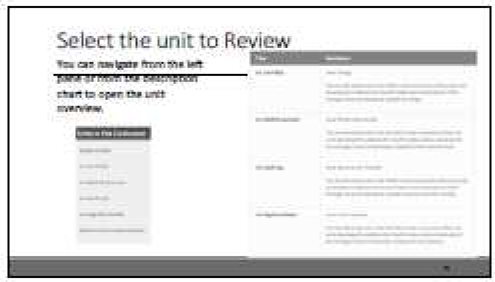
The units will:

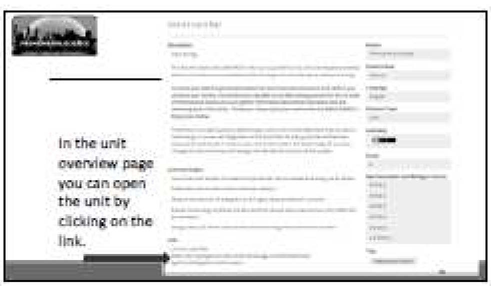
- Include a complete curriculum for K-5 three-dimensional science instruction spanning units in Physical, Life, and Earth Science
- Align to the Michigan Science Standards
- Be free to all educators
- Integrate science and engineering practices, English Language Arts and Mathematics

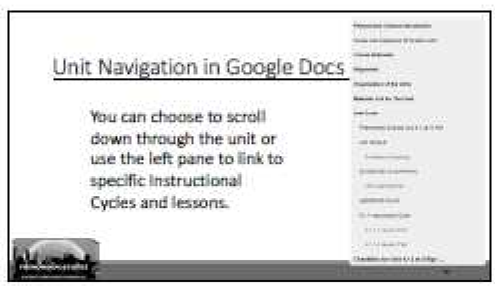

Aligned to MSS
Taken from the Scope and Sequence for the 21 units.

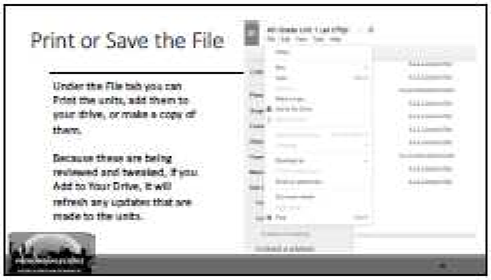

Grade Level Units
Each grade has 3-4 units that span all of the MSS Performance Expectations in Physical, Life, and Earth Science.

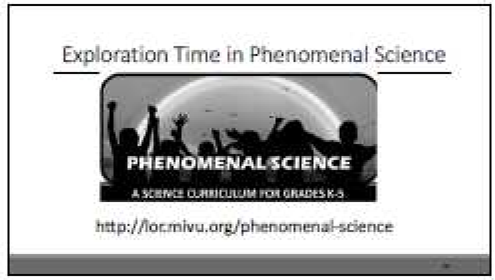

How to Navigate the Site to Review Units
Login: http://lor.mivu.org/phenomenal-science
Select your grade level


Select the unit to Review
You can navigate from the left pane or from the description chart to open the unit overview.


In the unit overview page you can open the unit by clicking on the link.


Unit Navigation in Google Docs
You can choose to scroll down through the unit or use the left pane to link to specific Instructional Cycles and lessons.


Print or Save the File
Under the File tab you can Print the units, add them to your drive, or make a copy of them.
Because these are being reviewed and tweaked, if you Add to Your Drive, it will refresh any updates that are made to the units.


Exploration Time in Phenomenal Science
PHENOMENAL SCIENCE
A SCIENCE CURRICULUM FOR GRADES K-5
http://lor.mivu.org/phenomenal-science


Questions?
time for questions


Thanks for all of your great work throughout this series!
Feel free to contact me if I can offer you additional support.
Rob Stephenson
STEM Consultant

Day 4 Handouts

Instructions for Skittles and Water Phenomenon

The facilitator will provide the materials. Please work in small groups.

Investigation Questions:

- If we add warm water to the cup with 5 skittles, what will happen?
- Why does this happen?

Individually, in your notebook, BEFORE DOING ANYTHING, make some predictions and explain your reasoning in the space below.

Investigate: Do the experiment together

- With your group, pour the warm water into the cup with the skittles.
- Use the spoon to turn the candies face up.
- Watch what happens over the next several minutes.
- Take pictures and notes.

Explanation of the phenomenon -- Without Talking to Anyone

Individually, after completing the activity, take a few minutes to answer the following two questions on the back of this paper.

- **How would you describe what you saw? (What happened?)**
- **How would you explain what you observed? (What caused it?)**

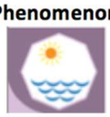
**You will use these your individual notes in the small group discussion and activity that follows.

KLEWS Chart

Driving Question ____

What do you think you know?	What are you learning? (Your claim) ↔	What is your evidence?	What do you still wonder about?	What science ideas and terms help explain the phenomenon?

Storyline Chart

Lesson/ Activity	Phenomenon ↔ 	Question(s) 	Science Practices To Engage In 	What Cross Cutting Concept Does This Connect To? 	What We Figure Out 

Summary Table

Driving Question: ____

Activity	What We Learned (What happened and why?)	How it Explains the Anchoring Phenomenon

Summary Table

Driving Question ____

What did we do?	What did we observe? What patterns did we notice?	What have we figured out?	How does this relate to the anchoring phenomenon?	What questions do we still have?

Additional Materials for Day 4 Training

Skittles Phenomenon Materials -- Per Group (teams of 4)

- Plastic Cup
- Plastic Spoon
- Skittles
- 1 cup hot water

Additional Reading

- Read chapter 3 from the Framework, with special emphasis on pages 50-53. A free pdf downloadable copy is available from: https://www.nap.edu/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.

- Read Appendix G: Cross Cutting Concepts Science and Engineering Practices paying close attention to pages 1-3; 11-12; and 14-17. A digital copy can be retrieved from http://nextgenscience.org/sites/default/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. National Academies Press.

- Read Tool 3 comparing teachers Coles and Rivera from AMNH's Five Tools and Processes for NGSS

American Museum of Natural History. (2016). *Five tools and processes for NGSS.* Retrieved from http://www.amnh.org/explore/curriculum-collections/five-tools-and-processes-for-ngss/tool-3

- Read a New Vision for Science Education, an excerpt from the National Research Council.

National Research Council. (2015). *Guide to implementing the Next Generation Science Standards* (pp. 8-9). Washington, DC: National Academies Press. http://www.nap.edu/catalog/18802/guide-to-implementing-the-next-generation-science-standards

Additional Links

- Nextgenscience.org
- www.bozemanscience.com/next-generation-science-standards/
- http://www.state.nj.us/education/modelcurriculum/sci/ms.shtml
- http://lor.mivu.org/phenomenal-science

Appendix B: Elementary Science Teacher Interview Guide

Note: Probing questions are in bold, with follow up questions indented and in plain font.

RQ 1:

How would you describe your students' level of understanding of science content?

In what topics do they excel or struggle?

Why do you think they excel in….? Why do you think they struggle with….?

What steps do you believe should be taken to improve student content knowledge in science?

Explain how you would prioritize those ideas.

How might these steps improve student content knowledge?

How might these steps best be achieved?

RQ 2:

Consider one of your most recent science lessons, tell me about the methods you used to teach the science concepts.

Why did you choose those strategies?

How did your students respond to those instructional strategies?

Describe the science teaching methods you believe are most effective for students to have an accurate conceptual understanding of science concepts.

Of those strategies you mentioned, which do you use?

How frequently do you integrate them?

If you are not using some of those teaching strategies you mentioned, why not?

RQ 3:

Tell me about the barriers that impact science instruction?

Explain which of these most impacts student learning in science.

Is time a barrier for your science instruction? If it is, how?

What can school leadership do to help minimize the barriers you described?

How would you prioritize those suggestions?

Recall a time when one of your science lessons did not go very well, what contributed to that outcome?

If you could teach that lesson again, what might you do differently?

RQ 4:

Describe your level of confidence teaching science.

How does your confidence in science compare to teaching other subjects?

What could district personnel do to support teacher confidence in science?

What experiences have impacted your confidence level?

How have these experiences impacted your teaching science?

Describe your content knowledge and training for teaching science.

How could the district assist you in further developing content knowledge for teaching science?

How has your training affected your confidence in teaching science?

You mentioned…..how did that impact student learning?