Synergies among Education Stakeholders in Supporting Elementary Science:

A Qualitative Study

Myra Lynn Thayer

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Carol A. Mullen, Chair
Elliot F. Bolles
John R. Gratto
Walter D. Mallory

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ABSTRACT

The decisions and actions of principals impact the work in schools. The purpose of this research was to investigate the decisions and actions of elementary principals who support science and then compare those to the decisions and actions of teachers and central office staff. The primary question guiding the research was, What are the decisions and actions of elementary principals that support science education? Secondary questions were (1) How are the decisions and actions of elementary principals regarding science instruction impacted by those of central office science leaders? (2) How are the decisions and actions of elementary teachers regarding science instruction impacted by those of principals?

This qualitative study involved interviewing six education stakeholders: one central office staff member, two school leaders, and three teachers that represented three schools in one school division. The questions focused on six components of principal leadership: high standards for student learning, rigorous curriculum, quality instruction, culture of learning and professional behavior, connections to external communities, and systemic performance accountability. The data were analyzed to compare the decisions and actions of the principal with the decisions and actions of the central office staff and teachers. The discussion of the findings includes components involving synergy among the three stakeholder groups. Decisions by the school leaders to build time for science instruction, curriculum planning, and professional development support science instruction. Curriculum resources and professional development from the central

office are supports for schools. Included are recommendations of decisions and actions that may increase the synergy among the groups and the support for science.

These components and practices are not unique to science and this framework could be used to ensure a cohesive instructional program across content areas. This research could provide school and division leaders with a series of actions for addressing the components of principal leadership and increase opportunities for all stakeholders to work together to enhance student achievement in science.

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GENERAL AUDIENCE ABSTRACT

Principals make a difference for student achievement in schools, but they do not work alone. Teachers and central office staff also work to increase student achievement. This research examined how decisions and actions of principals impacted the decisions and actions of the teachers and central office staff to support science instruction. The research question was, What are the decisions and actions of elementary principals that support science education? Additional questions were (1) How are the decisions and actions of elementary principals regarding science instruction impacted by those of central office science leaders? (2) How are the decisions and actions of elementary teachers regarding science instruction impacted by those of principals?

Two school leaders, three teachers, and a central office science leader from three schools in the same school division were interviewed about decisions regarding standards, curriculum, instruction, professional learning, partnerships, and accountability. Their responses were analyzed to determine where the work was complementary to support science learning. This research could provide school and division leaders with a series of actions for addressing components of principal leadership and increase the opportunities for all stakeholders to work together to enhance student achievement in science.

DEDICATION

To my parents, Hugh and Marilyn Koops,
My first teachers and models of life-long learning

To Margaret Bertalan,
Who ignited my love and appreciation for science

To Nel Noddings
Who modeled *caring* and helped me see how *caring* matters

To my husband, children, and now grandchildren
Who are constantly teaching me something new

To hundreds of students, teachers, and colleagues
Who challenged my assumptions, and made me a better educator and leader

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Writing is not my favorite pastime, so thank you, Dr. Nina Huff for being gracious with your advice. Editors do make the writing better!

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Chapter 1: Introduction to the Study

Significant research across decades has been conducted on the role of principals in impacting student achievement. However, there is a gap in the literature on how the decisions and actions of principals impact and are impacted by teachers and central office staff. This research focused on the decisions and actions of elementary principals in the support of science and compared principals' decisions and actions with those of teachers and central office science leaders. The primary question guiding the research was, What are the decisions and actions of elementary principals that support science education? Two secondary questions were (1) How are the decisions and actions of elementary principals regarding science instruction impacted by those of central office science leaders? (2) How are the decisions and actions of elementary teachers regarding science instruction impacted by those of principals? Understanding what elementary principals do to support science, and how their decisions and actions may be complementary to the decisions and actions of teachers and central office science leaders, could provide the educational community with strategies for supporting a quality elementary science program.

Background

In the State of the Union address in January 2012, President Barack Obama called on the United States to look to the future and invest in an America that would maintain leadership in technology and research (Obama, 2012). He claimed that this moment in time was comparable to the Sputnik challenge of the previous generation and Americans needed to invest in education and support mathematics and science instruction.

After the Russian satellite Sputnik launched in 1957, a cry arose for more science and mathematics education. A reformation of mathematics and science curriculum was already happening, but now there was more support. Additional education funding was made available through the National Defense Act in 1958 and the National Science Foundation. An unprecedented collaboration of university science faculty and staff at major institutions, including the National Academies of Science, developed new science materials for elementary and secondary classrooms (Bybee, 1997). For elementary students, the curriculum included the Elementary Science Study (ESS), Science-A Process Approach (S-APA) and the Science Curriculum Improvement Study (SCIS). Although all of the curricula included inquiry, each had a different focus: ESS included independent explorations for students; S-APA emphasized the science process skills such as observing, classifying and measuring; and SCIS used Robert Karplus' "learning cycle" (DeBoer, 2014). Secondary curriculum included resources for biology, chemistry and physics. Three different approaches to biology were developed by the Biological Sciences Curriculum Study. *Chemistry: An Experimental Science* was developed by Chemical Education Materials Study for chemistry students and the Physical Science Study Committee developed a physics course that was known as PSSC Physics. All these courses were designed by scientists to provide students a more accurate presentation of the structure of science including how scientific investigations are used for meaning making in science (DeBoer, 2014). The curriculum reforms shared the philosophy of replacing the *facts* of science with an emphasis on *discovery* and the *structure* of science (Bybee, 1997).

These curricular materials were adopted by schools and made an impact on student achievement in science. During the 1976-1977 school year about a third of the school divisions surveyed as part of the National Survey of Science, Mathematics, and Social Studies were using one or more of the elementary science programs, and 60% of the divisions were using the secondary programs (Weiss, 1978). Shymansky et al. (1983) reviewed the implementation from

105 different studies that impacted over 45,000 students. Their quantitative analysis found that students in these new curricular programs outperformed their peers using more traditional science textbooks in science content knowledge, understanding the methods of science, and using critical thinking and problem-solving skills.

In 1997, at the 40th anniversary of the launching of Sputnik, participants at a symposium held in Washington, DC reflected on the impact of Sputnik in science and mathematics. Bybee (1997) spoke about how the Sputnik era impacted the science reform movement. He commented on successes of the reform that included collaboration between scientists, engineers, teachers, and education reformers that resulted in quality curriculum materials that went beyond textbooks; the financial support from both public and private sources; and the birth of educational groups, like the Lawrence Hall of Science, that still support science and mathematics education. However, he also spoke to challenges that included curriculum materials that did not result in more systematic changes in science instruction as well as the lack of both corresponding support for professional development and an examination of preservice education. He also noted that there was not a coordinated effort among those who formulate and enforce policies, develop programs, and implement practices. That coordinated effort was needed if reform was to happen (Bybee, 1997).

What is the status of science education now, over 60 years after Sputnik? In the most recent Trends in International Mathematics and Science Study (TIMSS) completed in 2019, the United States was not in the top-performing nations. The average scaled score for fourth graders was eighth in rank order of the 58 nations that participated in the study. Eighth graders had an average scaled score that was eleventh in the 39 nations (Mullis et al., 2020). The results also showed that about 17% of fourth graders and about 22% of eighth graders participating were able to apply their science knowledge to solve complex problems. Top-performing nations had as many as twice that percentage of students able to perform those more complex tasks (Mullis et al., 2020). These results are similar to the Third International Science Study's that was administered in 1995, just two years before the symposium reflecting on the impact of Sputnik on science curriculum. Then eighth-grade science students in the United States scored in the middle of the comparison, with an average that was twelfth out of the 25 nations (Beaton et al., 1996). In the 1960s and 1970s the answer was to write quality curriculum, but history and the current status of student understanding would indicate that is not sufficient.

Statement of the Problem

Missing in the dialogue about science education, both 60 years ago and now, is the role of the principal in supporting quality science teaching and learning. Since Sputnik there has been more research about what makes a quality science program and how students learn science. There is also a wealth of research on school leadership and how principals can make a difference in schools (Duke & Salmonowicz, 2010; Grisson et al., 2021; Hallinger & Heck, 1998, 2010; Leithwood, 1994). However, there is limited research on the decisions and actions of principals that support science in elementary schools in this era of high accountability for mathematics and reading. Settlage et al. (2015) developed an instrument to capture teachers' perceptions of leadership practices, and they found that the "potentially unique aspects of science education have received little attention within studies of school organization and leadership" (p. 389).

On a national policy level, the National Academies of Sciences, Engineering, and Mathematics (NASEM) convened a study committee in 2020 called Enhancing Science in Prekindergarten through Fifth Grade to address the challenges in creating a more robust elementary science program. The report, published in 2022, makes 18 recommendations including prioritizing science, integrating science with other content areas, and providing professional learning on science instruction for school leadership. Areas for future research include equity and justice, family and community engagement, curriculum and instruction, teacher education and professional learning, and systems and leadership.

The report specifies the "need to better understand the connections between the work occurring at the system (e.g., district or state) level and at the classroom level" (NASEM, 2022b, p. 256). Casey et al. (2012) identified a similar gap in the research comparing how the principal's work in the school coincided with work at the district level. This study was designed to fit within that gap of the connections between the district office, the school leadership, and the teachers by exploring the decisions and actions of the principals in their support of science, and how those decisions and actions impact those of the central office and the teachers.

There are societal indications that it is important to improve science education. In 2008 the National Academy of Engineering released the 14 Grand Challenges of the 21st Century that reflect four cross-cutting themes: sustainability, health, security, and joy of living (NASEM, 2022a). To meet these challenges, science content understanding and engineering application is required. In 2020, the outbreak of a global pandemic, massive forest fires, and more hurricanes highlighted the need to understand the science behind these events and mitigate against future natural disasters. Scientists and engineers will need to meet these challenges both here in the United States and across the globe. The building of these future scientists and engineers happens in the education system.

These Grand Challenges that require science and engineering and the business and economic outlook that predict an increase in careers in the fields of science, technology, engineering, and mathematics (STEM) (Logan et al., 2021) seem to be at cross purposes with the accountability measures set by the federal government. When the elementary school accountability pressure revolves around language arts and mathematics, as it did first through No Child Left Behind (NCLB) in 2001 and continues through the Every Student Succeeds Act (ESSA) passed in 2015, it should not be a surprise that the most recent report of the National Survey of Science and Mathematics Education (NSSME) indicates that students in elementary school spend about three times as much instructional time in mathematics and five times as much instructional time in language arts than in science (Plumley, 2019). That instructional time in science amounts to about 17 minutes a day (Plumley, 2019). With the limited amount of time spent on science, it is also not surprising that less than 20% of the elementary teachers responding to the NSSME indicated that their students had the opportunity to regularly engage in scientific practices such as comparing data across different trials, defending a claim using data, or developing a scientific model (Plumley, 2019).

The NSSME also showed that many challenges in elementary science education go beyond the time limitations for the teaching of science. Elementary teachers lack confidence in teaching physical science and engineering, are not well prepared to encourage all students to engage in science, and are unable to anticipate student difficulties with science content (Plumley, 2019). These challenges around the teaching of elementary science stand to compromise the ability to train the next generation of scientists and engineers.

Purpose of the Study

The purpose of this study was to investigate the decisions and actions of elementary principals that support science education. A second purpose was to compare the decisions and actions of the principal with those of teachers and central office science leaders.

Looking at principal support in special education programs, Elliott and Clifford (2014) analyzed the literature on principal performance evaluation instruments with a strong psychometric basis. Their analysis identified six core components that are critical to school leadership: “high standards for student learning,” “rigorous curriculum,” “quality instruction,” “culture of learning and professional behavior,” “connections to external communities,” and “systemic performance accountability” (pp. 13-16). They also identified six processes: planning, implementing, supporting, advocating, communicating, and monitoring. These processes are “interconnected, recursive, and reactive to one another” (Elliott & Clifford, 2014, p.17).

Elliott and Clifford (2014) identified these six core components and processes as aspects of “principal practice” (p. 12) that make a difference in schools. They examined the components and processes as a framework to support special education students. This study expanded the use of the framework and examined how these components and processes are reflected in the decisions and actions of principals in the support of elementary science.

Schools that underperform academically in meeting federal accountability requirements face considerable pressure to increase achievement in mathematics and/or reading. The emphasis on mathematics and reading sometimes compromises the teaching and learning of other content areas (Plumley, 2019). Nevertheless, some schools manage to support the teaching and learning in all content areas. Analyzing the decisions and actions of the elementary principals’ support of science instruction using the components and processes of Elliott and Clifford (2014) may provide a guide for other principals in supporting science instruction. In addition, a comparison of the principals’ decisions and actions with those of central office science leaders and teachers may provide additional information on how to positively impact science instruction in elementary schools.

Research Questions

The primary research question for the study was, What are the decisions and actions of elementary principals that support science education?

Two secondary questions were,

(1) How are the decisions and actions of elementary principals impacted by those of central office science leaders?

(2) How are the decisions and actions of elementary teachers impacted by those of principals?

Summary

Since the launching of Sputnik in 1957, the teaching and learning of science have undergone various reforms. The importance of science has been highlighted with current concerns of the global pandemic and natural disasters. Likewise, the Grand Challenges highlight the need for engagement in science, engineering, technology, and mathematics. Schools carry that responsibility of training future generations to meet these challenges, and current national and international assessments raise concerns that students are not receiving the science education necessary. History shows that curriculum changes are not sufficient, and leadership committed to science is necessary as well. This study investigated the decisions and actions of elementary principals that support science, and compare those with the decisions and actions of the teachers and central office science leaders. With the analysis, it may be possible to provide principals with a deeper understanding of how they can support science teaching and learning.

Chapter 2: Review of the Literature

The purpose of this study was to investigate the decisions and actions of elementary principals that support science education. A second purpose was to compare the decisions and actions of principals with those of teachers and central office science leaders. The primary research question for the study was, What are the decisions and actions of elementary principals that support science education? Two secondary questions were (1) How are the decisions and actions of elementary principals impacted by those of central office science leaders? (2) How are the decisions and actions of elementary teachers impacted by those of principals? The literature review examined what is known about the teaching and learning of elementary science as a foundation for the analysis and an understanding of the challenges principals face when supporting elementary science. The framework of "principal practice" from Elliott and Clifford (2014, p. 12) was used for this study. The literature reviewed for this chapter is organized around six core components of principal practice: "high standards for student learning," "rigorous curriculum," "quality instruction," "culture of learning and professional behavior," "connections to external communities," and "systemic performance accountability" (pp. 13-16).

This review was not meant to make a case for the core components since Elliott and Clifford achieved that through their analysis. Instead, in this review these six components were reviewed specifically for science education, and, where possible, elementary science. This provided a framework by which to compare the principals' responses to those actions that support science as reported in educational research. A description of these six components and the connections to the science educational research follows.

Principal Practice Framework Applied to Science Education

"High Standards for Student Learning" (Elliott & Clifford, 2014, p. 13)

Elliott and Clifford (2014) described high standards for student learning as "the extent to which leadership ensures that there are individual, team, and school goals for rigorous academic and social learning" (p. 13). These academic goals meet the public standards in science, which have been in practice since 1993 when the AAAS published the Benchmarks for Scientific Literacy. The Benchmarks were designed to explicitly inform teachers about what students should know and be able to do by the end of grades 2, 5, 8, and 12 in science, mathematics, and technology. School districts could use the Benchmarks as a tool to develop curriculum focused on scientific literacy. In 1996 the National Academy of Science developed the National Science Education Standards (NSES) in response to a call to action to provide a blueprint for science instruction with the intent to have "science standards for all students" (NRC, 1996, p. 2).

A recent evolution of science standards is from the National Research Council (NRC). In 2011 the NRC released A Framework for K-12 Science Standards. In the United States, 26 states expanded on the framework and released the Next Generation Science Standards (NGSS) in 2013. Since then, 20 states have adopted NGSS for their state science standards, and 24 additional states have based their state standards on the NGSS framework (National Science Teachers Association, n.d.). The impact of the framework has extended even further than those 44 states. For example, although the Virginia 2018 *Science Standards of Learning* (Science SOLs) do not explicitly mention that they are based on NGSS, the Science SOLs include the following scientific and engineering practices:

- asking questions and defining problems
- planning and carrying out investigations

- interpreting, analyzing, and evaluating data
- constructing and critiquing conclusions and explanations
- developing and using models
- obtaining, evaluating, and communicating information (Virginia Board of Education, 2018, p. v)

These practices are similar to the eight science and engineering practices in NGSS:

1. asking questions (for science) and defining problems (for engineering)
2. developing and using models
3. planning and carrying out investigations
4. analyzing and interpreting data
5. using mathematics and computational thinking
6. constructing explanations (for science) and designing solutions (for engineering)
7. engaging in argument from evidence
8. obtaining, evaluating, and communicating information (NRC, 2013, p. xx)

Specific expectations on these scientific and engineering practices as well as the science content are explicit in both NGSS and Virginia science documents. A rigorous curriculum follows these expectations for all students.

"Rigorous Curriculum" (Elliott &Clifford, 2014, p. 14)

Elliott and Clifford (2014) separated rigorous curriculum from quality instruction by defining *rigorous curriculum* as "the content of instruction, rather than the pedagogy" (p. 14). In science, the content of the instruction is not just the knowledge about the facts about science, but also an understanding of how scientists go about their discoveries and the framework by which scientific knowledge is constructed. The content of instruction for science includes specific content, the process of inquiry, and the nature of science.

Content Understanding. The content that is expected to be taught to students is explicit in the various standards documents, and includes content in life, Earth, space, and physical sciences. This content is a challenge for elementary teachers because, unlike secondary teachers who can specialize in a science content area, they are expected to teach all these content areas. There is an additional expectation that elementary teachers are experts in mathematics, reading, writing, and social studies. Studies, as outlined below, suggest that teachers do not have the necessary content knowledge to teach all these science content areas.

Research over the decades continues to indicate a lack of science content understanding. Annetta and Dotger (2006) found that preservice teachers did not know the science content as it aligned to the Interstate New Teacher Assessment and Support Consortium (INTASC) Standards and the National Science Teachers Association (NSTA) Core Knowledge Standards for science teachers. This lack of content knowledge continues into the classroom. For example, elementary teachers did not have the scientific knowledge to accurately explain the causes of night and day (Atwood & Atwood, 1997). This lack of understanding was also evident in light, force, and motion topics (Krall et al., 2009), in animal classification (Burgoon & Duran, 2012), and in physical science content including gravity and magnetism (Burgoon et al., 2011). These specific examples continue a documented history that elementary teachers do not have the content knowledge to feel confident teaching science (Crawford, 2000; Keys & Bryan, 2001). The NSSME indicated that only 34% of the elementary teachers had content courses in Earth, life, and physical sciences (Plumley, 2019), so research that shows elementary teachers are not confident in their science content is understandable when considering that these teachers have not had formal coursework in the science content that they are teaching.

The recognition of a lack of science content knowledge can encourage teachers to learn the content and recognize the challenges for their students. In a study of principals in exemplary schools, Casey et al. (2012) discovered a principal that administered the fifth-grade science test to the fifth-grade teachers. When the teachers recognized the struggle they encountered with the test, they were motivated to look at the grade-level objectives and more closely align the curricula. The principal used this opportunity to improve science instruction across all grade levels.

Inquiry in Science Classrooms. The content of science matters, but there is also an emphasis on the process of discovery of that content. This process of discovery, or inquiry, is part of Benchmarks (AAAS, 1993), the NSES (NRC, 1996), and NGSS (NRC, 2013). Although there seems to be consensus that inquiry should be a part of the science curriculum, there is no consensus on exactly what *inquiry* is (Crawford, 2014). One interpretation of inquiry is that students construct their knowledge by engaging in scientific processes. From observations they pose questions; do research; use tools and experimentation to gather, analyze, and interpret data; propose explanations and conclusions; and then communicate their findings (NRC, 1996). The Next Generation Science Standards (NRC, 2013) actually moved away from the term *inquiry* and uses the term *science practices*, with the intent that students be engaged in scientific investigations, which was also the intent of inquiry in the NSES (NRC, 1996).

Despite the fact that there is not one definition of inquiry, the success of inquiry in classrooms has been a research focus. The initial curriculum work after Sputnik included a focus on inquiry (DeBoer, 2014), and that has continued. Inquiry is an important way for students to learn science (Aydeniz & Brown, 2010), and students who engage in an inquiry-based curriculum outperform students in more traditional classrooms (Shymansky et al., 1983; Wilson et al., 2010).

Whether an inquiry-focused experience is included for students in the classroom depends on whether the teacher had an inquiry-focused experience as part of their instructional learning. The research indicates that teachers have to experience inquiry-focused learning themselves before they are able to implement in their classrooms. There are different ways that these inquiry-focused experiences can be provided for teachers. If teachers have had a preservice program that includes inquiry experience as part of the training, they are more likely to teach using inquiry in their classrooms, and their self-efficacy in teaching science is higher than that of preservice teachers who did not have this experience (Bleicher & Lindgren, 2005; Luera & Otto, 2005). Teachers will also use inquiry in their classrooms if they have had a research experience or have greater content understanding (Windschitl, 2004). Sustained professional development on inquiry is also an indicator for more inquiry in the classroom (Smith et al., 2007).

Teachers' knowledge and self-efficacy about inquiry are not the only barriers to having an inquiry-based classroom. Harris and Rooks (2010) specified five aspects of classroom management that can challenge teachers: students, instructional materials, tasks, science ideas, and classroom community. Inquiry lessons take more time (Keys & Kennedy, 1999) and the emphasis on mathematics, reading, and writing encourages teachers to reduce the time for science (Griffith & Scharmann, 2008). All these barriers make implementing inquiry-based lessons harder for teachers.

Nature of Science. Science is more than just a collection of facts and inquiry. The framework by which scientific knowledge is constructed is called the Nature of Science (NOS).

The emphasis on NOS has been a part of the science education landscape since the 1950s (Abd-El-Khalick, 2014). Despite the longevity of NOS and the general support for NOS, there is no universal understanding of what NOS is (Lederman & Lederman, 2014). Yet, AAAS (1990, 1993) and the NRC (1996, 2012, 2013) all include expectations for students and teachers to understand NOS. Although the actual description in each varies, across the scientific community there is agreement that NOS includes the general ideas that scientific knowledge is tentative and subject to change with new data; based on empirical evidence through experimentation and observation of the natural world; built on the creativity and inferences of people who use their background knowledge; and embedded in a cultural and social context. Within these general statements is included the expectation that students know the difference between observations and inferences and the relationship between scientific theories and scientific laws (Lederman & Lederman, 2014). These ideas about scientific knowledge appear to cross all the various science disciplines (Schwartz & Lederman, 2008).

The importance of science teachers' understanding of NOS is based on two assumptions in the research about NOS (Lederman & Lederman, 2014). One is that the understanding of NOS will impact their students' understanding, and the second is that the teachers' behavior in the classroom will be dependent on their understanding of NOS. These assumptions support the premise that if teachers have an incorrect idea about how science is practiced, then they also have a harder time teaching science in an authentic way (Bencze, 2010).

If a teacher's understanding about NOS makes a difference in the science instruction, then the teaching of NOS to preservice and science teachers is important in developing an understanding about inquiry and the differences in scientific theories and laws (Faikhamta, 2013). The research involving the methodology for teaching NOS indicates that when NOS is taught explicitly, through discussion and hands-on activities followed by reflection, teachers grow in their understanding of NOS. This is true across all levels. Elementary teachers' (Abd-El-Khalick & Ackerson, 2009; Maeng et al., 2020), middle school teachers' (Seung et al., 2009), and secondary teachers' (Smith & Scharmann, 2008) understanding of NOS increased with instruction that made NOS visible to them in the classroom.

"Quality Instruction" (Elliott & Clifford, 2014, p. 14)

Having a rigorous curriculum is not valuable unless there is a corresponding *quality* of instruction, which is "defined as effective instructional practices that maximize student academic and social learning" (Elliott & Clifford, 2014, p. 14). As seen in the previous section on rigorous curriculum, elementary teachers often do not have the content understanding. As an example, the teacher has to know about inquiry, and then use inquiry as part of the effective instructional practice. One challenge for elementary teachers in terms of quality of instruction is time. The Center on Education Policy (McMurrer, 2008) found that 28% of the surveyed elementary schools reported a decrease in the amount of science taught per week by an average of 75 minutes per class. Over 50% of the schools indicated an increase in instructional time for language arts. Similarly, Griffith and Scharmann (2008) reported that a third of the elementary teachers in their study were instructed to cut the amount of time spent on science by their administration, while almost 10% of the teachers were instructed not to teach science at all. In the most recent NSSME, only 21% of elementary teachers reported that they taught science all or most days of the week for every week (Plumley, 2019). This same survey indicated that 77% of teachers do not engage students in activities because they don't have the time. However, time is important. A study by Curran and Kitchen (2019) found that the amount of time spent on science in the early grades was a predictor of science achievement. Time spent was more significant than the number of topics covered.

Additionally, over 60% of the teachers reported funding for science that was less than that provided for math or reading (Griffith & Scharmann, 2008). Since the teaching of science requires materials for the students to participate in a hands-on manner, this modest funding has a large impact on how science can be experienced by students. Science instruction is impacted by this lack of time and funding.

Because elementary teachers are responsible for all the content areas, a way to increase time spent on science is to see it as a complement to other content areas. There are successful models for this integration of content. One large study, implementing In-Depth Applications of Science (IDEAS) (Romance & Vitale, 2001), used a schedule that included a two-hour block for science, instead of having the block designated for language arts. This science time included time for reading, writing, and the hands-on experiences of science. Students in the classrooms that used IDEAS outperformed their peers in science content, attitude and self-confidence, and reading comprehension. During the first two years of the study only students considered average or above average were included in the study. For the next three years of the study, at-risk students were included. All groups of students showed significant growth in all areas on nationally normed standardized tests.

Another model used literature as a way to engage students and had students write about their science learning. Although the focus of the study reported by Shymansky et al. (2013) was on professional development (PD) for teachers, the outcome of the research provides insight on a way to include science in elementary school. The PD included having teachers adapt science inquiry lessons in ways that would enhance language art skills. Teachers involved in this sustained PD used literature as a way to spark the inquiry for the science lessons and included the science content that students were learning as the context for the writing and reading skills in language arts, thus efficiently using the limited time in the school day by integrating science with the language arts. Students of teachers involved in the PD showed significant gains on high-stakes science assessments.

Cervetti et al. (2012) took an approach that "inquiry-based science and literacy share skills, strategies, and goals that can be capitalized upon as the central features of integrated instruction" (p. 635). They worked with 94 fourth-grade teachers and their students on a light unit where the literacy skills were purposefully and explicitly interwoven with the science inquiry for the treatment group. Students in the treatment group outperformed the students in the more conventional classrooms on science concept learning, science vocabulary, and science writing.

On a smaller scale, Queenan (2011) showed how reading and writing skills could be incorporated into science. Her description of reading strategies and methodologies that could be used in an elementary school that only dedicated 30 minutes a week to science provides examples of how teachers can support and enforce student interest in science by using strategies such as "Here's What, So What, Now What, and Then What."

Cavagnetto et al. (2011) researched how different group sizes impacted student understanding using the Science Writing Heuristic (SWH). This framework uses both verbal and written language in the inquiry process of posing questions, collecting and analyzing data, and making claims based on evidence. The research question focused on whether small-group interactions of teachers with students were more effective than whole-class interactions in promoting and implementing inquiry-based science. The outcome of the study showed that teachers can use a whole-class approach, which is promising since it is harder to work with multiple small groups of students than the whole class. The study was not designed to examine language arts and inquiry connections, but the success with using SWH in a whole-group setting shows potential in that SWH could be used to support the growth of language arts skills for which students are held accountable.

Recognizing that elementary teachers do not have the expertise to teach science, one way to impact the quality of science instruction is to use teachers with expertise in science content and pedagogy to teach science to more students. Elementary science specialists, when compared with self-contained elementary teachers, were more likely to have a science degree, felt more prepared to teach science, and had more time to teach and plan (Brobst, 2017). Utilizing a science specialist can take a variety of forms. One model, where a specific teacher taught students math and science yet collaborated with the other grade-level teachers, resulted in students outperforming students on state assessments in schools that did not use this model (Nelson & Landel, 2006). However, having a science specialist does not mean that science is valued. Levy et al. (2016) found in a comparison of schools in the same district that the schools where classroom teachers taught science reported higher principal support, more collaborative planning time, and more support for additional science-related activities such as field trips, than the schools that had a science specialist.

The decision on whether to have a science specialist may reflect the culture of the school. In a study by Poland et al. (2017) interviews with teachers in schools where there was a science specialist reflected an emphasis on reducing workload and content mastery. Teachers in schools where the teacher taught science shared a more holistic view of the elementary classroom.

"Culture of Learning and Professional Behavior" (Elliott & Clifford, 2014, p. 15)

In the Elliott and Clifford (2014) framework, principals need to ensure "that there are integrated communities of professional practice in the service of student academic and social learning" (p. 15). As evidenced in the previous sections, elementary teachers face challenges in terms of understanding the rigorous curriculum and having the time and materials to implement quality instruction. This can make the professional practice around science difficult for teachers as well. The opportunities for teachers to engage in science-related PD are limited according to NSSME. The 2019 survey revealed that 43% of elementary teachers have not had science-related PD in the last three years and 20% have had less than six hours of science-related PD in that same period. Fortunately, the survey also showed that 57% of the teachers work closely with teachers in their school. If some of that work could focus on science, it might be possible for elementary teachers to grow in their understanding of both science curriculum and instruction.

Many small districts do not have resources to hire a specific specialist for a school, nor do they have central office science support for elementary teachers in teaching science. However, there are science teachers in the high school that can support the content knowledge of elementary teachers. Miller (2010) compared two different systems of support. Neither school system had district-level science staff. One school district built teams of grade-level representation across schools with high school science teachers providing content support. Students in this district outperformed on the state science assessments their peers in the neighboring school district that relied on district-level leaders to communicate with principals. Another model for leveraging local expertise is to have someone who understands the content and pedagogy of science coordinate and lead teachers in their professional development. Providing that support to teachers can be a critical component to transforming the science education in a school or system (Tytler, 2007), but a science specialist alone may not be the answer. Marco-Bujosa and Levy (2016) found in their study of science specialists serving schools in a large urban district that science specialists were reliant on the principal's support in order to be effective. The overall science program was impacted by the type of supports that the science specialist offered.

As already indicated, elementary teachers are not confident in the content or the pedagogy of science. Sustained PD can increase teacher confidence. The PD reported by Maeng et al. (2020) took place during four weeks in summer. Teachers were involved with planning and teaching a problem-based unit to campers in grades four through six. They also had the opportunity to engage in field investigations with scientists. At the end of the session, teachers developed a problem-based unit that they implemented during the school year. The teachers also had coaches during the school year. Teachers who participated significantly increased their understanding of inquiry and NOS, and implemented inquiry and explicit teaching of NOS in their classrooms as compared to the control group.

"Connections to External Communities" (Elliott & Clifford, 2014, p. 15)

Another area for principals to consider is the connection to other communities that can support student learning. Leaders focused on learning "play a key role in both establishing and supporting parental involvement and community partnerships" (Elliott & Clifford, 2014, p. 16). There are numerous models of partnerships, both in terms of the audience at the school and the identity of the external partners.

One model of a connection with an external community is a partnership of an institution of higher education working with a school division. Ross and Mason (2001) looked at one such model when they researched the outcome of a collaboration involving elementary teachers and science majors and university science faculty at San Diego State University. The collaboration resulted in increased teacher confidence in teaching science and also increased student engagement.

A partnership between Rutgers University (RU), New Brunswick Public Schools, and Johnson & Johnson (J&J) is an example of a business partnering with a university and school system with a focus on student achievement. J&J was interested in expanding their “Bridge-to-Employment” program to younger students to increase achievement in science. Students from RU led the after-school and summer, place-based, and nature-focused program serving disadvantaged elementary students. The students participating outperformed their peers who were not in the program on division-developed assessments in mathematics, language arts and science (Camasso & Jagannathan, 2018).

These connections to external organizations can also help reach students who have been traditionally left out of science. The literature review on research in gender equity in STEM by Hughes et al. (2020) lays out specific strategies to engage girls in STEM. Their conclusion was that girls, especially from underserved populations, need multiple opportunities to develop STEM identities. If schools can partner with external organizations, the students will have more opportunities to engage with science or STEM.

“Systemic Performance Accountability” (Elliott & Clifford, 2014, p. 16)

Schools have both internal and external accountability systems, and school leaders can “integrate internal and external accountability systems by holding their staff members accountable for implementing strategies that align teaching and learning with achievement goals and targets set by policy” (Elliott & Clifford, 2014, p. 16). The external accountability of the U.S. federal requirements for science are few, with only one assessment at each level:

elementary, middle, and high (U.S. Department of Education, 2017). With much greater external accountability in reading and mathematics at the federal level, it is not a surprise that science is not taught with the consistency that is reported for language arts (Plumley, 2019). If science is going to be a focus, schools and school divisions need to have internal assessments. Since science understanding includes skills, performance assessments can also be used. These can also be formative assessments, allowing teachers to make changes in instruction (Kruit et al., 2020).

High accountability can impact science in more ways than just the time and attention spent on science. A study by Hayes and Trexler (2016) found that in schools where teachers felt a high amount of pressure to meet accountability standards, the quality of the science program decreased. The number of hands-on investigations was significantly fewer than at schools where teachers felt less pressure. This is even more significant when one considers that the schools in the study that were under more pressure also had a higher percentage of students underrepresented in science.

Challenges for Principals

Using these six components of Elliott and Clifford (2014) as a leadership framework for science, there are challenges for principals that emerged in the research. The gaps in the teachers' understanding of science curriculum and instruction are compounded by similar gaps in the principals' knowledge. Sherman and MacDonald's (2008) study on instructional leadership focused on how principals supported science. They found that the principals, like many of their teachers, did not understand science. As a result, they were not able to give specific help to teachers. Questions that principals asked teachers in an effort to support science teaching were more about general instruction, and not specific to inquiry or NOS. Although a small sample--there were 25 principals in the study--it is important when one considers that only 3% of elementary teachers in 2018 had a science or engineering background (Smith, 2020). Principals need to support teachers and both have limited understanding of science content.

This lack of content knowledge is recognized as an area that needs attention in school leadership preparation programs (Stein & Nelson, 2003), and for science instruction to change, the principal must build a school climate that supports science (Lewthwaite, 2004). Though principals do not have science-specific expertise, they still have influence on instructional practices (Marks & Nance, 2007), and when principals are more involved in the core work of teaching and learning, student achievement increases (May & Supovitz, 2011). In schools where principals reported having a strong influence on instruction, the teachers also reported that they had a strong influence on instruction (Marks & Nance, 2007). This suggests that when teachers are involved in the decision making, science-oriented leadership may influence how teachers make decisions about science instruction.

Time, which is an issue for teachers in the classroom, is also an issue for principals. While there is research on the time principals spend on various tasks such as administration, interactions with students and parents, and curriculum and instruction concerns (Hoyer & Sparks, 2017), more needs to be known about what is actually happening during those tasks, especially as related to elementary school science.

Theoretical Framework for School Leadership

Over 30 years of research on the impact of the principal leadership in schools has shown that principals can make a difference on student learning. Although the impact of the principal is understood to be indirect, the actions of the principal can influence the direction of the school and the development of instructional capacity in teachers (Grisson et al., 2021; Hallinger & Heck, 1998). If the leadership can impact instructional practices, then student achievement can also increase (Hallinger & Heck, 2011; Marks & Printy, 2003). Grisson et al. (2021) in an analysis of decades of research on principal leadership reported that an effective principal can "result in an additional 2.9 months of math learning and 2.7 months of reading learning each year for students in that school" (p. xiii). An effective principal has an impact on the entire school, and with the increased accountability for student achievement, this wider influence is important (Grisson et al,, 2021). As a result, a low-performing school may undergo a leadership change in an effort to increase student achievement (Duke & Simonović, 2010).

The leadership style of the principal does seem to make a difference in student achievement. Principals who set a clear vision, but don't support teachers in their learning, don't see instructional changes (Marks & Printy, 2003). Research also shows that for instructional change to take place and student achievement to increase, teachers need to be a community of learners (Grisson et al, 2021; Hallinger & Heck, 2010; Urick & Bowers, 2014,).

Within this community of learners, data-driven, decision-making discussions are needed. Park and Datnow (2009) found that all the stakeholders—central office staff and school leaders as well as the teachers—played important roles. The central office staff and school leaders had to set an environment where these discussions were not evaluative, and one of the outcomes of the discussions was the identification of additional resources. Teachers needed time both within their grade-level teams, with other teams, and with teams from other schools to have discussions on instructional methods that would empower them to make changes in their classrooms.

The six core components that Elliott and Clifford (2014) recommended are supported through the research, and capture various aspects of different leadership models. As an example, ensuring high standards for student learning is compatible with the leadership setting a clear vision. Similarly, promoting a culture of learning and professional behavior is compatible with the work that supports professional learning communities or collaborative learning teams, and systemic performance accountability relates to both the external accountability measures that schools are subject to through ESSA as well as school-based or division-based accountability measures.

Conceptual Framework for Principal Practice

The research indicates that principal actions include setting the stage for the vision and supporting the collaboration and the decision-making opportunities for teachers in their schools (Grissom et al., 2021; Hallinger & Heck, 2010; Marks & Printy, 2003; Urick & Bowers, 2014). Instead of investigating the principal actions in the context of the whole school community, this study focused on the decisions and actions as they impact science instruction. The core components of Elliott and Clifford (2014) provided a framework for the current study. Leadership that works within this framework could impact both the behavior of teachers and the achievement of students. They presented these core components in a general way. Table 1 shows how each of the components can be translated for science leadership.

Table 1

Relationship of Core Components to Science Leadership

Core Component	Description for Science Leadership
High standards for student learning	Science is included as part of the vision for the school and there are expectations that science is for all students.
Rigorous curriculum	There is clearly articulated science content that is more than facts, and enforces concepts and skills.
Quality instruction	Instruction includes an experimental approach that embraces inquiry and the nature of science.
Culture of learning and professional behavior	Professional development about the teaching of science is available.
Connections to external communities	Partnerships include science-related organizations and parental involvement.
Systemic performance accountability	There is an accountability for science that is included in the school culture.

Elliott and Clifford (2014) also identified through their analysis six key processes: planning, implementing, supporting, advocating, communicating and monitoring. These processes are not linear, and are interconnected with one another and the components. Table 2 provides an example of a specific science action for each of the six key processes.

Table 2

Examples of Actions that Support Science in Relationship to Processes

Process	Action
Planning	Develop shared direction about the learning of science, science is included in the daily schedule.
Implementing	Schedule grade-level planning time for science.
Supporting	Use financial resources to support science instruction, support teachers in the learning of science.
Advocating	Ensure that all students have access to science.
Communicating	Communicate both within the school and to the external school community the importance of the science program.
Monitoring	Monitor student achievement in science, as well as the goals and curriculum alignment.

The processes are necessary in order for a core component to be visible. If high standards for student learning in science is a core component, then there should be a visible action of the six processes from the principal. An example of an action that supports a component might be the school’s vision on the web page that makes it clear that science is a focus for all students. Using this framework, the principal supports science instruction through actions such as time to plan the instruction (planning), time in the schedule to teach using quality pedagogy (implementing), materials available for hands-on experiences (supporting), and access to science for all students (advocating). There is also overlap in the core components and the processes. An action of planning PD for teachers around inquiry would support at least two core components: (1) quality instruction and (2) culture of learning and professional behavior. With six core components and six processes that are possible in each core component, there are 36 categories for principal action.

Summary

Principal support of science has six core components outlined in the “principal practice” framework (Elliott & Clifford, 2014, p. 12). The principal makes decisions on all of these components, but two components--rigorous curriculum and quality of instruction--have challenges based on what teachers know and are able to do in the classroom. Although research indicates that student achievement increases with instruction that includes inquiry, teachers are less likely to teach inquiry-based lessons when they are unsure of the science content knowledge, have limited experience with inquiry, and feel pressed for instructional time. The added federal accountability in mathematics and reading contributes to decreased time for, and emphasis on, teaching science. There are successful models for the integration of science with language arts that have the potential to support more science learning. Principals need to navigate the challenges if they are to support the teaching and learning of science in their schools.

Chapter 3: Methodology

Purpose of the Study

The purpose of the study was to investigate the decisions and actions of elementary principals that support science education. A second purpose was to compare the decisions and actions of principals with those of teachers and central office science leaders. In this chapter I explain the methodology as well as justify the research design that includes the review of interview questions, the setting, and the selection of participants. I also describe how the data were collected and analyzed.

This research was conducted in a context where school accountability systems place greater emphasis on reading and mathematics than on science, yet the larger political and national context is calling for more people to go into science careers as an economic driver and to help solve global challenges around climate, the environment, and health. Understanding the decisions and actions of principals to support science may inform, guide, and improve the quality of science programs for more students.

Qualitative Research Approach

Qualitative researchers explore a process in depth through the views of participants (Creswell, 2008) and address a "how" or "why" question in a study of a contemporary phenomenon in a real-world context (Yin, 2017). This constructivist approach of building knowledge from understanding the actions of participants also recognizes that research is not neutral, so the researcher needs to examine how their experiences, knowledge, and preconceptions may shape their understanding and analysis (Charmaz, 2014). I recognize that my experiences have shaped the worldview that I bring to this research and that it also shapes research design.

Researcher's Worldview and Background

A constructivist approach recognizes that the construction of the knowledge is occurring under conditions that include the researcher's assumptions (Charmaz, 2014). For the research to be meaningful I must examine my experiences and how those experiences impact my research designs. I have experience teaching science in both middle and high school. I also taught science to students in grades K–5 when I was hired by an elementary principal who recognized that the teachers in his school did not consistently teach science. My appointment as a science coordinator in a large Virginia school system coincided with the use of state assessments as accountability measures for schools, followed by the federal accountability under NCLB. During that time, I watched and listened as some elementary principals struggled to balance the demands of the federal and state accountability systems with the need for instruction across the content areas. As the federal accountability moved to look at specific subgroups and placed a higher emphasis on reading and mathematics, principals faced decisions about the amount of time for teaching science and social studies. They were also trying to find remediation time for language arts and mathematics. There were frequent conversations with teachers who felt that the priorities of the school and principal were detrimental to the teaching and learning of science. These included taking students out of science for mathematics remediation, encouraging the memorization of terms at the expense of conceptual understanding, and minimizing science instructional time.

I also had the opportunity to serve as president of a statewide science leadership association. In that role I worked with science leaders across the state. The variation in the support these division leaders were allowed to provide was surprising to me. Some of these leaders were able to provide significant support to their elementary schools, which included specific lessons, professional development for the lessons, and all the materials. This contrasts with other science leaders who had less interaction with their schools. In those schools the principals were the primary decision makers for science resources and professional development (PD). Depending on the decisions made at the division level, the principal had more or fewer decisions to make about science instruction. Seeing the variations in how science instructional decisions are made, from both the division and school perspective, led me to this research.

Research Questions and Design Process

The primary research question for the study was, What are the decisions and actions of elementary principals that support science education?

Two secondary questions were:

(1) How are the decisions and actions of elementary principals impacted by central office science leaders?

(2) How are the decisions and actions of elementary teachers impacted by principals?

Table 3 shows my research design processes building on Creswell’s (2009) characteristics of qualitative studies.

Table 3

Research Design Processes Related to Characteristics of Qualitative Studies

Creswell Characteristics	Research Design Processes
Natural setting	Participants were interviewed over Zoom and they were in their chosen settings.
Researcher as key instrument	The researcher conducted the interviews. Interviews were initially transcribed using the automated feature in Zoom that provides audio transcriptions. The transcriptions were matched to the audio recordings.
Data sources	Interviews were conducted with representatives from different groups involved in science education: principals, teachers, and a central office specialist. Information about the school improvement plan and information from the websites, such as announcements and tweets, were also examined.
Data analysis	Interview transcripts were organized by question and the role of the participant. Keywords from my research questions including *decision, action, support, science, principal, central office*, and *teachers* and additional keywords from my search terms including *inquiry, professional development, leadership,* and *partnership* were used. Comparisons were made between the responses on a given component. More details are included in the following Data Analysis section.
Participants' statements	The focus was on the decisions and actions of the participants and learning about how they made those decisions and actions based on their particular context.
Interpretive	Interpretations were made based on participants' statements.

Site Selection

This research was conducted in a large mid-Atlantic school division. The school division met the criteria because there were multiple schools that had increased the fifth-grade science assessment scores by at least 5% from spring, 2017–spring, 2019. The division had also implemented an after-school STEM program in Title I schools where there was school leader support.

Participant Selection

The participants in the study were purposefully selected. According to Creswell (2009), purposefully selected participants are those "individuals who will best help … understand the research problem and the research questions" (p. 231). For this study, principals, teachers, and a central office science leader helped gain an understanding of the decisions and actions of these stakeholders in supporting science.

A minimum increase of 5% in the state's 5th-grade science assessment scores from spring, 2017-spring, 2019 was used as one form of evidence that the school principal supported science. The assessment scores from spring, 2017-spring, 2019 were the most recent years that science scores were available since all assessments were cancelled in 2020 because of the pandemic. Federal accountability required assessments for the 2020-2021 school year, but many schools were still meeting virtually because of the pandemic. School systems did not have a way to deliver and monitor these assessments in homes, so any assessment data for 2020-2021 cannot be reliably used for comparison to previous years. There were 10 elementary schools that showed this minimum increase in science scores.

Another form of evidence used to indicate principal support of science was additional science programs supported by the school. There were eight schools that the division science office recommended because of principal support in adding an after-school STEM program. There were six schools that had this after-school program during the school years (SY) 2016-2019 time frame. Two of these schools were also on the list of those schools that had had an increase in science scores. As a result, there were 16 schools that met the criteria.

Of those 16 schools, five had principals who were new to their position. In two schools it was possible to contact the former principal, and in two schools the current principals had worked previously in an eligible school. Two principals had served at the schools during the SY 2016-19, but were no longer at those schools. Two additional principals were currently at eligible schools and had served in other eligible schools during the time frame for this research.

In order to investigate how the decisions and actions of the interviewed principals impacted the teachers, a teacher was also interviewed. The principal recommended a teacher within the school to be interviewed.

Participant Sample

Fourteen principals were emailed invitations to participate. Eleven principals did not respond to the initial email and were sent a follow up email. There was no response from these principals. There was a response from three principals. One principal was not able to participate, but the assistant principal, who had worked with the after-school STEM program, was recommended instead. This assistant principal agreed to be interviewed. There was a positive response from two other principals, one of whom was interviewed. The other principal scheduled an interview twice but cancelled both times. Although there were many email communications, the interview was not rescheduled a third time. As a result, there were two school leaders who were interviewed.

Each of the three school leaders who initially agreed to participate recommended a teacher. All of the teachers agreed to be interviewed. This resulted in representation from three elementary schools.

A representative from the central office who supported elementary science from 2016 to 2019 was also interviewed. This person was responsible for the curriculum writing and professional development for elementary science in the school division. She was also responsible for the implementation of the after-school STEM program which involved developing the model of the program, choosing the activities for the students, and leading the professional development of the administrator and teachers in the selected schools.

Limitations and Delimitations

There were limitations in the research that impacted the ability to generalize the results. One limitation was related to the sample selection. The eligibility imposed by the research design limited the number of school divisions and schools that could participate to schools where there was an increase of at least 5% in the state science assessment scores from spring, 2017 to spring, 2019 or schools that were identified by central office science leaders as having school leader support for science programing. In a review of all the fifth-grade science assessment scores on the state website from that time frame, fewer than 10 school divisions had six or more elementary schools that showed a minimum of 5% increase in the elementary science assessment scores.

The initial research design also included interviewing stakeholders from three to six schools. The response met the minimum of three schools, but only a teachers was interviewed for the third school.

The research design also required that there be someone who worked specifically with elementary science, and that is not the case for all school divisions. This study was limited to one large school division in one state, and may not reflect the practices in other states or divisions that rely on other personnel structures to support elementary science education.

Another limitation was the selection of the participants. Only one school leader and one teacher were interviewed from each school. The school leader recommended the teacher who was interviewed. The teachers who were recommended had experiences teaching third grade and fifth grade and taught all of the subject areas. Although there was a STEM teacher in one of the schools, that was not the teacher who was recommended.

The global pandemic also imposed limitations. The interviews took place through a 30–60-minute Zoom call instead of in person. The participants were also asked to reflect on time prior to the COVID-19 pandemic. It is unknown how the responses would have been different had the teachers who were more involved in STEM been included, interviews taken more time or in person, been conducted over a period of time, or happened closer to the SY 2016-2019 and prior to the pandemic.

The limitations for the generalizations are related to the delimitations, or imposed boundaries set by the researcher. These delimitations include interviewing only one school leader and one teacher from each school, having participants from only one school division, and doing the interviews only over Zoom. The selection of the teacher to be interviewed by the school leader is also a delimitation and it is not known why the school leaders did not choose for the interview a teacher who was more involved in science through the STEM program. Another delimitation is that only the school leaders and teachers in schools that had an increase in science assessment scores at the state level or were identified by central office staff as supporting science were selected for interviews. A comparison with school leaders and teachers in schools where there were consistently high science assessment scores, low scores, or scores that dropped from 2017-2019 is not possible from this study.

Data Collection Process

Before any research could take place, it was necessary to complete the CITI training (Appendix A). The Institutional Review Board (IRB) application was submitted through the Human Research Protection Program (HRPP) at VA Tech and IRB #21-938 was approved on 11/22/2021, pending the IRB approval of the school system. The IRB of the school system approved the research on 1/5/2022.

After receiving IRB approval, an elementary principal, a fifth-grade teacher, and a retired elementary science specialist, who were not in the school division being researched, were contacted to pilot the research questions. They were sent an invitation to participate in the pilot (Appendix B) and the Information Sheet for Participation in a Pilot of a Research Study (Appendix C). After agreeing to participate they were sent the questions corresponding to the roles: Interview Questions for Principals (Appendix D). Interview Questions for Teachers (Appendix E), and Interview Questions for Central Office Science Leader (Appendix F). These interviews occurred over Zoom and were not recorded; notes were taken on the responses. After the interviews there was a discussion about possible follow-up questions that could be asked.

There was also a meeting with the central office science staff at the school division to finalize the list of schools and to make sure that the principals had been in the schools during the time period from SY 2016-2019. Identified principals were sent an invitation email (Appendix G). When the principal and assistant principals accepted the invitation, they were sent the interview questions and the Information Sheet for Participation in Research Study (Appendix H). The time and date were set for the interview, and the Zoom link was sent.

The invitation email for the principals asked for the name of a teacher who was familiar with their leadership in science to be interviewed. All of the school leaders recommended a teacher, and those teachers were sent the invitation email (Appendix I). All the teachers accepted the invitation and were then sent the interview questions and Information Sheet for Participation in Research Study. After the time and date were set, an email was sent with the login information.

The same process was followed for the central office science leader. The invitation email was sent (Appendix J) and that was followed by the interview questions and Information Sheet for Participation in Research Study.

All interviews were conducted over Zoom at a time that was convenient for participants. The interviews were recorded using the recording capability in Zoom and a digital recorder. The guidelines for qualitative interviews suggested by Creswell (2009), which include having a standard introduction for all the interviews, asking the introductory icebreaker questions first, and then asking the questions that fit the research plan, were followed. In this case the questions, or interview prompts, are those that I developed in consultation with my committee chair Dr. Carol A. Mullen in alignment with Elliott and Clifford's (2014) framework and six components. Additional follow-up questions were asked in order to clarify or expand on the answers, especially regarding specifics about science. The consent for the interview was done verbally per the IRB and is included in the Interview Protocol (Appendix K). Participants received an email with the transcriptions after the interview (Appendix L).

Instrument Design and Validation

The first step for the instrument design is determining the questions. The review of the literature did not yield prompts that fit this study. Some of the studies included questions that fit a Likert scale and did not lend themselves to allowing the participants to describe their personal experience. For example, Settlage et al. (2015) developed the School Science Infrastucture (SSI) survey for use with teachers that includes a rating for "Teachers incorporate community resources into instruction to advance student learning." For this interview, the question has been made more open ended for the principal: "How are families and community organizations included?" Another example is the statement "Teachers at this school have the opportunity to receive ongoing science curriculum professional support" (Lewthwaite, 2004, p. 149). This statement has been rewritten as a more open-ended question, "What professional development in science is available to you?" The introductory questions for the principals were based on research from Lochmiller (2015) and questions regarding rigorous curriculum were based on research from Lochmiller and Cunningham (2019). Questions regarding high standards for student learning were based on Hallinger and Murphy (2013). The quality instruction questions were based on research from Carlone (2010) and Johnson and Dabney (2018). Shrigley's survey from 1980 was used to determine questions for the central office staff member. Wu et al. (2020) was also used to develop questions. Appendix M illustrates the alignment of the questions with the literature.

The interview questions were constructed using the components from Elliott and Clifford (2014). Yin (2017) suggests doing a pilot to develop, test and refine the questions. Since the interview questions did not come directly from a researched source, they were validated through the pilot. The pilot did not indicate the need to change any of the questions, but did provide cues as to when a follow-up question might be necessary. Clarification questions on the types of assessments, acquisition of materials, types of professional development, and grade level work were asked.

Interview Protocol

In the standard introduction the participants were told that the audio was the only aspect of the interview that was being recorded and that they would receive a transcription to check that it accurately reflected their answers to the questions. The final question asked if there was anything that they would like to add about science instruction in their context that was not included in the interview questions. The interview closed with a thank you for their time and sharing of experiences.

The connections between the components, interview questions, and research are in Appendix M. The following tables contain the interview questions. Table 4 lists the questions for principals as related to the components.

Table 4

Interview Questions for Principals

Component	Interview Questions
Introductory	Tell me a little about your experience as an educator, including your undergraduate degree and teaching and leadership experience. Describe the demographics of your school. What challenges do you face in terms of staffing or meeting accountability measures?
High standards for student learning	What are your school goals? How do you communicate them?
Rigorous curriculum	What science curriculum program do you use? How is the science curriculum selected?
Quality instruction	How do you know when you see effective science teaching? What do you do when you see science teaching that is not effective?
Culture of learning and professional behavior	How are teachers included in the decisions of the school? How do you support the professional learning of your teachers?
Connections to external communities	How are families and community organizations included?
Systemic performance accountability	How do you monitor student progress in science?

Table 5 lists the questions for teachers as related to the components.

Table 5

Interview Questions for Teachers

Component	Interview Questions
Introductory	Tell me about your background and experience as a teacher. What aspects of your job make you feel valued?
High standards for student learning	How is the importance of science communicated in your school?
Rigorous curriculum	What curriculum do you use? How do you make decisions about the curriculum that you implement in your classroom?
Quality instruction	What supports allow you to include science in the curriculum? What barriers exist in your efforts to include science in the curriculum? What methods of teaching science do you include in a typical lesson?
Culture of learning and professional behavior	What professional development in science is available to you?
Connections to external communities	How are parents or community organizations involved in your science program?
Systemic performance accountability	How have standardized testing requirements impacted science instruction? How is science achievement monitored?

Table 6 lists the questions for central office science leaders as related to the components.

Table 6

Interview Questions for Central Office Science Leader

Component	Interview Questions
Introductory	What is your background that brought you to this position? Describe the demographics of your district. What are the main challenges that you see in science teaching and learning?
High standards for student learning	How does the district communicate the importance of science?
Rigorous curriculum	How do you plan major curriculum decisions? What do you look for in curriculum? What science materials are currently being used in the district?
Quality instruction	How are science materials purchased and distributed in the district?
Culture of learning and professional behavior	How does your office support the professional development of teachers? What are the successes and challenges the office faces in supporting teachers?
Connections to external communities	How are parents or community organizations involved in your science program?
Systemic performance accountability	How does the division monitor science performance?

Confidentiality and Ethical Treatment of Data

In order to maintain confidentiality of the participants, pseudonyms are used for the names of the schools. Instead of names or pseudonyms, the participants are identified by their position in the school and school name. As an example, Teacher EES refers to the teacher at East Elementary School.

In the storage of the transcriptions, each participant's transcription was initially assigned a letter and number that identifies their role. As an example, a given principal was P1 and the teacher in that same school was T1. This way the participants' identity and privacy were protected, but the relationships in the study were evident. The digital audio recordings were stored in a password-protected VT Zoom account and deleted after the transcriptions were verified by participants. The transcriptions, which include the consent, are stored on a password-protected VT Google drive and will be deleted in 2025. The names of the schools and the key that matches the participants and their transcripts are kept in a locked cabinet in the researcher's office, to be destroyed after three years. Only the researcher has the identifiable participant information.

Data Analysis

The interviews were transcribed using the automated transcription available through Zoom. The transcriptions were shared with the participants to validate that the transcriptions reflected their answers (Appendix L). The responses were organized in an Excel spreadsheet by the participant and the component. For example, all answers that related to the questions about high standards for student learning were on one sheet by participant, and the answers that related to questions about rigorous curriculum were on another sheet.

As stated in Table 4, the transcripts were initially deductively coded using the key words in the research questions (e.g., *decision, action, support, science, central office*) and search terms (e.g., *inquiry, professional development, leadership,* and *partnership*) used for the literature review. These words were not common in the responses. The interviews were then reread many times and deductively coded. The code is "most often a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data" (Saldaña, 2013, p. 3). These codes were then related to a process (planning, implementing, supporting, advocating, communicating, monitoring). Organizing, reading through data, coding, finding themes, integrating the themes, and then interpreting the themes follows the process for validity described by Creswell (2009). The analysis was recursive as the processes, such as planning, were revealed under the components.

The codes across the types of participants were also examined for any themes. As an example, school improvement plans emerged as a theme across the science leaders. Additionally, the codes for the principal and the teacher were compared to determine if there were themes that emerged in a school. The use of time was one of those themes that emerged under the process of planning and implementing. Two science leaders with qualitative research and coding experience coded a sample of responses across the different cases to determine the validity of the coding.

The interviews were the main source of data, but there were also data from artifacts that are in the public domain or are seen as important by the interviewees. This included the school improvement plans and an examination of the school website for curriculum information. The tweets from the school were also examined, but it was harder to determine themes. The number of tweets about science was smaller compared to total tweets. The number of tweets varied greatly among the schools, with SES having three times more tweets than NES. Many of the tweets were retweets and came from one teacher. An examination of the tweets is not included here.

Additionally, the researcher wrote analytic memos. This made it possible to "document and reflect on (the) coding processes and code choices; how the process of inquiry is taking shape; and the emergent patterns, categories and subcategories, themes, and concepts in (the) data" (Saldaña, 2013, p. 41). These analytic memos gave the researcher the opportunity to reflect and write about the process of coding, problems that emerged, and future directions. The memos allowed the researcher to see the frustrations in using the key words as the coding mechanisms, and helped uncover some assumptions around the communication of science. The memos also helped separate the decisions from the best practices in science education.

Summary

This qualitative study collected data from interviews in order to understand the decisions and actions of elementary principals to support science education, and compare those with the decisions and actions of teachers and the central office science staff. The interview questions were based on the six components from Elliott and Clifford (2014). Interviews provided a more complete picture of the actions and decisions that the participants make in their support of science instruction. The interviews were transcribed, coded, and analyzed within the core components and process of the framework. The potential synergies among the principals, teachers, and central office staff were investigated.

Chapter 4: Data Analysis and Findings

Introduction

The purpose of this qualitative study was to investigate the decisions and actions of elementary principals that support science education. Additionally, the decisions and actions of the principals were compared to the decisions and actions of the teachers to determine the synergies in the school that support science. The actions and decisions of the central office science specialist was also examined to determine how those actions and decisions impact the school. The primary research question for the study was, What decisions and actions of elementary principals support science education? Two secondary questions were (1) How are the decisions and actions of elementary principals impacted by those of central office science leaders? (2) How are the decisions and actions of elementary teachers impacted by the principals?

Participants in the research represented three elementary schools: East Elementary School (EES), North Elementary School (NES), and South Elementary School (SES). Only East Elementary School had recorded an increase in the science assessment scores from spring, 2017 – spring, 2019. All of the schools were Title I schools and involved in the after-school STEM program. The demographics of the schools are in Table 7.

Table 7

Demographics of Participating Schools

School	Economically Disadvantaged	Students with Disabilities	English Learners
East Elementary School (EES)	50%	10%	45%
North Elementary School (NES)	71%	10%	69%
South Elementary School (SES)	86%	11%	78%

All the participants were working in the school system during SY 16-19. One principal, one assistant principal (AP), three teachers, and the central office elementary science specialist

(CO specialist) were interviewed. Each teacher represented a different school and was recommended by their school principal or AP. Table 8 is a description of the educational experiences of the participants.

Table 8

Description of Educational Background and Experience

Participant	Description of Educational Background and Experience
CO specialist	Her work in inquiry and teaching inquiry to teachers brought her into administration after being an elementary and middle school teacher for 25 years.
Teachers	All the teachers were classroom teachers during SY 2016-2019. Their experience ranged from five – 18 years. All of them had taught only in the one school. Their undergraduate backgrounds included a liberal arts major with a focus on science and mathematics, special education, and reading. One teacher taught third grade, and two were fifth-grade teachers.
School leaders	Both school leaders had previous elementary teaching experience, other administrative experience before their current position, and were instrumental in implementing the after-school STEM program. One had a degree in English and the other a degree in reading.

Data Analysis

The interview questions were designed to uncover aspects of the six components of the framework. The analysis of each component begins with a description of the component, a summary of the questions, and a claim from the analysis of the data. This is followed by evidence from the interviews and other documentation for each of the six processes. A table at the end of the section indicates which processes were apparent from the interviews of the participants and public documents. Under each component a theme emerged from the interviews. A figure has been added to show the processes that each group of stakeholders exhibited for that theme. This is followed by a synthesis of the synergies among the various stakeholders.

"High Standards for Student Learning" (Elliott & Clifford, 2014, p. 13)

This first component under the framework reflects the academic expectations for all students. The expectation is that school leaders ensure that there are high standards and school goals. The questions that reflected this component focused on school goals and how the importance of science is communicated. School personnel agreed that the state science standards define the high standards for student learning. There were different perspectives in how the school goals were developed and communicated.

The interviews were analyzed for evidence of the processes under high standards for student learning. The presentation of this evidence follows.

Planning. The state science standards were mentioned by all school personnel as the standards that defined the curriculum and instruction. AP NES was explicit when he said, “We follow the science standards.” Principal SES made the connection to all the teachers and students when she said, “We all are responsible from kindergarten through 5th grade for teaching the science standards to every one of our learners.” Teacher SES said, “And then we would just look at the standards.” Teacher NES included part of their process: “So it starts at the standards level, and then we do a pacing guide that breaks it down for us.” Teacher EES added a student component when she said, “We utilize the science standards from the Department of Education, and we kind of cater it to our students.”

The school leaders added the school improvement plan as a document that illustrated the school goals. Principal SES included the development of the goals in her comment, “So the school goals are surrounded by the school improvement plan, which is developed by the entire staff and all the stakeholders in it. So stakeholders meaning the parent teacher organization, the families themselves.” Principal NES spoke specifically about increasing achievement: “We have our school improvement plan where we have areas of focusing goals in terms of improving our reading achievement and our math achievement and certain percentages and scores.”

Implementing. Both school leaders mentioned the implementation of the school improvement plan. Principal SES indicated how action items were used when she said, “So there's opportunities for everybody to start to look at the progress of the specific goals, update them and develop action items as a result of them.” AP NES mentioned the work in meeting the needs of the students, such as food insecurities and their social and emotional health, as necessary to meet the goals. He said, “The way to meet the needs or to have growth in certain academic areas, it's not just drill down and just focus on math. It's also that community school approach to focusing on the whole child.”

The teachers implement the high standards through their work on curriculum and instruction. The evidence for the teachers’ implementation will be discussed in the components of rigorous curriculum and quality instruction.

Supporting. Both school leaders mentioned the challenges in supporting high standards. AP NES reflected on the challenges in his school population, and how working to meet so many different needs was necessary in order to meet the goals. He mentioned after-school clubs and connections as ways to support the school goals: “Some of the things that we do, for example, are our after-school STEM program provides them with free after-school coding and science opportunities and activities” and “that really makes a big impact to them.” Principal SES mentioned, “When you are tasked with supporting the needs of every learner, that requires additional work as an adult practitioner.”

The CO specialist offered support for the high standards with the lessons and professional development (PD) that were provided to teachers. The evidence for this support will be discussed under rigorous curriculum, quality instruction, and culture of learning and professional behavior.

Advocating. This particular process was not evident in the interviews as related to high standards for student learning.

Communicating. The communication of the goals for science learning and the importance of science in the school were not consistent among the stakeholders. Both school leaders mentioned the school improvement plan as a mechanism for communicating their goals. Principal SES said, “Then they're communicated. You know something as simply being placed on our website, but certainly discussed.” She added that the school improvement plan was shared at meetings with parents and staff because she wanted them to see that it “is a living, breathing document, and we review that on a quarterly basis. It's also part of department and grade-level meetings.” AP NES commented, “We have our school improvement plan where we have areas of focusing goals in terms of like, improving our reading achievement and our math achievement and certain percentages and scores.” He added, “Also I would say our next main focus is … science.”

The other stakeholders did not share the school improvement plan as the evidence for the importance of science, and they looked at communication around the importance of science differently. Teacher SES interpreted the inclusion of science in the schedule and that they had a science committee as evidence that science was important. She said, “So, one element of that is we devote time to science in our schedule, although it does sometimes alternate with social studies. And we've had a science committee pretty much as long as I've been at SES.” Teacher ESS looked at the additional science-related programming as evidence: “…really through STEAM (Science, Technology, Engineering, Arts, and Math). Our school was a part of the ‘Code to the Future’ initiative.” The Teacher NES admitted that there has not been communication on the importance of science by saying, “There was probably a gap a couple years ago, where the importance of science wasn't communicated as much.” She added that “it kind of seemed as if reading and math were the frontrunners, and from the lower grades to fourth grade, push reading, push math, and fourth grade push social studies.”

From the central office level, communication of the importance of science differed by organization level of the school district. She stated, “From our supervisor level it's always communicated, but above the science supervisor it's never communicated. I have never heard anything about science come from the county level.”

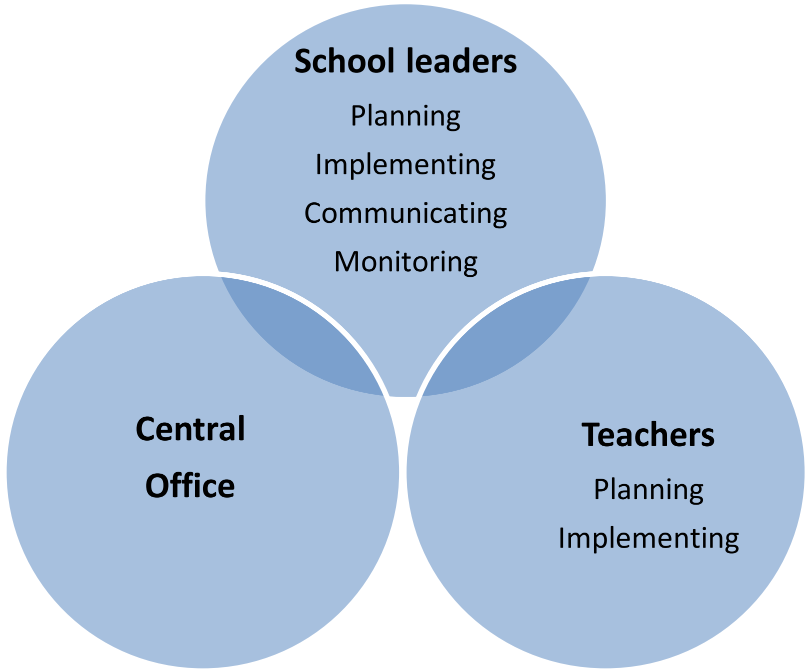
Monitoring. Principal SES gave an example of monitoring the school improvement plan where everyone had opportunities “to start to look at the progress of the specific goals, update them and develop action items as a result of them and then provide check-ins and progress reports for everyone.”

The school improvement plan was mentioned by both school leaders as evidence for high standards and the communication about the importance of science, and some details about the school improvement plan are available on the schools’ websites. The school improvement plan for NES from 2018-2019 included an action plan for science that had the STEM teacher co-planning and co-teaching and all classrooms utilizing the STEM lab. The current school improvement plan for SES does not include any current science goals.

The school leaders included examples of planning, implementing, communicating, and monitoring around the school improvement plan. Though the teachers did not mention the school improvement plan, the principals did give examples of how teachers were included in the planning and implementing. The science staff in the central office was not reported as being a part of the school improvement plan process. Figure 1 shows the relationships of the processes among stakeholders in the school improvement plan.

Figure 1

Relationships of Processes among Stakeholders in School Improvement Plan



Note. The planning and implementing for teachers was evident from the school leaders, but the teachers did not mention it.

Table 9 shows which processes under high standards for student learning were evident from the interviews.

Table 9

Processes under High Standards for Student Learning by Stakeholder

Processes	CO	AP-NES	P-SES	T-NES	T-SES	T-EES
Planning		X	X	X	X	X
Implementing		X	X			
Supporting		X	X			
Advocating						
Communicating	*X*	X	X	*X*	X	X
Monitoring			X			

Note. An italicized *X* denotes that the stakeholder indicated that this process is not positively supporting science.

Synthesis. School leaders are responsible for setting the expectations (Grisson et al., 2021; Lewthwaite, 2004), and that was evident across the school personnel as they identified the state science standards as important in planning the high standards for student learning. The school improvement plan was identified by the school leaders as a vehicle for planning, implementing, communicating and monitoring the school goals and communicating the importance of science. The school leaders included teachers in the planning and implementing of the school plan, but the teachers did not mention the school improvement plan. Although the school leaders and teachers did not mention the same action as representing the importance of science, the decision to include science in the schedule or support after-school activities are decisions that school leaders make.

"Rigorous Curriculum" (Elliott & Clifford, 2014, p. 14)

The rigorous curriculum is "what" is being taught. The expectation is that school leaders are "knowledgeable about and deeply involved in the school's curricular programs' (Elliott & Clifford, 2014, p. 14). The questions that reflected this component focused on the curriculum that was being used. The literature review described content, inquiry, and NOS as three important aspects in science curriculum, but only inquiry was mentioned in the interviews.

The interview responses primarily addressed the resources that they have for teaching the content. The standards were used to plan the rigorous curriculum, as evident in the analysis above. During the SY 2016-2019, there was not a reliance on a textbook for teaching the content, although all the teachers mentioned a new tech book that is currently being used (Teacher EES, Teacher SES, Teacher NES). The actual curriculum was designed by teachers using resources provided by the county and that they created.

In order for the students to participate in an inquiry-focused classroom, teachers need to have science materials in order to conduct investigation. The acquisition and organization of materials was mentioned in the responses. Having the materials was seen as a support to teaching science. However, not all the teachers reported that it was easy to get the materials.

The interviews were analyzed for evidence of the processes under rigorous instruction. The presentation of this evidence follows.

Planning. Textbooks were not used for the planning of the curriculum. AP NES indicated, “We don't follow a textbook or like a basal like reader for reading or, like you know you go page by page, which is frankly less engaging is a very outdated practice, especially nowadays.” Teacher NES shared a similar statement: “We do not have a set named curriculum. We have an online tech book, but we do not have a chapter by chapter, here are the materials, here's everything you need curriculum built in in our county.” Teacher SES said, “I was never really a textbook teacher in elementary school, in any subject really.”

There were three models of planning that teachers shared. One was a more departmentalized process: “I was the math planning person for three years and then I was the writing planning person for three years. And so I, we sort of relied on another team member to do the science planning” (Teacher SES). She added that since COVID, “we're really trying to break down that habit and do more collaborative planning so that everyone has equal opportunity to have a voice.” She continued, “And now we sort of look at everything together and we decide the pace of everything, what topics do we want to cover when.” That collaborative approach was also described by Teacher NES: “We will meet and plan and say, these are the SOLs. This is what we need to hit. This is ABC. And then we all kind of take a little piece of it and bring it together to make the final product." She continued to describe the roles in the collaboration:

> So one time it might be someone's job to find readings for the kids to do, while someone else might be in charge of finding a couple of experiments. Someone else might be the creator of the material that the kids are going to work on.

Using this process meant that she was not planning on her own.

Teacher EES described how teachers worked together to create a repository of resources that allowed them to take a "holistic approach of our students and to our students, and think about how they will best receive the information, and how we can best connect it to our students."

Teaching in an inquiry-based way requires materials, and the types of materials needed were considered by the central office in their curriculum planning: The CO specialist explained, "Science asks for a lot of equipment and supplies. At the elementary level it's not as much equipment, but when kids can use equipment, they feel more like scientists." The district provided the equipment to the schools and wrote that equipment into the lessons. She said, "If we bought supplies, durable equipment for second grade, we would write lessons that would go right with the equipment so teachers could use it," and added that consumable materials had to be materials that teachers would already have in the classroom, to minimize the need to go out and purchase them. Principal SES also recognized the resources that were available "so that elementary school teachers could teach science utilizing all the information that the subject area leader had and that curriculum is really selected truly by the county science department."

Implementing. The implementation of curriculum is related to quality instruction, and is analyzed in the quality instruction section.

Supporting. One support for inquiry is the access to materials for the students to use. The central office specialist spoke to providing materials for lessons: “So, we needed to be sure to, number one, supply schools with all the equipment they would need to give the lesson (and) to teach the teachers how to use the equipment.” Teacher SES explained the organization of the materials: “So we have shelves of different science topics and materials that would go with it so you have like a weather tools bin, then you might have a soil bin, fossil bin, rock samples bin.” She also mentioned that “the system makes sense, so that teachers have a lot of resources to be able to teach, whatever they're doing in science, in a hands-on way.” Teacher NES gave an example of both having and not having the necessary materials. Although she had an electricity bin that included many of the materials, it did not include a nail or bolt for the electromagnet, so she had to go out and buy the nails. She said that “not very many consumable materials are provided, they're mostly non-consumables that we could use again and again.”

All of the teachers could get consumable materials for their classrooms. Teacher SES said, “So, if there's something we need, even if it's food to do something within science, our principal will make it happen.” That principal support meant that Teacher SES did not “feel like we're always going into our pockets to purchase a lot of these things.” Teacher EES explained the process as, “We bring it up to our administration first and if there are funds, or our administration that we have, they're really great about just saying ‘Yeah, price it out, send it to our bookkeeper.’ ” Teacher NES had a difference experience in that she found it harder to get consumable materials: “We do have funds, especially with being your Title I school and the STEAM lab to go and get some materials, but most of the materials are the non-consumable kind.” When asked what she had to do when she wanted consumable materials, she described a procedure where she would have to do the research to find the object, find a link to order it, bring that to the bookkeeper, and then get it to the school.

The teachers at NES and SES both talked about having access to a room that is set up for teaching science. Teacher SES said, “We have a STEAM lab at our school. We also have that space to bring students in to do experiences with them, or to do maker space stuff with them, or computer science.” Teacher NES also takes her students into a “separate classroom. It holds all the science materials. There's tables. There's plenty of space where every group has their own area that they can work in and not be disruptive or disrupted by those around them.” At NES the students go to the STEM room once a week. “They love going there. They love doing the activities, the experiment, or the investigation that the STEM teacher has set up for them. And I love that they love it.” She described the STEM room as the students’ “time in the week to go and do investigating, and science in a different way.”

Teachers mentioned the central office person as being a support. Teacher SES described the relationship between the school and the central office: “The science committee is led by the science contact, so that's a representative who goes to district monthly meetings to get information from the district to then share with the committee members and grade levels.” She went on to give an example of activities at those meetings that was supportive. She talked about looking at the curriculum across grade levels “and looking at--if I'm a third-grade teacher--what do they learn in second grade and what do they learn in fourth grade and how can I do that bridge so getting some of that vertical articulation.” Teacher EES, who is a science contact in her school, said, “We can always, as the science contact, reach out to district and ask them any questions that grade levels might have.” She also spoke specifically to how she could get resources if there was something missing for the standards: “That’s another thing where you know we can let our district science contact know that information, and she really works as hard as she can to try to get us everything that we need."

Advocating. One aspect of advocating is making sure that there are opportunities for the teachers to work together on the curriculum. Both school leaders indicated dedicated planning time. AP NES said, "In terms of planning they have at least about 4 hours a week that they're able to plan and collaborate together to design lessons." He added, "The purpose of that is really in so many ways to have alignment across the grade level, have common formative assessments to be able to improve and work on what they're developing." From the collaborative planning mentioned above by Teacher NES, some of that is used for planning science. Principal SES stated, "So they all had collaborative learning time together at a weekly basis, so that they could actually plan with their co-teachers their different lessons within science and ensuring accommodations for EL learners or special education learners."

Communicating. Teacher EES mentioned her role as a science contact as a conduit for the communication about curriculum from the division. She said, "As a science contact it's really my job to make sure that I'm passing along any of the changes or anything that I was relayed at the science contact meeting to the specific grade levels, to all the staff that it's really applying to." Principal SES also mentioned the scheduled meetings that school-based science contacts had with division science staff. She said that these meetings "provided information about curriculum, instructional practices, resources you could utilize to teach science" and how that information would come back to the school staff, and by doing so, "we could create teacher capacity."

The school division and school websites are also used as a way to communicate the curriculum. The division's science website is where teachers can access links to Google sites and science curricular resources at every grade level. Each school also has a website with grade-level webpages. Table 10 summarizes the science curriculum resources information on the grade-level pages at the schools' websites.

Table 10

Science Curriculum Resources on School Websites

School	Grade Level	Summary of Science Curriculum Resources
EES	K-5	Little curricular information is on the websites. Grade 4 includes science vocabulary. Grades 2 and 5 had a Google site that required permission.
NES	K-5	Curricular science content information is available in documents that can be downloaded in K-3. Science curriculum is not listed for grade 4. Quarterly topics are included for grade 5
SES	K-5	Curricular science topics are included on nine-week calendars for grades K, 1, 3 and 4. Science topics are included for grade 2, but science is not included every week. Grade 5 has a Google site that requires permission to access.

Monitoring. The process of monitoring curriculum was identified only at NES. Teacher NES said that the start of the 2019- 2020 school year "our admin said to all grade levels across the board, okay, science lesson plans must be turned in when you turn in reading and math." It is not evident in the interview if there was any follow up from the administration regarding the lesson plans.

The importance of having materials was a theme in the interviews from the teachers and the central office specialist. The support from the principals was recognized by the teachers, but it was not reflected in the school leader interviews. Figure 2 shows the relationships of the processes among stakeholders in the acquisition of science materials.

Figure 2

Relationships of Processes among Stakeholders in Acquisition of Science Materials

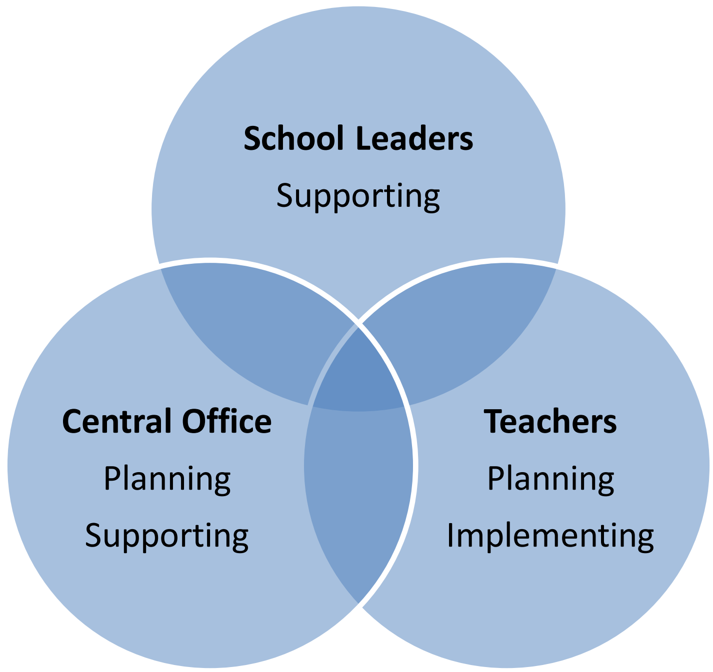


Table 11 shows which processes under rigorous curriculum were evident from the interviews.

Table 11

Processes under Rigorous Curriculum by Stakeholder

Processes	CO	AP-NES	P-SES	T-NES	T-SES	T-EES
Planning	X	X	X	X	X	X
Implementing			not analyzed for this component			
Supporting	**X**	**X**	**X**	X	X	X
Advocating		X	X			
Communicating	X	X	X			X
Monitoring		**X**				

Note. A bolded X indicates that evidence for this process is in another stakeholder's interview.

Synthesis. All of the stakeholders were involved in the planning and supporting the rigorous curriculum. The school leaders advocated for and supported the teachers by dedicating planning time in the schedule and providing processes for the acquisition of materials. One way that school leaders communicated the science curriculum was through the websites, although the information was limited. Science materials and spaces for experimentation were important for teachers and the CO specialist. The central office supported the schools by providing curriculum resources and materials to schools.

"Quality Instruction" (Elliott & Clifford, 2014, p. 14)

Quality instruction can be described as the "how" or the pedagogy. It is the "effective instructional practices that maximize student academic and social learning" (Elliott & Clifford, 2014, p. 14). The expectation is that school leaders understand quality instruction and support teachers in ways that improve instruction. The questions that reflected this component focused on the activities and methods in the classroom and the support of teachers when quality science instruction was not taking place.

The time to teach science is an instructional concern in the literature and time was mentioned by all the stakeholders. Being able to weave in other disciplines with science, particularly language arts, is a scheduling method that gives time for science and improves science achievement. Using other instructional staff, like a STEM teacher, can also support the teaching of science. When asked about the science lessons, the school leaders talked more about the level of thinking and engagement aspects of the lessons. The teachers mentioned specific activities.

The interviews were analyzed for evidence of the processes under quality instruction. The presentation of this evidence follows.

Planning. The CO specialist spoke to integration and time in the planning of the curriculum that was developed centrally. The lessons implemented "an integrated approach using literature as our base, so that teachers would be more likely to teach it. They could use their book as part of their reading, and then they could carry into the science from there." She also mentioned integrating as much as possible into "STEM, knowing that STEM is important for students, it is important for their futures. It's important for their success in school. In other subject areas besides just science." Understanding that a STEM lesson would also include reading and math "would help teachers to realize that …to do a STEM plan or activity was worthy of their time and of the teaching that needed to be done." She added that "time is of the essence. We can't give teachers a long lesson plan that's going to take days and days and days to teach." She described the lessons as needing to be "strong, powerful" and "fun and engaging and cross curricular."

All of these schools are Title I schools and have teachers who specifically support English Learners (EL). These teachers are included in the planning for the lessons. Teacher SES said, "We have one to two EL teachers on every team. I feel like they are very valuable in the content areas, because the vocabulary can be so high level and so specific." She gave examples of what the EL teachers do, including "bringing the vocabulary in and a seven-step format" and "seeing it from an EL lens to make sure that we're keeping pictures realistic and providing hands-on opportunities for students to really experience and see the scientific concepts." Principal SES added, "So they all had collaborative learning time together on a weekly basis, so that they could actually plan with their co-teachers their different lessons within science. This was important to ensure "that accommodations for EL learners or special education learners, or students who are reading multiple grade levels below standard were afforded those accessible opportunities." AP NES also talked about the EL support teachers who participated in the planning. He also mentioned the special education case managers and said, "We have 4 full-time case managers. So, they, along with the classroom teachers, have time to plan daily."

The collaborative teams that planned the curriculum also planned the instruction. As Teacher SES explained, “Some people divide up by week or by standard and partner up on different pieces, or even, people take certain elements of the unit like I'm going to build the assessments, you're going to do the slideshow. You're going to do the vocabulary and sort of everyone has a piece to contribute to the whole.” Teacher EES and Teacher NES also described collaborative planning.

Implementing. In order for teachers to implement science lessons, they have to have time for the science in their schedules. Although all the teachers said that they had time to teach science, that time was described differently. Teacher NES said, “It is built into our schedule. We have it at the same time every day” and then she added, “It's always been that way. It just was not always a priority in some classrooms. It's always been a priority in fifth grade though.” Teacher SES shared that “in most grade levels, we do give it time anywhere from 30 minutes to an hour depending on the grade level. I think that's important first because that is not the case everywhere.” The time issue also came up for Teacher EES, “So we do science every single day.” She added, “We do more towards the end of the quarter. We'll take a week or week and a half off of science, and then we'll implement social studies.”

Since the state assessment for science happens in fifth grade, there can be tension between the fifth-grade teachers and the lower grade teachers. Teacher SES spoke to this tension. Since the fifth grade has the assessment, those teachers “feel a lot of pressure of like, you know, fourth grade maybe doesn't spend as much time on science.” That results in the fifth-grade teachers having to “reteach fourth grade and teach fifth-grade concepts and so I feel like that maybe not seeing the value from K all the way up to five is a barrier.” Teacher NES also said that she didn’t think that the fourth-grade teachers taught as much science. They had a system where “one teacher devoted their time to teaching fourth-grade-only material, and we did kind of like the rotation of sorts, where students would be retaught, but most likely taught the material that was from the fourth-grade science curriculum.”

Teacher EES also described a difference between fourth and fifth grade: “Fourth grade looks a little bit different. They do more social studies, and then they have kind of like the flip-flop of us.” She did not see this schedule as a problem and said that “the fourth graders do get access to all of the science curriculum that they need.” When they got to fifth grade they spent time “reviewing fourth-grade curriculum through projects, and just kind of end-of-the-year review as well to get them ready” for the state assessments.

Both of the school leaders spoke to the thinking and engagement aspects of the science lessons. AP NES said that he looked for students that were “…highly engaged, they're focused, they're asking questions, they're applying what they're learning. It's not just a very passive experience; it’s an active experience.” He added, “So, more hands-on, more authentic, the more that they're applying and they're asking questions and thinking, the better.” He also included vocabulary when he said, “So the more hands-on and authentic, with visuals and pictures and vocabulary focused, and using those things that they can do, the better.” Principal SES said successful lessons were ones where “you are able to identify the level of rigor. When students are doing a lot of the communicating, when teachers are facilitating that learning, and students are able to share with you what they're doing.”

All of the teachers mentioned experiments and hands-on experiences when they talked about the methods they use to teach science. Teacher SES shared how behavior management impacts the hands-on experience: “I would say it's a lot of ‘I do, we do, you do’, or maybe some experiments, but I feel, personally, a lot of my experiments became demonstrations because it was just stressful to control all the kids doing this stuff." Her comments infer a level of personal growth as she goes on to explain, "So, they would maybe do some of the documenting of the observations, but are they going to be the ones pouring the stuff and everything. I don't think I had a ton of trust in eight-year-olds doing that, back then."

Teacher NES focused on the lack of background knowledge for her students. Her lessons focused on "building background. A lot of these kids don't have the background for some of this science academic vocabulary. So building the background, finding a way to connect or relate it to their life." She continued with the vocabulary: "Definitely vocab, multiple ways, multiple modalities of teaching it and showing it and representing it." She also talked about the needs of hands-on and gave the example of students learning about static electricity by rubbing a balloon on something and seeing where the balloon would stick.

Teacher EES described the lessons in this way: "We like to use a mix throughout the entire unit. We like to use a lot of videos. We like to use a lot of interactive activities and a lot of different exploration activities." Students work independently on activities that have been preselected by their teachers: "Some days the students are just completing interactive activities on their computers. Sometimes they're off just working on their playlist where again they can watch videos. They can try creating something, they can do more exploration." She added, "We like to just kind of introduce a vocabulary after doing that gallery walk, and then lots of experiments." Using hands-on was seen as a method to help students remember content: "We try to get their hands on materials as much as possible, just because that tends to connect to their brain a little bit more."

Teacher SES spoke to a barrier to teaching science. She said, "I think one piece of it is maybe not realizing the importance of varying your teaching style when teaching science." She gave an example that could be any content area: “Sometimes it can become very much like, here's a slideshow, let's go through all these pictures, let's watch a video and take a quick quiz and like that. That's it. That's science.” She recognized that this was not impactful for teaching science. She added, “We've seen that it's having a negative impact on fifth grade, because fifth grade is the only grade that has the … test.”

Cross curricular and integrated lessons did come up in the responses. Teacher SES mentioned lessons from the central office that “they suggested that you teach with certain units that had cross curricular connections.” AP NES said, “So we really do a lot of authentic STEAM-based activities for math and science.”

Supporting. Having time to teach inquiry-based lessons is important for implementing science. It is also part of the school leaders’ support for both the planning and implementing of science. AP NES talked about the daily schedule that allows teachers to “have an hour of common planning, give or take, sometimes that's 45 minutes, every single day and so that's really critical.” He also added, “Science has been really a priority for us, but also, we do a lot of cross curricular focus, so they can weave it into their reading time at certain moments. But obviously mathematics and things like that, too.” He also mentioned the schedule for teaching science: “We really do have that emphasis on daily science, because it really is absolutely critical.” Although Principal SES didn’t specifically mention the instructional time for science, Teacher SES spoke about the importance of time. Master scheduling is a principal’s responsibility.

CO specialist spoke to the lack of support for science. She said, “The first thing teachers complain about is time. They can't teach science because they simply don't have the time.” The placement during the day also matters when looking at the time allocated for science. She explained, “It's often scheduled before or after recess or lunch. And it wasn't even a full 30 minutes' worth of time, and it's every other day if it is at all." She also saw that time was not the only reason it wasn't taught. She added, "But many times we see that science is not taught because of time constraints and because it's not encouraged to be taught."

She also talked about how integrated lessons could support science and gave an example of how using books like *The Three Little Javelins*, *The Big Bad Shark*, and *The Three Little Pigs* could be used to teach biomes and "how those biomes affected the way those animals lived and chose their housing, and that goes back to Native Americans … so you know once we could show teachers connections to their other curriculum, we had a lot of success."

Advocating. One way to advocate for science is to make sure that science is actually taught on a regular basis in every classroom. All of the teachers, as evidenced in the implementing process, spoke to the challenges of teaching science in fourth grade. Principals have a role in advocating for science every day and at every grade level.

Communicating. This particular process was not evident in the interviews as related to quality instruction.

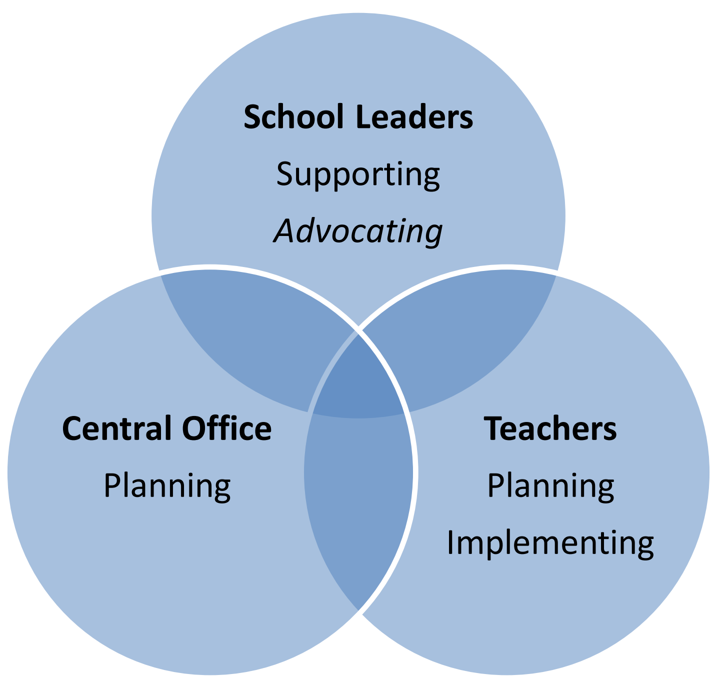
Monitoring. The school leaders spoke to monitoring science instruction. Principal SES talked about walkthroughs and how those gave her and the assistant principal a clear vision of what they expected and "we shared with staff that this is what we're expecting to see for teaching and learning experiences within specific content areas." She mentioned working with teachers who were struggling teaching science and providing opportunities for coaching to teachers who were not as effective. This coaching "could come from somebody from the department of science, that coaching could come from our school-based instructional facilitator, and it could come certainly from that assistant principal and myself." AP NES talked about "just having meetings with teachers and kind of talking about better ways, that they're able to engage students, that they're able to make it cross-curricular and connect different subjects." He added, "So when they're collaborating, working together, we are able to see that growth in that improvement."

The literature review indicates that time for teaching science is important but is not always available for instruction which was also revealed in the interviews. The CO specialist mentioned the importance of time in the planning of the lessons. The school leaders supported science time in the schedule, but the actual implementation of the time was mentioned differently by the teachers. As a result, there isn't the accompanying advocacy for science at all grade levels.

Figure 3 shows the relationships of the processes among stakeholders with time.

Figure 3

Relationships of Processes among Stakeholders with Time



Note. The italicized process for advocating indicates that it is not evident in support of science.

Table 12 shows which processes under quality instruction were evident from the interviews.

Table 12

Processes under Quality Instruction by Stakeholder

Processes	CO	AP-NES	P-SES	T-NES	T-SES	T-EES
Planning	X	X	X	X	X	X
Implementing		X	X	X	X	X
Supporting	X	X	**X**			
Advocating		*X*	*X*			
Communicating						
Monitoring		X	X			

Note. A bolded **X** indicates that this process is evident in another stakeholder's interview. An italicized *X* indicates that this process is evident, but not in a supportive way for science.

Synthesis. As evidenced in Table 12, the processes of the school leaders were the same. Planning and implementing were the processes that the teachers had in common. Those two processes by the teachers benefitted from the support of the school leaders in including time for science in the schedule. Time was mentioned by all the stakeholders, and the instruction is designed to fit into the time constraints. The time for science across grade levels was mentioned by the teachers and the CO specialist. The advocating for time across all grade levels every day was not evident. The school leaders' work with teacher quality shows evidence of monitoring instruction.

"Culture of Learning and Professional Behavior" (Elliott & Clifford, 2014, p. 15)

The culture of learning and professional behavior reflects the building of a professional community that promotes student learning and professional practice. The questions that reflected this component focused on teacher inclusion in decision making and in supports and offerings for professional development. The stakeholders shared a number of examples of the communities for professional learning.

The interviews were analyzed for evidence of the processes under culture of learning and professional behavior. The presentation of this evidence follows.

Planning. Principal SES described herself as a servant leader and included teachers in all the decisions. The school leadership team and the teachers write the school plan. She said, “We divide the actual teams themselves in order to look at that information and disaggregate it, analyze it, and then come up with what they believe to be best practice to support the actual area of deficit.” The staff then decide on actions that they would like to take. They monitor those actions and tweak as necessary. She added, “That's how you create the opportunity for people to be invested in the work. Because what you build, you will not destroy, you will tweak and modify.” She also mentioned how she tied professional development to the teacher performance standards of professional knowledge and instructional practices: “Depending upon the area of the goals, they had already established themselves, we would say, Okay, what is your professional learning area that you'd like to have?” She also said, “I think it's really important that you take structures that you … already have in place like the evaluation process and tie that into that professional learning piece and tie it into the school improvement goals.” She added that the teachers decide on the topics for their collaborative learning. For example, maybe the teachers would decide on “vocabulary instruction--that's where we should focus our instruction. Or we should focus our energy on inquiry-based instruction. We should focus … on connecting literature that's related to science concepts.” Each year teachers would choose the action item and “all the staff members who were really teaching science would be the ones who would make those decisions.”

AP NES also said that the teachers were “really part of everything that we do. We decide things as a school.” When new programs are suggested, the teachers make the decisions about whether or not the school will implement the program. The school followed that process when they decided to offer the after-school STEM program. The teachers were asked if they were interested in the program. AP NES explained, “Do they want to be engaged in that? If we get the buy-in, then we kind of explain it and roll it. But they always understand there's a bit of training that comes on with it.”

Implementing. The CO specialist provided PD to individual schools if there was a principal request. CO specialist said, “I came to faculty meetings when principals asked, and gave professional development on teaching science. Cross grade level, some basics.” She modeled the type of instruction that was expected in the PD that she offered: “I gave them basic inquiry lessons so that they would know how to use inquiry and I would do that by using inquiry as I taught them.” Principal SES also mentioned the central office: “When we started talking about our science instruction and ways we can increase our science student achievement, we reached out to their offices to have them really work with our teachers and provide professional development.” She also talked about working to meet the needs of the teachers. “It could be, I'm not really familiar with how to utilize that resource, I'm not understanding the standard, I'm not quite sure-- It could be just lack of knowledge within their content like the standards themselves.”

School personnel also provided professional development. Teacher EES led PD in her school on the new technology book. Principal SES had teachers provide PD and that was “an opportunity for them to have teacher leadership opportunities.” Depending on the topic, she added that sometimes “we have outside entities come in and provide that professionally.” Principal SES also talked about creating a mechanism for learning within the school community. There was a structure for teacher to say, “I'm working on this and I'm looking for somebody who would be willing to let me come in and visit the classroom and see like whatever it was, and staff would have an opportunity."

The implementation of PD happened at various times. Some PD was done during the school day (Principal SES, AP NES, Teacher EES). Some PD was offered by the school and held after school (AP NES). There were also professional development days that were offered by the school system and teachers could choose the sessions (CO Specialist). Teacher SES said, "There's often a lot of options and some of those may correlate with science. And it's the teachers' choice to go to them." Teacher NES exemplified the challenges in the PD when she said, "I try to do some things when I have some time, or do some research, or read some articles when I have time. But I don't take advantage of the science PD that is offered." CO specialist indicated, "It was always teachers making the time for the professional development. There were times that we had one or two teachers show up in a county our size that's kind of discouraging." The CO specialist did report that teachers appreciated having an opportunity to make or receive the materials that they need to teach a lesson. She described the structure: "We teach them some lessons that they could teach and then they could make the supplies they needed, like, cut outs, or posters or, you know, interactive posters or things like that and that was a huge hit." She shared that the "teachers love that because they walked away with everything they need for that lesson, and they felt comfortable teaching that lesson." Teacher NES echoed that when she said that on PD days she looked for sessions on "how to, if we have certain materials, how to implement them into your classroom."

An unexpected form of PD came from the teachers who worked in the after-school STEM program. Principal SES described the impact on the teachers who worked in that program:

> Because individuals who went to training … provided those lessons, those activities within the after-school program then started to shift their practice during the day and their regular science instruction because they became comfortable with them, with the structure of the delivery, and before it may have been very driven by facts or by content. You know, they may have provided visuals and had some type of interactive 'notebook' or something, right? But then it became more open-ended. It became more conceptual understanding versus procedural understanding and that shifted for the teachers who were in the program.

AP NES described something similar:

> It enables them to see more of what the students are able to do. How engaging, exciting it can be and then that leans into when the classroom of lessons that they want to teach, research they want to use whether it's kind of like coding and things that are like robotics and such, you see more of that in the classroom because since we've started doing some of those things after school.

He added, "Now, can I definitely say that these things would not have been present in the classroom if we did not have the after-school STEM program? Not definitely, but I strongly believe they did that." Teacher ESS taught in the program, and she described her experience. She mentioned that in the after-school program she was more of a coach, and she found that she "brought that [coaching] into the classroom a little bit more, and not just within science, but across all just to try to give them more of that accountability and ownership."

Supporting. One support that Principal NES provided for the PD was to schedule it during the day during Collaborative Learning Team (CLT) time for planning. He also gave an example of "lunch and learn" with lunch provided at the training. He added, "We also have professional learning days where teachers can sign for different sessions. But we also provide things after school as a staff."

Principal SES talked about a process where division leaders and selected contacts from the schools would meet. The school contact "would be provided information about curriculum, instructional practices, resources you could utilize to teach science and then they would come back and share that with staff, so that we could create teacher capacity." However, Teacher SES mentioned that it was difficult for the division to provide extensive PD because the division doesn't "have a lot of bodies to support science."

Advocating. This process was not evident in the interviews.

Communicating. The science contacts have a role in communicating professional development opportunities and other resources. Teacher EES said, "Then a lot of the times we do get emails from the actual lead of the science program for the district**."** Those emails "provide opportunities for PD, for grants, for updates, for performance assessments and everything."

Monitoring. AP NES talked about the monitoring of the PD in terms of how the actions were working for the students. He said that during the implementation they are constantly receiving feedback. They are asking themselves, "How does this work for our students? How does this work with the way that we do things? How can we find time to fit this in?" The leadership then responds to the feedback. He summarized as follows: "They're really a part of that process from the beginning to end, because without that, it's impossible to have any initiative be effective."

Principal SES mentioned that after the teachers decided on their action items, as described under the process of planning, "then we collectively reach consensus, and we write it down. And then we monitor that which we write. And we hold each other accountable to that work, and that's how we operate."

Professional development was a theme that came from the interviews. School leaders and central office overlap in the processes. Figure 4 shows the relationships of the processes among stakeholders in professional learning opportunities.

Figure 4

Relationships of Processes among Stakeholders in Professional Learning Opportunities

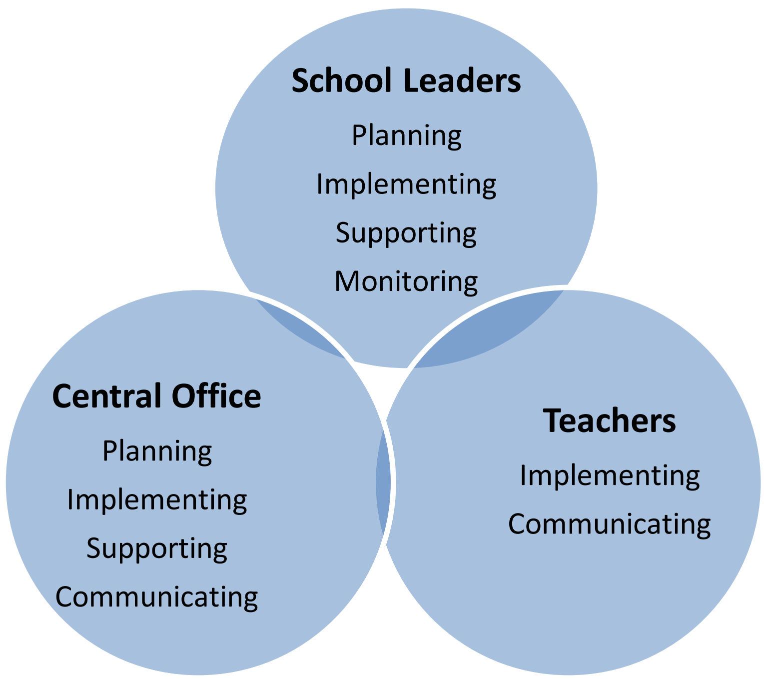


Table 13 shows which processes under the culture of learning and professional behavior were evident from the interviews.

Table 13

Processes under Culture of Learning and Professional Behavior by Stakeholder

Processes	CO	AP-NES	P-SES	T-NES	T-SES	T-EES
Planning	X	X	X			
Implementing	X	X	X	X	X	X
Supporting	**X**	**X**	X			
Advocating						
Communicating	**X**					X
Monitoring		X	X			

Note: A bolded **X** indicates that evidence for this process is in another stakeholder's interview.

Synthesis. School leaders and the CO specialist are primarily involved in the planning and implementing of the PD opportunities, although teachers did offer some PD. Scheduling time for PD by school leaders was important in building a culture of learning. Advocating for PD was not evident in the interviews.

"Connections to External Communities" (Elliott & Clifford, 2014, p. 15)

Connections to external communities can make a difference for students. Partnerships can be built around exciting students about science, increasing science achievement, and strengthening relationships with families. The question that reflected this component focused on the inclusion of families and community organizations. All of these schools had the after-school STEM program that was designed through the central office.

The interviews were analyzed for evidence of the processes under connections to external communities. The presentation of this evidence follows.

Planning. An important connection to an external community at the county level was with a foundation that provided funding for a STEM program for students who would otherwise not have those opportunities. The central office staff looked at a number of different programs around the country and then developed a program that "would engage kids, increase their English language skills as they were ELL learners that they would start looking into science as future career options them." It also had to be a program "that principals would agree to, that teachers would stay after to teach, and that would engage students who would want to stay after school."

Implementing. The central office reached out to eligible schools and the schools then made the decision to offer the after-school STEM program. The planning and implementation moved to the school with central office support. These schools had the after-school STEM program, and the teacher and school leaders mentioned that parents are invited to an evening program where "the students share what they're working on, so that the parents are able to kind of see what they're developing and doing" (AP NES). The schools also had a local science center come and provide a Family Science Night. Teacher SES and Teacher NES mentioned the relationship with some retired scientists and engineers who volunteer at the schools, as well as a nearby science research group that brings different experiences to the school. Teacher SES also mentioned the embryology program and said that "bringing in the eggs and watching them hatch and getting to hold the chicks and stuff. That's always a memorable piece."

Principal NES talked about incorporating "families…in terms of volunteers and things. Although it's been harder because we're working-class community." He said, "We bring in parents to have the students share what they're working on, so that the parents are able to kind of see what they're developing and doing."

Supporting. Principal SES talked about more than just the events: "We want families to support that and talk to their kids about science. Talk to their kids about what they're doing in school, because that is truly a partnership and the partnership exists when everybody has understanding." She added, "It's really about supporting kids in their thinking."

CO specialist supported the after-school STEM program through the PD for the school leaders and teachers. The central office also acquired the funding and provided all the materials.

Advocating. Teacher NES gave an example of the need for more advocating of the connections when she said, “Parents are not involved in our science program.” There was advocacy for the after-school STEM program by all the stakeholders. The central office was a proponent for the program in these schools, the school leaders advocated for the program, and the teachers and the school leaders were responsible for choosing the students who participated.

Communicating. For Teacher EES the partnership with parents includes keeping parents informed: “For the parents, they are kept in a loop about what's going on in our classrooms, so they are definitely very aware of what their students are learning.” As examined under high standards for all, the school leaders communicated with families through the school improvement plan.

Monitoring. Teacher SES wondered about the monitoring of the after-school STEM program. Since they’ve had the program for a while, the students who were in the program in the beginning will be entering high school. She explained, “I would be curious to see if it's had an impact on who is applying or getting into [science specialty high schools] or things like that down the line because that's its true purpose.” This program made a noticeable difference for students. CO specialist mentioned that students “took the lead in their classrooms where they had previously not.”

All of these schools had implemented the after-school STEM program which also exemplifies the synergies among the processes of the central office and school leaders. This program was initiated and developed by the central office staff, but the implementation was collaborative with the schools. Figure 5 shows the relationships of the processes among stakeholders in the after-school STEM program.

Figure 5

Relationships of Processes among Stakeholders in After-school STEM Program

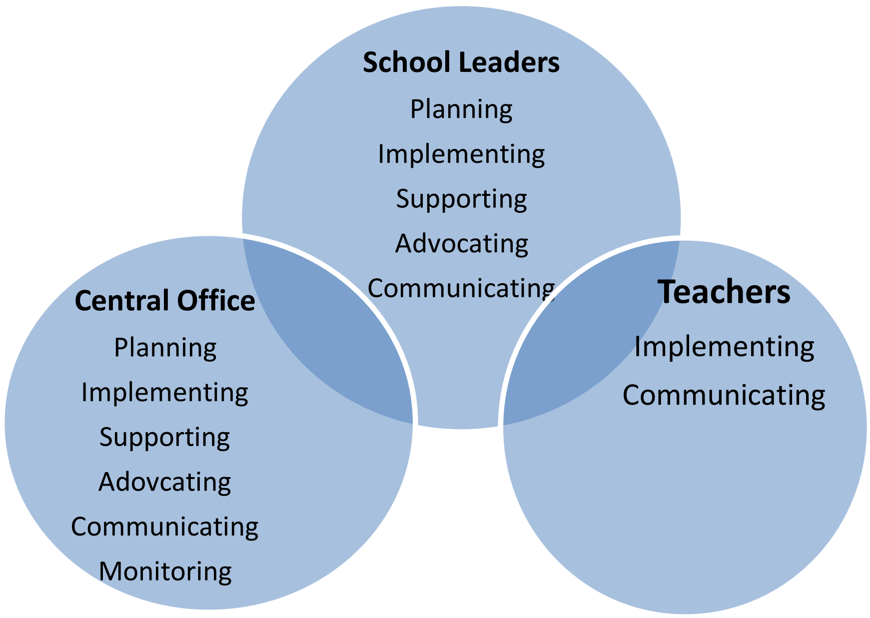


Table 14 shows which processes under connections to external communities were evident from the interviews.

Table 14

Processes under Connections to External Communities by Stakeholder

Processes	CO	AP-NES	P-SES	T-NES	T-SES	T-EES
Planning	X	X	X			
Implementing	X	X	X	X	X	X
Supporting	X	X	X			
Advocating	X	X	X	*X*		
Communicating	X	X	X			X
Monitoring	X				X	

Note. An italicized *X* indicates that there was an expressed need for more of this process.

Synthesis. The schools offered a variety of programs that included external communities. The after-school STEM program exemplified the synergy of the processes of the school leaders and the central office. The central office was responsible for the funding for the program which came from an external community, and then was collaboratively implemented and supported in the schools. wo of the interviewed teachers were also involved in this program. Monitoring, for this example, was interpreted as whether or not the stakeholders mentioned an increased interest in science or the building of skills.

"Systemic Performance Accountability" (Elliott & Clifford, 2014, p. 16)

In order to know if high standards and goals are being met, there needs to be an accountability system in place. The questions related to this component asked about how science achievement is monitored and how the state science assessment has impacted instruction. The state science assessment in fifth grade was mentioned as a source of accountability. Required division-level performance assessments were also mentioned. Most of the accountability was classroom based.

The interviews were analyzed for evidence of the processes under systemic performance accountability. The presentation of this evidence follows.

Planning. AP NES shared the collaborative process the teachers used. He said, "The teachers work on the collaborative assessments that align with their curriculum." He added a monitoring piece that "then they have discussions during their collaborative learning team meeting to see how things are progressing."

Teacher SES gave an example of how the assessments are used to determine the science content gaps from the previous grade level. In SES the teachers "give the fourth-grade student growth assessment to the fifth graders to get a gauge of what they may or may not remember from fourth grade."

Teacher EES shared how lack of time and the standardized test impact the planning for instruction. In order to make sure you can cover everything, she explained, "there are those times when you have a unit, and you have to, so, spend less time in that unit than you would really like to, …so the kids are ready for their standard testing." She added, "Standardized testing … does kind of scare them a little bit." She thinks that the fear may "impact their ability to really learn. So we try to keep it on the back burner as much as possible and make science as impactful as possible. And as fun as possible."

Implementing. CO specialist used the quarterly performance assessment as an example for the accountability for science. She said, "Teachers had a lot of problems giving those to begin with because they still wanted to give the students the information rather than let them work through it." AP NES said, "So for that we have a variety of different formative assessments that the teachers utilize. We also have things that kind of replicate the standards of learning assessment." He added, "They take assessments at the beginning of the year in fifth grade. That gives an idea of the information that they're learning from fourth grade when they're coming in, and then they take an end-of-year assessment in fifth grade" to prepare them for the state assessment. Teacher SES said, "We have like a bank of questions to look at so it helps in a way with some like formative assessments and quick checks and exit tickets and stuff…as much as I'd love to just do performance assessments for everything."

CO specialist mentioned the change in thinking for teachers when they did the performance assessment: "It really became something where the teachers were like, 'Can we have more of these.' So, performance assessments are the other way that I think teachers are really using to judge how well their kids are doing science," and then she added the caveat, "if they're teaching science." Teacher SES said that performance assessments were something that she had to do, but she added, "I would rather do that with the kids than make them take another test."

Teacher NES spoke about how the standardized assessments, that covered two years of science is hard for the students. She gave an ocean unit as an example: "Well, we don't live near an ocean so not only is that something that they're not readily familiar with, but it's not something that is constantly near them." She also shared her frustration with a Student Growth Assessment (SGA) that was given, and how the administration supported the teachers to make the assessment more useful. She said,

> We talked about how taking a fifth-grade student growth assessment is not beneficial to us at all. Our population and our community they don't have that science background. So we were wasting our time. We were having the kids stress and worry about a test that meant nothing, and we weren't able to use the data effectively because it showed us what we already knew. Students didn't know science. So, our principal took that to the people in admin, and we got the okay to take the fourth grade SGA. That way when we receive that data back, we could help that to drive our instruction as far as what students needed from the fourth-grade curriculum the most. So that helped us to determine which units to kind of do for fourth grade, because of course, we couldn't do the entire curriculum.

Supporting. The central office staff supported the performance assessments through their development and the PD for teachers for implementation. The CO specialist mentioned how the assessments support instruction by providing information for changes needed in the curriculum. She gave an example around camouflage as an adaptation. The teachers noticed that camouflage was the only adaptation that students were mentioning, and that helped them realize that camouflage was the only adaptation they were teaching.

Advocating. As mentioned above in implementing, the principal at NES advocated for the teachers to make the assessments more useful.

Communicating. All the stakeholders mentioned the standardized assessments in fifth grade as a communication science achievement. Teacher SES mentioned that the classroom assessments are "really just assessed in our grade book system."

Monitoring: CO specialist mentioned how the district monitored science achievement. She said, "Every grade level at every school has to submit an example of students doing exemplary, students doing okay, and students that are failing a performance assessment, every year."

Principal SES shared different ways that science is monitored: "Sometimes it was the division having student growth assessments, and quarterly benchmarks, in which case those would be developed by the division." She also mentioned that teachers "would create assessment for the beginning, middle, and end-of-year benchmark assessment based on sample … released questions." She said that the teachers would "meet and segregate that, and come up with a plan for intervention or enrichment depending upon the needs of the learners." Teacher SES talked about how achievement on the performance assessments was determined. The teachers "bring the products, the final products, and do a vertical calibration protocol. They sort of bring the rubrics to the meeting and talk through what they feel is a meeting or exceeding or progressing sample." AP NES also mentioned the collaboration around analyzing the assessment data: "Whether they're thinking about these different questions, what's working, what's not working." He found this process valuable because "that way they're all able to not just see their own classroom, but see all the students on a grade level."

Teacher NES mentioned that most of the monitoring was "my classroom, formal and informal, you know assessments, activities, these experiments." That corresponded with Teacher EES' description of the use of the assessments. She said that science is monitored through the formative and summative assessments that they do: "So throughout each of our units, we are collecting data based on formatives. So, things that are not impacting their grades, but just kind of getting a feel for where they're at, and how they're growing."

Teacher SES mentioned that "most grade levels, it's really just like assessed in our grade book system. Like kindergarten they don't even get grades for that. For first through fourth grade, they get their formative and summative grades on the report card."

One of the themes in the interviews was the quarterly performance assessments. These assessments are designed by the central office. Schools submit samples that exemplify performance levels. Figure 6 shows the relationships of the processes among stakeholders in performance assessments.

Figure 6

Relationships of Processes among Stakeholders in Performance Assessments

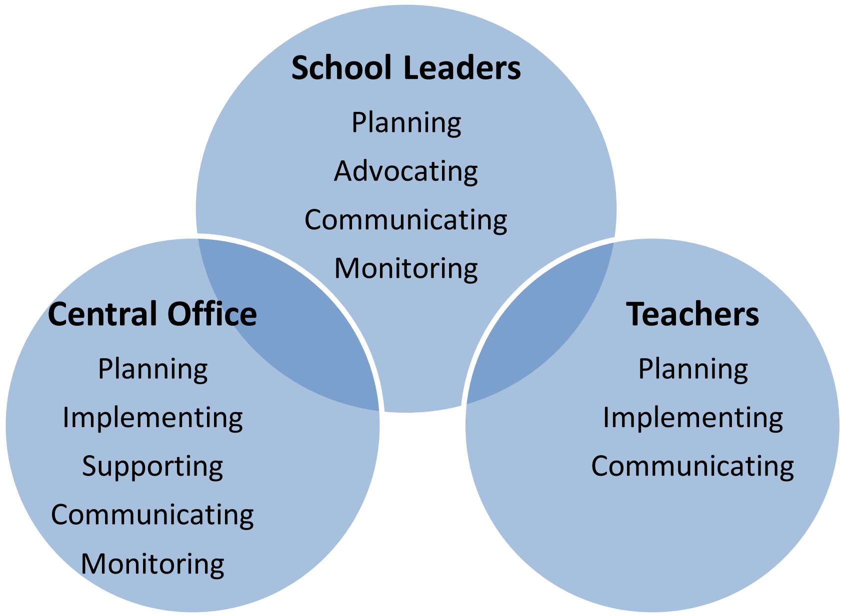


Table 15 shows which processes under systemic performance accountability were evident from the interviews.

Table 15

Processes under Systemic Performance Accountability by Stakeholder

Processes	CO	AP-NES	P-SES	T-NES	T-SES	T-EES
Planning	X	X			X	X
Implementing	X	X		X	X	
Supporting	X					
Advocating		**X**				
Communicating	X	X	X	X	X	X
Monitoring	X	**X**	X	X	X	X

Note. A bolded X indicates that evidence for this process is in another stakeholder's interview.

Synthesis. This was the only component in which monitoring was evident by all stakeholders, but it was primarily with the fifth-grade state assessment. The state assessment was also used to communicate science achievement on a school level. The processes of planning, implementing, and supporting were primarily around the performance assessments which were developed and supported by the central office

Summary

One central office science specialist, two school leaders and three teachers were interviewed with questions based on “principal practice” from Elliott and Clifford (2014, p. 12). The questions were designed to reflect the six components in the framework, and the responses were analyzed to determine how the decisions and actions reflected the six processes. The data shows that there were areas of synergies under all the components. The processes by the school leaders under high standards for student learning were interpreted differently by the teachers. The central office impacted the decisions and actions of the principals in rigorous curriculum and quality instruction through the lessons and materials provided. In this division, the school leaders and the central office had synergy with the processes in the after-school STEM program. Advocating and monitoring are two processes that did not appear in all of the components. Collaborating was not a separate process, but was evident in many of the components and processes, including planning and implementing under rigorous curriculum and quality instruction

Chapter 5: Discussion of Findings and Implications

Introduction

The purpose of this research was to investigate the decisions and actions of elementary principals in the support of science and then compare principals' decisions and actions with those of teachers and central office science leaders. The primary question guiding the research was, What are the decisions and actions of elementary principals that support science education? Secondary questions were, (1) How are the decisions and actions of elementary principals impacted by those of central office science leaders? (2) How are the decisions and actions of elementary teachers impacted by those of principals? This research aimed to investigate synergies among the principals, teachers, and central office science leaders by using a qualitative approach that incorporated interviews with elementary principals, teachers, and central office science leaders regarding the science program in their schools and district. Chapter 5 offers a discussion of the comparison of the practices among the education stakeholders, implications for practitioners and policy, and recommendations for future research.

Review of Findings

The interviews included questions that were based on the six components of principal practice: "high standards for student learning," "rigorous curriculum," "quality instruction," "culture of learning and professional behavior," "connections to external communities," and "systemic performance accountability" (Elliott & Clifford, 2014, pp. 13-16). The analysis of the responses included comparisons of the various stakeholders with the six processes. A discussion of each follows.

"High Standards for Student Learning" (Elliott & Clifford, 2014, p. 13)

The decision to make the state science standards the focus for high standards for student learning was consistent for all the school personnel. Both school leaders mentioned the school improvement plan as an avenue for implementing high standards and communicating the school goals. Although the school leaders mentioned how the school plan is written and implemented collaboratively with the teachers, the teachers did not mention the school improvement plan. For teachers the importance of science was communicated through the scheduling of time, the addition of science-related programs, or not at all. The connections with the central office were not apparent in the interviews for high standards for student learning, although the central office does work with the schools regarding rigorous curriculum and quality instruction.

"Rigorous Curriculum" (Elliott & Clifford, 2014, p. 14)

Rigorous curriculum makes the high standards visible in the classroom. The actions around rigorous curriculum were primarily the planning, supporting, and communicating of the curriculum. Principals make decisions around the planning, implementing, supporting, and communicating of the curriculum, but the decisions are informed by the resources provided by the central office. The teachers are primarily involved in the planning of the curriculum and implementing the materials from the central office. The central office plays a role in the planning, supporting, and communicating of the curriculum.

Of the three aspects of science curriculum--content, inquiry, and NOS--inquiry was the only one that was mentioned in the interviews. In order to teach inquiry-based science, materials need to be available. This is one area where the synergy was evident. Principal support for the procurement of materials and, in two cases, dedicated classroom space, impacts the activities that teachers do with students. The design of inquiry-based lessons and purchase of durable materials by the central office adds to that synergy. All three stakeholders were participating in processes that support rigorous curriculum.

A challenge for school leaders is knowing the decisions about curriculum that promote the best practices for science. Inquiry is one of the best practices for teaching science, but inquiry and hands-on are not identical. Teachers have the materials for the hands-on activities, but they did not describe inquiry-driven lessons. The CO specialist delivers the professional development (PD) using inquiry, but there is no guarantee that the teachers have participated in the PD. In this case there isn't synergy that supports science.

"Quality Instruction" (Elliott & Clifford, 2014, p. 14)

The process most frequently seen under quality instruction was implementing. As with rigorous instruction, the support of the central office and the school leader provides the synergy for the teachers to offer quality instruction. Quality instruction requires time, and time for teaching science was in the schedule for all the teachers interviewed. The central office also created lessons that were integrated with language arts, enabling science and language arts to share time. Despite having time in the schedule for science, there was concern that not all teachers, particularly those in 4^{th} grade, gave science time. The school leaders are supporting quality instruction with the time in the schedule, but there is a need to advocate for and monitor science in all grade levels.

The school leaders can also support science instruction by promoting teaching science in an integrated fashion with language arts. This model of instruction can result in increased student achievement in reading and science (Cervitti et al., 2012; Shymansky et al., 2013). This model is supported by the lessons provided through the central office, but it was not described by the teachers as the model for their planning or for their instruction. There was an emphasis on vocabulary in the responses about instruction. Researched-based vocabulary instruction in science requires rich, inquiry-based experiences where students build their science vocabulary through the unit (Lee et al., 2018). For teachers to change their practice, they will need to be engaged in PD.

School leaders in this study made decisions to include science in the schedule, and the teachers recognized that as important. However, time is finite, and there are ways to maximize time for science and supporting other content areas. The central office has written model lessons that integrate the language arts with the science. The teachers know that those lessons are there, but it is not clear that they implement them as designed, or that they use that model for all science lessons. Teachers may need PD in order to plan and implement integrated lessons. Principals could support science instruction by advocating for PD and monitoring the implementation of the integration.

"Culture of Learning and Professional Behavior" (Elliott & Clifford, 2014, p. 15)

School leaders and the central office were primarily involved in the processes under culture of learning and professional behavior. The processes of planning, implementing and supporting were evident in the interviews. Time for professional learning was one way school leaders were supportive of professional development. Both the central office and the school leaders are planning and implementing PD. The central office provides PD on a division basis, and teachers have the choice of whether or not they want to attend. The central office PD may or may not be connected to the PD from the school, but the central office is available to bring PD to the schools by invitation. The school leaders indicated a monitoring of PD as part of the discussions in collaborative teams at the schools, but monitoring was not a process that came from the teachers.

"Connections to External Communities" (Elliott & Clifford, 2014, p. 15)

This component represented the strongest synergy between the central office and the school leaders with the example of the after-school STEM program. The central office took the lead in the initial planning, implementing, supporting, and advocating through the development of the program. The school leaders also had to plan, implement, support, and advocate at the school level. This was the only example of the school leaders being required to participate in the professional learning with the teachers. Anecdotal information was shared about successes in the program, but a formal monitoring system was not evident.

This program had an impact that went beyond providing science opportunities to students. School leaders and teachers who were involved in the program noticed a difference in how they approached science in their classroom. Although this design doesn't match the program that Maeng et al. (2020) described, there is carry over from the non-classroom experience to the classroom.

Other programs with external communities were shared including opportunities for family engagement, enrichment activities by science groups, and classroom support from retired scientist volunteers. Planning, implementing, and supporting were seen in those programs, but those were exhibited primarily by the school leaders.

"Systemic Performance Accountability" (Elliott & Clifford, 2014, p. 16)

This was the only component where the process of monitoring was visible from all the stakeholders, and the state science assessment was an example. In this component, the central office had a lead role in the planning, implementing, supporting, and communicating of the quarterly performance assessments. Teachers also talked about classroom assessments being used to monitor science achievement. Only the discussion around performance assessments indicated an impact on instruction.

Implications for Practitioners

The six components represent areas where school leaders have decision-making responsibility. As evident from the literature, school leaders have challenges in supporting these components through the lens of science. This research has illustrated how two school leaders have navigated these components with the six processes around science instruction, but this is transferable to other content areas as well. The primary implication for practitioners is to think through the six processes when making decisions or taking actions. The components and the processes interweave, so this is not a linear process, but leaving a process out can have ramifications. From this study, processes of advocating and monitoring were not as evident, and communicating was not consistent. Explicitly making the connections of the decision or action to these processes may improve the outcome.

STEM integration was mentioned in the interviews by all the stakeholder groups. School leaders could support the integration of science across content areas. This could take the form of providing PD, scheduling collaboration time for lesson development, and hiring staff, such as a STEM teacher, with science integration expertise.

Another implication is the overlap between the connections to external communities and the culture of learning and professional behavior. One of the teachers who participated in the after-school STEM program changed her behaviors in the classroom as a result. The school leaders also noticed a difference. There may be a way to leverage teachers working in after-school or summer school programs as a PD experience that can transfer to the classroom.

Collaboration was evident in many of the components and processes. It was evident in building the school plan, developing the curriculum, planning the instruction, and evaluating student work. Having the time in the schedule and the expectation for collaboration among the stakeholders may be critical for student success.

Implications for Policy

From NCLB to ESSA, policy is looking for student achievement. Language arts and mathematics are a focus, but there is concern that students are not achieving in science and that there will not be enough people pursuing science to meet future job demands. There can be policy changes that address one or more of the six components and use the processes to support and promote quality science instruction.

Departments of Education

There is a balance between local and state control in policies at state education departments. Curriculum materials are one area where there is local control, but there is usually a list of textbooks or other materials that have been state approved. Consideration should be given to providing a higher level of support for schools in choosing materials. In the schools represented here, the teachers did not have a reliance on textbooks. Nor does the central office have enough staff to write a specific curriculum for all grade levels. OpenSciEd (www.opensiced.org) is working to develop quality science materials that are free. A change in policy that would allow for adoption of outside vetted materials may make it possible for more teachers to access quality, aligned curriculum resources. Materials that integrate science content with other content areas could also be a part of the adoption process, providing teachers with curriculum that would support the learning of all content areas.

Assessments are another area where Departments of Education can make a difference for supporting science. Since science is only tested once in elementary, there is a perception that it is not as important at other grade levels. A more integrative assessment system at all grade levels that would assess more than one content in an assessment could provide teachers, students, and parents with a better picture of what students know across content.

Teacher and Principal Preparation System

Although science courses are required for elementary education majors, they are usually taught in the more traditional lecture and lab section format. Teacher preparation programs that included science content courses that modeled the inquiry that is expected in elementary classrooms would benefit the teachers. Teachers also learn about lesson planning in their preparation program. A greater focus on the integration of content in these programs would support teachers in teaching science. If these elementary teachers choose to become elementary school leaders, they will be more prepared to supervise science because of these experiences in their pre-service programs.

The school leaders in this study represent a majority of principals in that they do not have a science or science education background. Programs for administrative licensure often include a curriculum and instruction course. This course could highlight specific aspects of different content areas, including science, which could help principals be more prepared to supervise all content areas.

Future Research

This research focused on the school leaders, teachers, and central office. This did not include other stakeholders such as family, state education policy makers, higher education institutions, or community science organizations. Understanding how these other stakeholders can be included in these components or processes could be beneficial for increasing science achievement and science interest for students.

This research also did not include STEM teachers or teachers who specialized in teaching science. More research on the impact of different models of optimizing staff who have an expertise in science would be helpful in providing evidence for principals on different ways to use the expertise of their staff to support all students in science.

Conclusion

Schools are complicated systems. This research examined part of that system by looking at the decisions and actions of school leaders, a central office science leader, and teachers in supporting elementary science. All of these stakeholders had a role in the six components of the principal practice framework and differences in the processes were evident. There was synergy among these groups, especially around the planning and implementing of the curriculum and instruction. The support of the school leaders was important to the teachers in both curriculum and instruction. The processes of advocating and monitoring were not as evident in the interviews, and are areas for more consideration. The importance of science was not communicated with synergy among the stakeholders. All stakeholders should work collaboratively around the processes of planning, implementing, supporting, advocating, communicating, and monitoring to help ensure that all students have opportunities in science.

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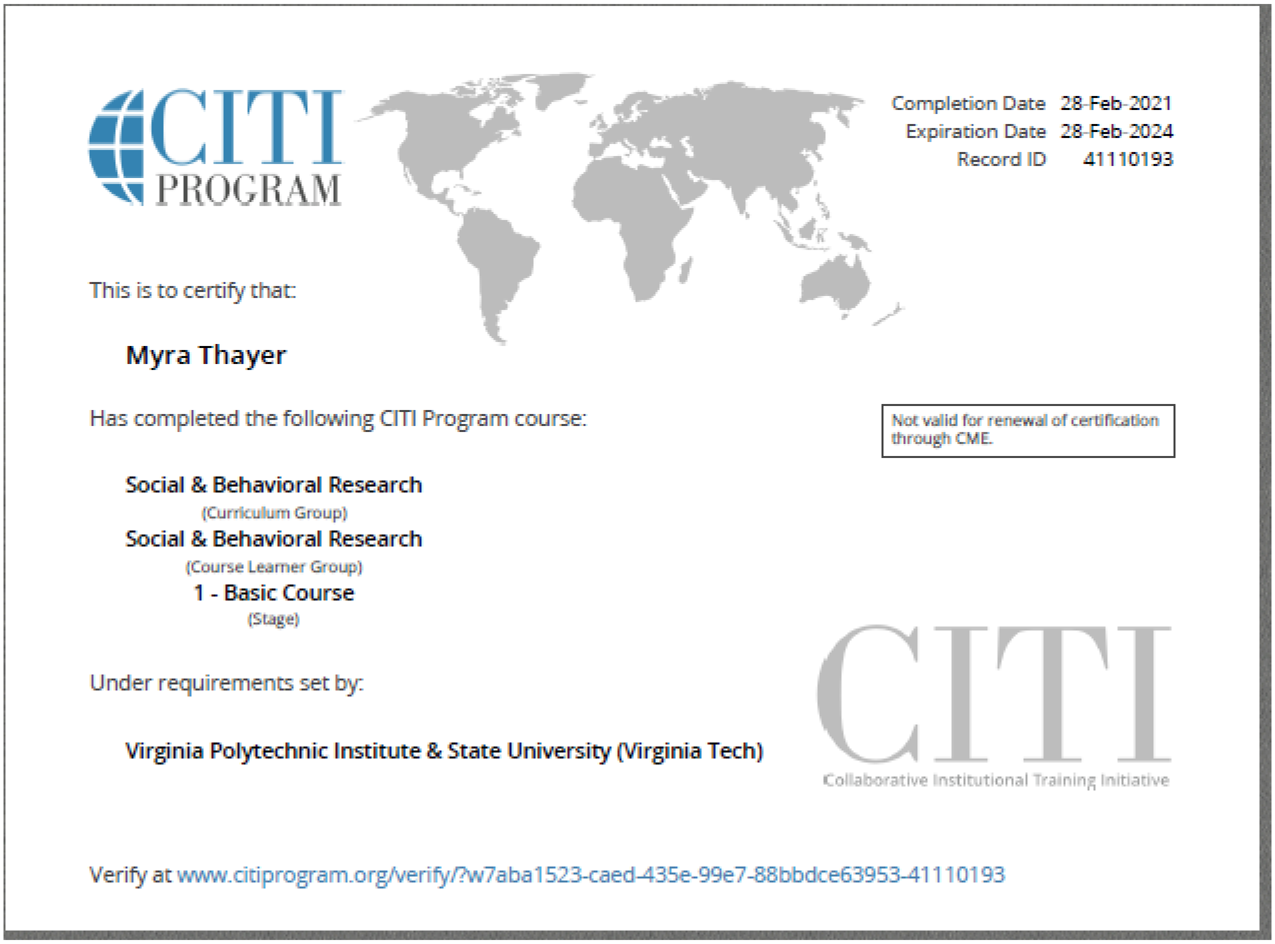
Appendix A: CITI Program Certificate

CITI Program Certificate



CITI PROGRAM

Completion Date 28-Feb-2021
Expiration Date 28-Feb-2024
Record ID 41110193

This is to certify that:

Myra Thayer

Has completed the following CITI Program course:

Not valid for renewal of certification through CME.

Social & Behavioral Research
(Curriculum Group)
Social & Behavioral Research
(Course Learner Group)
1 - Basic Course
(Stage)

Under requirements set by:

Virginia Polytechnic Institute & State University (Virginia Tech)

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?w7aba1523-caed-435e-99e7-88bbdce63953-41110193

Appendix B: Invitation Email to Participate in Pilot

Invitation Email to Participate in Pilot

Subject Line: Invitation to participate in pilot

Dear ____________:

Thank you so much for agreeing to help me in my doctoral research and to provide feedback on my interview questions. As you know, I have been a science teacher and a division science leader, and am currently working on my dissertation in the Educational Leadership and Policy Studies Program at Virginia Tech under the supervision of Dr. Carol A. Mullen. My lifetime work in science education has led me to this study to determine how the decisions and actions that elementary principals, teachers, and central office personnel take support science education. This research, Investigating Synergies of Education Stakeholders in Supporting Elementary Science: A Qualitative Study has been approved through VA Tech (IRB#21-938). The interview will be conducted over Zoom at a time that is convenient for you. The interview should take between 45-60 minutes. The interview will not be recorded, but I will take some notes while you are talking. At the end of the interview, I would like to know if there are questions that you think I should add so that I capture your work in supporting science education. Attached you will find an information form and the research questions.

I look forward to hearing from you to set up the time and date for the interview and thank you for your support of science education.

Sincerely,

Myra Thayer
Doctoral candidate
Virginia Polytechnic Institute and State University

Appendix C: Information Sheet for Participation in a Pilot for a Research Study

Information Sheet for Participation in a Pilot for a Research Study

Principal Investigator: Dr. Carol A. Mullen, PhD
IRB# and Title of Study: 21-938 Synergies of Education Stakeholders In Supporting Elementary Science: A Qualitative Study

You are invited to participate in a pilot for a research study. This form includes information about the study and contact information if you have any questions. This research has been approved through Virginia Tech. I am a doctoral candidate in the Virginia Tech Educational Leadership Program at Virginia Tech, and I am conducting this research as part of my course work.

WHAT SHOULD I KNOW?

If you decide to participate, this is a pilot to check the interview questions. You will complete a 45-60 minute interview. You will be asked open-ended questions about your support of science teaching and learning, and you will receive the questions in advance. The interview will be done over Zoom. The interview will not be recorded or transcribed. Handwritten notes by the researcher will be taken. After the interview, you will be asked if there are questions that should be asked to capture actions and decisions that support elementary science.

We do not anticipate any risks from completing this study.

You can choose whether to be in this pilot or not. If you volunteer to be in this pilot, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

CONFIDENTIALITY

We will do our best to protect the confidentiality of the information we gather from you, but we cannot guarantee 100% confidentiality.

No personal information will be collected during this pilot study. Any notes taken will be kept in a locked file in the researcher's office, and destroyed three years after the dissertation defense.

WHO CAN I TALK TO?

If you have any questions or concerns about the research, please feel free to contact Myra Thayer or the Principal Investigator, Dr. Carol A. Mullen, PhD at the College of Liberal Arts & Human Sciences, School of Education, Educational Leadership Program at Virginia Polytechnic Institute and State University. You are not waiving any legal claims, rights or remedies because of your participation in this pilot. If you have questions regarding your rights as a research participant, contact the Virginia Tech HRPP Office.

Please print out a copy of this information sheet for your records.

Appendix D: Interview Questions for Principals

Interview Questions for Principals

Interview Questions
1) Tell me a little about your experience as an educator, including your undergraduate degree and teaching and leadership experience.
2) Describe the demographics of your school. What challenges do you face in terms of staffing or meeting accountability measures?
3) What are your school goals? How do you communicate them?
4) What science curriculum program do you use? How is the science curriculum selected?
5) How do you know when you see effective science teaching?
6) What do you do when you see science teaching that is not that effective?
7) How are teachers included in the decisions of the school?
8) How do you support the professional learning of your teachers?
9) How do you monitor student progress in science?
10) How are families and community organizations included?

Appendix E: Interview Questions for Teachers

Interview Questions for Teachers

Interview Questions
1) Tell me a little about your experience as a teacher.
2) What aspects of your job make you feel valued?
3) How is the importance of science communicated in your school?
4) What curriculum do you use?
5) How do you make decisions about the curriculum that you implement in your classroom?
6) What supports allow you to include science in the curriculum?
7) What barriers exist in your efforts to include science in the curriculum?
8) What methods of teaching science do you include in a typical lesson?
9) What professional development in science is available to you?
10) How have standardized testing requirements impacted science instruction?
11) How is science achievement monitored?
12) How are families and community organizations included in your science program?

Appendix F: Interview Questions for Central Office Science Leader

Interview Questions for Central Office Science Leader

Interview Questions
1) What is your background that brought you to this position?
2) Describe the demographics of your district. What are the main challenges that you see in science teaching and learning?
3) How does the district communicate the importance of science?
4) How do you make major curriculum decisions? What do you look for in curriculum? What science materials are currently being used in the district?
5) How are science materials purchased and distributed in the district?
6) How does your office support the professional development of teachers?
7) What are the successes and challenges the office faces in supporting teachers?
8) How does the division monitor science performance?
9) How are families and community organizations included in your science program?

Appendix G: Invitation Email to Principals

Invitation Email to Principals

Subject Line: Invitation to Participate in Study

Dear _________:

Greetings! My name is Myra Thayer, and I have worked as a science teacher and a division science leader and am now a doctoral candidate in the Educational Leadership and Policy Studies Program at Virginia Tech under the supervision of Dr. Carol A. Mullen. I am excited to write this email to you, because you have been identified as a principal who has supported science as evident in the increase in science scores (OR participation in the after school-STEM program) at (insert school name here). The purpose of my study is to determine the decisions and actions that elementary principals take when they support science, and how those decisions and actions impact the teachers as well as central office science leaders. Your participation in the study will provide data that will be part of the analysis to determine how principals support science.

This study, Investigating Synergies of Education Stakeholders in Supporting Elementary Science: A Qualitative Study has been approved by Virginia Tech (IRB#21-938) and I have been granted permission through the school system's Institutional Review Board to request your participation in this study. This is a qualitative study and I have an interview protocol that should take between 45-60 minutes through Zoom. We will schedule the interview at your convenience and you will receive the questions before the interview. All responses are confidential and there is no identifying information of your name, school, school division or region. With your permission, the interview will be recorded. I will share the transcript of your interview with you before I do the analysis. Participation is voluntary and greatly appreciated.

In addition to interviewing you, I would also like to interview a teacher who is familiar with your leadership in science and supports science. I will let the teacher know that I received their name and contact information from you. Is there a teacher you would recommend to participate in this research?

Your participation in this study may be helpful in determining ways for others to also support science education and I hope you will be willing to participant. If you are interested, I will share the analysis of the interview with you once the dissertation is successfully defended. I look forward to hearing from you and thank you for your support of science education.

Sincerely,

Myra Thayer
Doctoral candidate
Virginia Polytechnic Institute and State University

Appendix H: Information Sheet for Participation in a Research Study

Information Sheet for Participation in a Research Study

Principal Investigator: Dr. Carol A. Mullen, PhD

IRB# and Title of Study: 21-938 Investigating Synergies of Education Stakeholders In Supporting Elementary Science: A Qualitative Study

You are invited to participate in a research study. This form includes information about the study and contact information if you have any questions. This research has been approved both through Virginia Tech and Loudoun County Public Schools. I am a doctoral candidate in the Virginia Tech Educational Leadership Program at Virginia Tech, and I am conducting this research as part of my course work.

WHAT SHOULD I KNOW?

If you decide to participate in this study, you will complete a 45-60 minute interview. You will be asked open-ended questions about your support of science teaching and learning, and you will receive the questions in advance. The interview will be done over Zoom and will be audio recorded and transcribed through Zoom. You will receive the transcription of the interview to review, and you can make clarifications at that time. Handwritten notes by the researcher will be taken in addition to recordings and transcriptions to be utilized in data analysis.

We do not anticipate any risks from completing this study.

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer and remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

CONFIDENTIALITY

We will do our best to protect the confidentiality of the information we gather from you, but we cannot guarantee 100% confidentiality.

All interview data collected during this research study will be kept confidential by the researchers. Your interview will be audio-recorded through Zoom and then transcribed. All participants will have the opportunity to verify the transcription. The researchers will code the transcripts using a number. The recordings will be uploaded to a secure VT Google drive and will be deleted after the verification of the transcriptions by the participants. The researchers will maintain a hard copy list that includes a key to the code of the data. The hard copy will be kept in a locked file cabinet in the researcher's home office. The master key and the transcriptions will be stored for 3 years after the study has been completed and then destroyed.

WHO CAN I TALK TO?

If you have any questions or concerns about the research, please feel free to contact Myra Thayer or the Principal Investigator, Dr. Carol A. Mullen, PhD at the College of Liberal Arts & Human Sciences, School of Education, Educational Leadership Program at Virginia Polytechnic Institute and State University. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research participant, contact the Virginia Tech HRPP Office.

Please print out a copy of this information sheet for your records

Appendix I: Invitation Email to Teachers

Invitation Email to Teachers

Subject Line: Invitation to participate in research study

Dear ____________:

Greetings! You are receiving this email because you have been identified by your principal, (insert name here), as a teacher who supports science and can speak to the leadership in science in your school. I have been a science teacher and a division science leader, and am currently working on my dissertation in the Educational Leadership and Policy Studies Program at Virginia Tech under the supervision of Dr. Carol A. Mullen. My lifetime work in science education has led me to this study to determine how the decisions and actions that elementary principals take when they support science impact the teachers. This research, Investigating Synergies of Education Stakeholders In Supporting Elementary Science: A Qualitative Study has been approved through VA Tech (IRB#21-938). I have also been granted permission through the school system's Institutional Review Board to request your participation in this study. This is a qualitative study, and I hope you will allow me to interview you. You will receive the interview questions in advance, and the interview will be conducted over Zoom at a time that is convenient for you. The interview should take between 45—60 minutes and, with your permission, will be audio recorded. All responses are confidential and there is no identifying information of your name, school, school division or region. Your interview answers will not be shared with your principal. I will share the transcript of your interview with you before I do the analysis.

Your participation in this study may be helpful in determining ways for others to also support science education and I hope you will be willing to participant. If you are interested, I will share the analysis of the interview with you once the dissertation is successfully defended. I look forward to hearing from you and thank you for your support of science education.

Sincerely,

Myra Thayer
Doctoral candidate
Virginia Polytechnic Institute and State University

Appendix J: Invitation Email to Central Office Science Leader

Invitation Email to Central Office Science Leader

Subject Line: Invitation to Participate in Study

Dear _________:

Greetings! My name is Myra Thayer, and I have worked as a science teacher and a division science leader and am now a doctoral candidate in the Educational Leadership and Policy Studies Program at Virginia Tech under the supervision of Dr. Carol A. Mullen. I am excited to write this email to you. My research, Investigating Synergies of Education Stakeholders in Supporting Elementary Science: A Qualitative Study, will examine how the decisions and actions of various stakeholders impact elementary science. Your decisions and actions as a central office science administrator are an important aspect of this work. Your participation in the study will provide data that will be part of the analysis to determine how the central office supports science.

This research has been approved by Virginia Tech (IRB#21-938). I have also been granted permission through the school system's Institutional Review Board to request your participation in this study. This is a qualitative study and I have an interview protocol that should take between 45-60 minutes through Zoom. We will schedule the interview at your convenience and you will receive the questions before the interview. Your information and all responses will remain confidential. There is no identifying information of your name, school, school division or region. With your permission, the interview will be recorded. I will share the transcript of your interview with you before I do the analysis. Participation is voluntary and greatly appreciated.

Your participation in this study may be helpful in determining ways for others to also support science education and I hope you will be willing to participant. If you are interested, I will share the analysis of the interview with you once the dissertation is successfully defended. I look forward to hearing from you and thank you for your support of science education.

Sincerely,

Myra Thayer
Doctoral candidate
Virginia Polytechnic Institute and State University

Appendix K: Interview Protocol

Interview Protocol

Title of the Research Study: Investigating Synergies of Education Stakeholders In Supporting Elementary Science: A Qualitative Study, IRB#21-938

Principal Investigator: Carol A. Mullen, PhD, Educational Leadership & Policy Studies, Virginia Polytechnic Institute and State University

Co-Investigator: Myra Thayer, Educational Leadership & Policy Studies, Virginia Polytechnic Institute and State University

Each interview will be conducted through Zoom.

Interviewer:

Thank you so much for allowing me to interview you. Before we begin, I would like to tell you a little about this study. I have been involved in science education for many years, and have been curious about how principals, teachers, and central office personnel work together to provide and support science instruction. The purpose of this qualitative study is to investigate the decisions and actions of these stakeholders in supporting science. Your participation will require no more than 45 to 60 minutes. I will be interviewing between 7 and 14 of these stakeholders, and then I will analyze the responses and look for common themes, similarities, differences and patterns.

I will be recording this interview on audio only, so we will turn off our cameras. Your information will be identified with a number. The interview will be transcribed, and you will receive the transcription. Upon reviewing the transcript, you may make changes in the transcription you believe are necessary. The audio recording will be destroyed after you have verified the transcription. The transcription will be stored on a secured VA Tech google drive, and destroyed three years about the successful completion of the dissertation. Only myself and the principal investigator will have access to this data.

There is no compensation for participating, and the risk to you is minimal. Through your participation and those of others, the science educational community will benefit by having additional information on how science teaching and learning can be supported in elementary schools.

At any time, you are free to withdraw from this study with no penalty to you. Do you wish to participate? Do you agree to be audio-taped? Do you have any questions prior to beginning?

At the end of the interview:
Thank you so much for you time and your willingness to share your experiences in elementary science education. I will be sending you the transcript, and, if you are interested, would love to share with you the analysis of the data after the dissertation defense.

Appendix L: Email to Participants with Transcription

Email to participants with transcription

Subject Line: Transcript from Interviews

Hello, (name of participant)
It was so good to interview you on (date). Please find attached the transcript of the interview. If you want to make any deletions or clarifications to the interview, please let me know. If I don't hear from you by (date one week after) I will proceed with the data analysis on this transcript.

Thanks, again, for contributing to this research and supporting science education.

Sincerely,
Myra

Appendix M: Interview Protocol Alignment with Literature

Interview Protocol Alignment with Literature

Interview Questions

These interview questions will be asked of participants. Although the exact questions are not in the literature, the relevance of the questions to the component is evident in the studies listed.

Principal Questions

Component	Interview Questions	Study	Relevance
Introductory	Tell me a little about your experience as an educator, including your undergraduate degree and teaching and leadership experience.	Lochmiller (2015)	Principals differ in their responses to supporting teachers based on their background and experiences.
Introductory	Describe the demographics of your school. What challenges do you face in terms of staffing or meeting accountability measures?	Settlage et al. (2015)	The demographics of a school influences principals' practices.
High standards for student learning	What are your school goals? How do you communicate them?	Hallinger & Murphy (2013), Lewthwaite (2004)	Principals set the goals and vision of the school.
Rigorous curriculum	What science curriculum program do you use? How is the science curriculum selected?	Lochmiller & Cunningham (2019)	Curriculum that is inquiry based better supports student learning.
Quality instruction	How do you know when you see effective science teaching? What do you do when you see science teaching that is not effective?	Lochmller & Cunningham (2019), Sherman & MacDonald (2008)	Principals are the instructional leaders in the schools. Their understanding of what good science teaching looks like impacts what teachers do or do not do in their classrooms.

Component	Interview Questions	Study	Relevance
Culture of learning and professional behavior	How are teachers included in the decisions of the school?	Settlage et al. (2015), Wu et al. (2020)	Teacher decision making has correlations with student achievement.
Culture of learning and professional behavior	How do you support the professional learning of your teachers?	Settlage et al. (2015), Sherman & MacDonald, (2008)	The culture of the school, including the support for professional learning of teachers, can impact student achievement. The collaboration between teachers is significant for student achievement.
Connections to external communities	How are parents or community organizations involved in your science program?	Settlage et al (2015)	Communication with and inclusion of families and community organizations can make a difference in student achievement.
Systemic performance accountability	How do you monitor student progress in science?	Hallinger & Murphy (2013)	Monitoring student progress is a tool for focusing teaching and learning, specifically the teaching and learning of science.

Teacher Questions

Component	Interview Questions	Study	Relevance
Introductory	Tell me about your background and experience as a teacher.	Carlone et al. (2010)	Teachers with more science experiences have more efficacy in teaching science. Some teachers see themselves as "science people."
Introductory, General information	What aspects of your job make you feel valued?	Settlage et al. (2015), Wu et al. (2020)	Job satisfaction is related to principal leadership.

Component	Interview Questions	Study	Relevance
High Standards for student learning	How is the importance of science communicated in your school?	Settlage et al. (2015)	The vision that is set through the principal needs to be visible to teachers
Rigorous curriculum	What curriculum do you use? How do you make decisions about the curriculum that you implement in your classroom?	Carlone et al. (2010)	Teachers make decisions about how the curriculum is used in their classroom. Those curricular decisions determine the type of science experiences students have.
Quality instruction	What supports allow you to include science in the curriculum?	Carlone et al. (2010)	There are a variety of resources that teachers need in order to be able to teach science.
Quality instruction	What barriers exist in your efforts to include science in the curriculum?	Carlone et al. (2010)	Teachers can experience a variety of barriers that keep them from using the pedagogy for teaching science that they think would be best for their students.
Quality instruction	What methods of teaching science do you include in a typical lesson?	Carlone et al. (2010), Johnson & Dabney (2018)	The methods that teachers use during lessons provides insight into what they think is meaningful for science instruction.
Culture of learning and professional behavior	What professional development in science is available to you?	Casey et al. (2012), Lewthwaite (2004)	Professional learning in both content and pedagogy is important for teachers. Building a culture of teacher collaboration is important for student achievement.
Connections to external communities	How are parents or community organizations involved in your science program?	Settlage et al. (2015)	Communication with and inclusion of families and community organizations can make a difference in student achievement.
Systemic performance accountability	How have standardized testing requirements impacted science instruction? How is science achievement monitored?	Johnson & Dabney (2018)	Assessments impact what teachers feel they should do and how they should teach.

Central Office Science Leader Questions

Component	Interview Questions	Study	Relevance
Introductory	What is your background that brought you to this position?	Lochmiller (2015)	As district leaders, their experience could impact how they support the schools and teachers.
Introductory	Describe the demographics of your district. What are the main challenges that you see in science teaching and learning?	Lochmiller (2015)	The demographics of district, like the demographics of a school, can influence the types of decisions that can be made.
High standards for student learning	How does the district communicate the importance of science?	Lewthwaite (2004)	The research is related to the principals' work.
Rigorous curriculum	How do you plan major curriculum decisions? What do you look for in curriculum? What science materials are currently being used in the district?	Shirgley (1980)	Many central office personnel are involved in curriculum decisions.
Quality instruction	How are science materials purchased and distributed in the district?	Nowicki et al. (2013)	Resource acquisition and management is important for the teaching of science.
Culture of learning and professional behavior	How does your office support the professional development of teachers? What are the successes and challenges the office faces in supporting teachers?	Shrigley (1980), Casey et al. (2012)	Elementary teachers often need support in content and pedagogy. Principals use the support that districts offer.
Connections to external communities	How are parents or community organizations involved in your science program?	Settlage et al. (2015)	Communication with and inclusion of families and community organizations can make a difference in student achievement.
Systemic performance accountability	How does the division monitor science performance?	Hallinger & Murphy (2013)	Monitoring student progress is a tool for focusing teaching and learning, specifically the teaching and learning of science.

APPENDIX N: Literature Review on Educational Leadership and Science Pedagogy

Literature Review on Educational Leadership and Science Pedagogy

The following research articles were significant in the literature for this proposed study. The studies are color-coded for different parts of the study:

Leadership Science Content Science Pedagogy PD Teacher Characteristics

Author and Year	Location and Participants	Focus and Themes	Methodology and Data Sources	Findings	Significance
Bencze (2010)	78 pre-service elementary teachers in Canada, focused case study with 1	Increasing scientific inquiry and promotion of student-led investigations	Qualitative case study approach: anecdotal records, samples of work, surveys, questionnaire, interviews; curriculum content analysis	Very limited use of open-ended student work; teachers felt that there was discouragement for the open-ended work. When there was success in pre-service, the teacher was more willing to do the work later .	Opportunities to work on open-ended projects with students in supported setting in pre-service programs.
Casey, Dunlap, Brown, & Davison (2012)	16 principals at high performing science schools in TX	Communication; collaboration; alignment; scheduling	Open ended questions and Likert scaled questionnaires	Elementary principals suggest important components including a) collaboration with teachers, b) changing teaching assignments, and c) teacher motivation.	Principal's perspective and acknowledge the need to look at teacher and district administrator views.
Carlone, Haun-Frank, & Kimmel (2010)	13 teachers identified from a larger study	Identity, Manifestation of agency and hope; Resources	Single ethnographic case: interviews	Difficult to teach in ways consistent with reform-based science	Testing creates a competition. Don't care about science Policy can bear down on the best teachers, making it difficult for the best teachers

Author and Year	Location and Participants	Focus and Themes	Methodology and Data Sources	Findings	Significance
Cavagnetto, Hand, & Norton-Meier (2010)	2 teachers using SWH	Science, Writing Heuristic Small or large group	Quasi-experimental; student achievement and teacher observations and interviews	Whole class or small class doesn't matter—it is the scaffolds that matter	Successful ways to teach science with language arts, regardless of the science of the group.
Cervitti, Barber, Dorph, Pearson, & Goldschmidt (2012)	94 fourth grade classrooms, Southern state	Integration of literacy with science	Randomly assigned to integrated or separate light; students given pretest and posttest	Students in treatment group showed growth in science concepts, writing, vocabulary	Connections with literacy increase achievement in science and literacy.
Elliott & Clifford (2014)	Analysis of principal evaluation tools	Proposed six components and six processes for principal practiice	Review of principal leadership research and principal evaluation tool	Principal practices that includes 6 core components and 6 processes	Provided the framework for this study
Faikhamata (2012)	25 M Ed Sci students	NOS	Qualitative: pre-post questionnaires; journal entries; assignments; field notes	Move from implicit science process to explicit inquiry approach	Important for teachers to have an experience with NOS that is explicit.
Johnson & Dabney (2018)	4 beginning teachers considered science enthusiasts	Constraints in science teaching	Multiple case study – semi structured interviews	Teachers experienced constraints in terms of time, adequate materials, curriculum standards, and strategies	More evidence to challenges for teachers in science; provided interview questions
Lewthwaite (2004)	18 teachers in one school NZ	Resource Adequacy, Time, Professional support, School Ethos, Professional science	Quantitative study-Science Curriculum Implementation Questionnaire; followed by remediation with principal	Science was not a focus; identified the role of the principal in leading and influencing instruction	Changing the actions of the principal changed the school

Author and Year	Location and Participants	Focus and Themes	Methodology and Data Sources	Findings	Significance
		knowledge, interest and motivation, adequacy			
Lochmiller & Cunningham (2019)	Literature review	Leadership in science	Systematic review of leadership practices; Articles from peer reviewed articles, book chapters and scholarly books published since 2008	Leaders play a role in monitoring curriculum, importance of alignment between the grade levels, small amount of attention because of policy, melding of science with literacy	Supports the need for more research regarding specific content leadership
Nowicki., Sullivan-Watts, Shim, Young, & Pockalny (2013)	54 preservice and inservice teachers	Science content accuracy	Mixed methods – survey and observations	Science content is better when teachers are using kit materials. PD was included with kits. Higher content accuracy was correlated with teachers liking science.	The materials are important for the teaching of science—both for the teachers and the students.
Plumley (2019)	Nationwide, 919 elementary teachers	Effective teaching of science, characteristics of teachers, common resources, PD opportunities	Analysis of survey information	Findings include information on Elementary science teachers' backgrounds and beliefs; Professional development of elementary science teachers; Elementary science instruction; Resources available for elementary science instruction; and Factors affecting elementary science instruction	Provides comprehensive information on elementary teachers and their work with science instruction,

Author and Year	Location and Participants	Focus and Themes	Methodology and Data Sources	Findings	Significance
Romance & Vitale (2001)	51 teachers, 1200 students over 5 years	In-depth expanded applications of science (IDEAS)	Comparison studies with students in IDEAS classroom and those not	Students –across all groups- had better achievement in science and reading.	Integrating reading with science is especially impactful for minority students.
Shymansky, Wang, Annetta, Yore, & Everett (2013)	K-6 staff in 33 rural districts over 5 years	Build PCK integrated with LA; included PD Adapting science inquiry lessons (ASIL)	Mixed methods: questionnaires, interviews, classroom observations, surveys of resources Had comparison districts	Higher achievement for students in ASIL, even though number of units was less	High student achievement with inquiry based lessons
Wu, Shen, Zhang, & Zheng (2020)	PISA participants	Principal Actions	Quantitative study of the analysis of questions regarding teachers, principals and achievement	Teacher rating of principal leadership had a direct and positive relationships on student science achievement.	Shows that relationship between the principal and the teacher, and now that relates to student achievement.