Summer 7-31-2023

How Middle School Students Describe and Explain Their Elementary Science Experiences

Tryna Knox
tknox@smu.edu

HOW MIDDLE SCHOOL STUDENTS DESCRIBE AND EXPLAIN THEIR ELEMENTARY SCIENCE EXPERIENCES

Approved by:

____
Prof. Quentin Sedlacek
Assistant Professor

____
Prof. Alexandra Pavlakis
Associate Professor

____
Prof. Amy Gillespie Rouse
Associate Professor

____
Prof. Robert Tai
Associate Professor

HOW MIDDLE SCHOOL STUDENTS DESCRIBE AND EXPLAIN THEIR ELEMENTARY SCIENCE EXPERIENCES

A Dissertation Presented to the Graduate Faculty of the

Simmons School of Education and Human Development

Southern Methodist University

in

Partial Fulfillment of the Requirements

for the degree of

Doctor of Philosophy

by

Tryna H. Knox

BS, Engineering, University of Central Florida
Master of Business Administration, Brenau University
Master of Education Leadership, Southern Methodist University

July 31, 2023

ACKNOWLEDGMENTS

Thank you to my family for supporting me on this fantastic voyage. I appreciate the many ways you helped me along the way, kept me focused on what is most important, and encouraged me along the way. Your grace and understanding are appreciated more than you know.

Thank you to my running friends. You helped me cross many *finish lines* over the past five years!

Much gratitude to my PhD committee, each of you inspired me in a special way. Your time and commitment to my work is immeasurable. I appreciate your guidance and many lessons as I grew from graduate student into a researcher and colleague. Your place on this journey was not accidental. Alex, your passion for qualitative research is impressive! You've taught me much over the years. Amy, you've impressed me since you led our meta class. Your expertise in writing was invaluable to this study. Robert, your research has inspired this work. I may not have answers yet but I am getting closer. Thank you for setting me on this pathway. Quentin, thank you for helping me see a way forward and giving me direction. I've learned a lot from you and this work was more meaningful because of you!

A special thank you to the fifty-two students who shared their voices and made this work possible, and far more interesting! I want you to know that I'm listening. Your voices have been heard. Speak up! You have important things to say and you've helped me better understand your lived elementary science experiences. You've inspired me to continue this work.

Abstract

The purpose of this study was to elicit students' voices to examine elementary science experiences to better understand foundational learning. The grounding philosophy and framework of phenomenology guided this work as I sought to capture the lived elementary science experiences of students. I administered a handwritten science autobiography to 52 middle school students at a private middle school in a suburban southwestern community. Utilizing a hermeneutic analytic approach, I learned that middle school students describe and explain elementary science experiences in many interesting ways. For example, students shared a preference for participating in hands-on, active, or engaged learning experiences over more passive forms of learning science. Students wrote favorably and in-depth about doing dissections during each elementary grade. Another important finding was the role of the teacher in the elementary science classroom. Teachers may positively or negatively influence science experiences for students. Some of the important implications for this work include social and emotional aspects of teaching and learning. Teachers can learn how instructional practices and classroom relationships influence a student's science experience. Student benefit by personally reflecting on prior learning experiences and become empowered when they share their voices in science classrooms. School decision makers can benefit when they have robust measures of academic outcomes that include qualitative information that includes the students' perspective and tells a more complete story. And finally, the research community can benefit from new research that supports and extends studies of lived elementary science experiences using the science autobiography as a tool for eliciting student voice.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Thanks be to GOD, from whom all the blessings in my life have flowed.

Chapter I

Introduction

“In a climate that respects the market and the consumer it is strange that pupils in school have not been seen as consumers worth consulting.” (Rudduck & Flutter, 2000)

A scientifically educated citizenry is equipped to problem solve by making educated decisions to improve the quality of life for all people. In fact, being literate in science has been deemed essential to life on Earth (Zen, 1990). Studies reveal that many students have already started thinking about science careers by middle school or even the end of elementary school and sustained positive engagement in science experiences at the elementary level have been linked to a student’s prolonged interest (Lindahl, 2007; Osborne, 2007; Maltese & Tai, 2011). Arguments have been made in support of early foundations because students' aspirations towards science are formed before middle school (Lindahl, 2007; Maltese & Tai, 2010) they are unlikely to change dramatically (DeWitt & Archer, 2015). I believe middle school students have important views to share about their elementary science experiences. If we want to better understand elementary science from the students' perspective, we need to ask them to explain and describe their lived experiences.

Elementary science is tested once, at the end of 5th grade in Texas. Based on scores from that 5th grade state science assessment, many students are struggling to grasp foundational science concepts (Texas Education Agency, 2022). Low proficiency levels in foundational learning indicates some elementary students are not being adequately prepared in science.

One problem with this is that state test scores may be used to determine access to more rigorous or advanced coursework in middle school and can influence academic pathway opportunities in science. When 5th grade test scores in science are high, we can conclude that students have achieved an acceptable level of preparation, knowledge, and skills needed to advance from elementary school. When 5th grade test scores in science are low, we can conclude that students have not achieved an acceptable level of preparation, knowledge, and skills needed to advance from elementary school.

From 2016 to 2019, approximately 26% of students in Texas were deemed academically unsuccessful in elementary science learning as measured on the annual state assessment completed at the end of 5th grade (Texas Education Agency, 2022). After the Covid-19 pandemic in 2020 and 2021, 39% of students were deemed academically unsuccessful in science across the state. However, this decline may be attributed to school closures, necessary adjustments made to instructional modality, and limited test preparation. Scores for the 2022 school year improved to 34% of students in Texas scoring below passing on the state assessment in 5th grade science (Texas Education Agency, 2022). While a majority of students are deemed academically successful in science at the end of elementary school, outcomes suggest there is room for improvement.

There are plausible reasons why 5th grade science scores are low in the state of Texas. For example, a priority has often been given to mathematics and reading instruction over science instruction and this reduces time for science instruction (VanFossen, 2005). Other reasons include a lack of teacher preparation in science (Duschl et al., 2007; Lederman, 1992) and the quality and amount of instructional resources and supplies available in science (Oakes, 1990). The rate of failure in elementary science learning is concerning, and it does not have to be that way. If we accept state test scores in science as accurately depicting a student's academic knowledge and skills, "what students should know and be able to do" (Texas Education Agency, 2022), then this is a problem of practice. We can conclude students are not prepared with adequate knowledge and skills in science, and something must be done.

Elementary schools follow many similar organizational and structural patterns but also represent a wide variety of approaches to teaching and learning science. Many factors have been examined using quantitative methods in an attempt to explain student performance on the state assessment in science. There may be disparity in educational opportunities that produce the discrepancies in student outcomes in mathematics and science (Oakes, 1990). Using data from a national survey of mathematics and science from 1985-1986, Oakes (1990) found categorical differences in learning opportunities between low socioeconomic schools and more advantaged schools. Different types of students were shown to receive dissimilar experiences in mathematics and science learning. Specifically, findings showed that compared to more advantaged schools, schools in low socioeconomic and high minority settings were likely to face challenges in obtaining quality educational resources for mathematics and science. Students in those same marginalized settings received substandard instruction resulting from the inferior learning materials, facilities, and inadequately prepared teachers. These factors led to notable academic differences when measured at the secondary level. Findings also showed that low-ability students attending more advantaged schools had a better opportunity to receive more rigorous mathematics and science instruction than their high ability peers attending low-socioeconomic, high minority schools (Oakes, 1990).

In another example, Tenebaum and Ruck (2007) completed a meta-analysis and found teachers had higher academic expectations, and were more likely to make positive referrals, for

Asian and European American students over Latino/a or African American students. They also discovered teachers had more positive speech patterns with European American students over minority students and concluded those practices created disparity in educational opportunities for Latino/a and African American students.

School systems are often structured to weigh quantitative outcomes of science learning, like test scores and grades, more heavily than qualitative measures, like interviews, focus groups, or narrative writing, that produces the human side of the education story. Quantitative methods can tell us something, but alone, do not provide the complete picture of a student's learning experiences. To understand and give meaning to the highly subjective, unique personal lived experiences of students, we must gather descriptive explanations. One approach is to use qualitative methods to fill gaps in understanding by asking middle school students to describe and explain their lived elementary science experiences.

The qualitative side of the elementary science story is missing and can expose new understandings (Van Manen, 2016) and will tell a more nuanced story of science teaching and learning. In contrast to quantitative methods that rely on statistical data, qualitative methods rely on rich descriptive data that can "lead to serendipitous findings" (Miles et al., 2018, p. 3) and may offer new plausible explanations for phenomena of interest (Miles et al., 2018). This does not mean that doing qualitative research is easy, instead, it is quite complex. Qualitative methods are complicated to conduct, are considered highly subjective, and can be open to multiple interpretations (Denzin & Lincoln, 2018; Miles et al., 2018). In their *SAGE Handbook of Qualitative Research*, Denzin and Lincoln (2018) provide competing definitions of qualitative research methods. However, for the purposes of this study, a general definition extracted from their work will be used to define qualitative research. Qualitative research is a "situated activity that locates the observer in the world" (p. 10), that uses interpretive practices to discover, and narratively describe: what people do, how they make sense, and how they create meaning from their actions (Denzin & Lincoln, 2018).

One example of qualitative research involved middle school African American girls' construction of science identity (Brickhouse et al., 2000). Authors maintained that the way a student identifies in science is influenced by the many ways they participate in science and how they are seen by others. Personal profiles were constructed using interviews, observations, and focus groups. These profiles were then used to understand how a small group of African American middle school girls constructed science identities. Among girls with a demonstrated interest and aptitude for science, the ones that followed more compliant behaviors and traditional social roles had more positive responses from their teachers. They were also seen as more eligible for advanced science, over their less compliant peers. For example, turning work in on-time and being well-behaved were two criteria used to determine entrance into more rigorous, high school coursework, regardless of student interests or academic outcomes (Brickhouse et al., 2000). What this shows is that teachers, students, and others make decisions that essentially track students into certain science courses at the junior or high school level. The basis for decisions may include criteria that rely on pre-existing stereotypes or personal characteristics rather than academic accomplishment or potential. The very practices that researchers identified, disputed, and often referenced as invalid techniques.

In the study, qualitative methods provided a way to capture and expose individual stories from participants. The narratives were more detailed and personal than what quantitative methods alone could have produced. The qualitative approach to understanding ethnic science identities of African American middle school girls provided rich and textured profiles and depicted the various ways they engaged in science. This study illustrated how qualitative data can be used to describe and explain reasons a student perseveres in science, more than quantitative data on gender and stereotypical norms.

Over decades of examining school topics, the outcomes that have been used to drive and promote change in schools typically do not involve students' voices. There are however, strong normative arguments to support student involvement and participation (Levin, 2000) when telling the complete story of science. The students' side of the science education story – those directly participating at the classroom level, those whose meaning is derived from personal experiences, and those who are openly rewarded or penalized by science education outcomes – should be included in decisions made about science education (Hagay & Baram-Tsabari, 2012; Jenkins, 2006; Levin, 2000; Lubelfeld et al., 2018; Mead & Métraux, 1957; Polman & Pea, 2001).

We need a way of understanding the intricacies of elementary science, and how it is lived and experienced from the students' view. In the literature review that follows, I will highlight some of the ways people have attempted to achieve that understanding.

Chapter 2

Literature Review

Students are experts on their own lives and lived experiences and hold unique expertise about certain aspects of schooling that involve the process of teaching and learning (Cook-Sather, 2006; Lubelfeld et al., 2018; Oldfather, 1995). Student voices can be an effective mechanism for feedback about teaching and learning (Gomez-Arizaga et al., 2016). Views of school that come directly from students are important because they are active and required participants of school. Being directly affected by school decisions, some argued they have an overarching and democratic right to participate in shaping school decisions (Fielding, 2007; Fletcher, 2004; Laux, 2018; Lubelfeld et al., 2018; Ochoa-Becker et al., 2001; Rudduck & Flutter, 2000). Student voice research may be used to drive teacher accountability and performance evaluations (Fielding, 2001) however, that is not the intended purpose for this work. This study will examine student voice as research to understand the lived elementary science experiences of students.

Systems of schooling were founded on hierarchical decision making, imbalanced power dynamics, and policy-driven standards that often produce punitive accountability practices. Teaching styles that follow a more authoritarian model of teaching and learning tend to derive solutions to less favorable outcomes from only partial understandings. Those teaching practices are not easy to adjust because they were founded on a more monologic model of learning where students passively accept what is taught, rather than being active and collaborative participants in the learning (Alexander, 2006; Lubelfeld et al., 2018). These traditional and longstanding practices present constraints that, some argue, are fundamentally out of date based on educational soundness and current climate (Osborne, 2007; Polman & Pea, 2001). Another challenge schools face is that of teacher preparedness to teach science. Elementary teachers may not have depth in understanding scientific concepts. As a result, they may rely on activities that are less authentic, relevant, and engaging for students (Duschl et al., 2007; Lederman, 1992).

Decisions made about school may be based on outcomes that are removed from firsthand experiences of the children the schools are designed for (Lubelfeld et al., 2018; Rudduck & Flutter, 2000). Some argue that sustainable education reform efforts cannot and should not proceed without meaningful and ongoing involvement of students as active participants (Levin, 2000). Yet, despite compelling empirical evidence and the promise of valuable insights and perspectives about educational experiences, students are rarely engaged in conversations about, review of, or decision making about teaching and learning (Hagay & Baram-Tsabari, 2012; Laux, 2018; Mead & Métraux, 1957; Mitra, 2018; Oldfather, 1995). Some argue that giving students a voice could adversely challenge traditional systems and uncover deeply rooted sociocultural issues (Jenkins, 2005). Others have advocated for inclusion of student voice to fill gaps left by out-of-date structures and systems of schooling that tend to exclude the student from conversations about them and decisions made on their behalf. Students spend a lot of time in school and are a great resource for examining effective teaching practices (Lubelfeld et al. 2018). They also care about school and want to have engaging experiences (Oldfather, 1995). Regardless of perspective, students are the experts on their own unique lived experiences and only they can offer firsthand insights on what it means to be on the receiving end of science education. Educators must listen to the voices of students, hear what they have to say, strive to understand their meaning, and we must work in partnership towards improved academic outcomes.

Student Voice Defined

In this study, I define student voice as adults soliciting students to share their authentic and personal lived educational experiences. Student voice has been expressed in different ways, including, writing, speech, or drawings. In elementary school settings, adults solicit voice from students by providing time and space for them to share input and feedback about personal lived educational experiences. Ideas behind the concept of student voice are premised on several beliefs. First, participation can serve to increase interest and reduce disengagement and low self-esteem among learners (MacBeath et al., 2003; Rogers, 2005). Second, insights provided by students may help improve learning experiences and academic outcomes for all (Fielding, 2007; Rudduck & Flutter, 2000). Finally, I argue that students should respond more favorably in settings where they are worked-with, rather than subject-to, learning.

Student voice has been called a pragmatic concern (Levin, 2000; Rogers, 2005) that offers a way for students to share their lived experiences through individual thoughts, ideas, opinions, perceptions, and perspectives (Gonzalez et al., 2017). When students share their voice, they use deeper cognitive processes to reflect on lived experiences (Rogers, 2005). Student voice provides a way to capture the subjective, human side of the education story and serves to position students in a different role, as active participants. When students have a voice, they are represented. They have active opportunities to communicate, share insights, express opinions, and contribute to decisions about teaching and learning (Jenkins, 2006; Lubelfeld et al., 2018); Rogers, 2005). Students also learn qualities and responsibilities of democracy (Fletcher, 2004; Kahne et al., 2022; Rudduck & Flutter, 2000) and master knowledge and skills required of progressive science learning and application (Polman & Pea, 2001). And finally, student voice opportunities have been shown to contribute to the development of key assets for high school students when coupled with adult and student relationships (Mitra, 2004).

Student voice research in education has sometimes been used by researchers and educators in understanding unique student perspectives or what students think and know about education (Conner et al., 2015; Jenkins, 2006; Laux, 2018; Rogers, 2005). In their systematic literature review of K-12 student voice research in the United States, Gonzalez et al. (2017) found the usage of student voice in research was trending upward. In the 49 studies they selected between 1990 and 2010, they found none met their selection criteria before 1996. More than 80% of the studies reviewed on student voice occurred after 2000. A vast majority of those studies, over 70%, occurred after 2005. Mitra (2004) also noted a shift in the focus of student voice work from the early 2000s that moved from “rights and empowerment” to a “notion that student outcomes will improve and school reform will be more successful if students actively participate in shaping it” (Mitra, 2004, p. 652).

In another systematic literature review, Laux (2018) examined 29 studies on student voice in science education settings. She reported that despite positive benefits of including student voice in science classrooms, students are not often consulted and few studies described ways of implementing pedagogical changes based on input from students. Several themes emerged from the review of student voice work that included better communication and improved student-teacher relationships. Studies found students were capable partners, had relevant experiences, and were able to help negotiate selection of science topics. Studies also revealed student specific benefits like improved agency, empowerment, and identity in science.

Laux (2018) concluded student voice in science education is vital and ignoring student voice could be averse to students' learning experiences.

At the most basic level, enacting student voice involves providing time and space for students to share their thoughts, opinions, ideas, and critiques, offers an opportunity for adult listening, and creates pathways for partnerships in collaborative problem solving where meaning is co-constructed (Alexander, 2006; Conner et al., 2015; Cook-Sather, 2020; Mitra & Serriere, 2012). Advocates for student voice research argue that it can and should influence policy decisions, democratic principles, school change efforts, or a focus on teaching and learning. What counts as voice should include big and little things, anecdotal or trivial issues, and generally topics that both matter to students and are relevant to their learning experiences (Lubelfeld et al., 2018; Jenkins, 2006). The goal of the proposed study is to elicit the voices of middle school students to understand how they explain and describe their lived elementary science experiences. Findings from my study may provide input and direction for policy decisions, school change efforts, and teaching and learning practices.

Early work in Student Voice

Current work on student voice in science education has been informed by a long history of consideration and discourse around the topic. Long ago, Dewey (1910) contributed to the topic of student voice in science education when he argued for the benefits of learning directly from students about pedagogical practices. He promoted the idea of asking students about their learning experiences in science education and recommended using those understandings to inform instructional practices. Half a century later, Mead and Métraux (1957, p. 357) claimed:

> There is a great disparity between the large amount of effort and money being devoted to interesting young people in careers as scientists or engineers and the small amount of

information we have on the attitudes these young people hold towards science and scientists.

In their pilot study, they used a nation-wide sample of over 120 essays from high school students to examine students' beliefs about science. They used student voice data as a way to reimagine how scientific life and science could be presented and understood. The research team recognized a big gap between what students really think about scientists and science and engineering careers in comparison to the number of resources used to increase student interest in science and engineering careers. Study results covered broad territory and many of the views and recommendations still have relevance today. For example, Mead and Métraux (1957) recommended beginning in kindergarten "to open children's eyes to the wonder and delight in the natural world" (p. 389), a concept they believed was foundational to support and extend young children's interests in science. They promoted the use of classroom techniques that required group projects and active participation by students to replace more passive forms of knowledge transfer from teachers. They also argued that portrayals of scientists were off-putting to many young students because scientists were depicted in positions that were unattainable to many students, instead of being depicted in everyday roles that children could relate to. A more balanced portrayal of science was recommended that is more appealing as "a vineyard in which there is a place for many kinds of workers" (Mead & Métraux, 1957, p. 389).

Student Voice as Pedagogy versus Student Voice as Research

The concept of student voice in education is neither new nor understudied and has taken on different orientations. Student voice may involve a focus on pedagogical practices in traditional classroom settings where teachers routinely interact with students during teaching and learning. In these settings student voice may involve solicited or unsolicited feedback from students about curriculum, pedagogical practices, or learning processes. One form of student voice work is dialogic pedagogy, where teachers and students work in close proximity to critically interrogate classroom practices and approaches to learning (Alexander, 2006; Teo, 2019). On the other hand, student voice *research* may involve researchers eliciting student voice to understand personal experiences. This approach, which has been labeled a new opportunity for students to share their voices, has been called a pillar of successful school reform (Jenkins, 2006). Further, student voice as research has been considered potentially transformative when student voices are elicited, elevated, and heard (Lubelfeld et al., 2018).

In Chicago, during 2017-2019, a large-scale quantitative study was conducted to examine student records and results from a district-wide student survey. Researchers discovered that students had better grades and attendance patterns in high schools where students perceived there was a responsiveness to their critiques (Kahne et al., 2022). Using the study findings, district and campus leaders established a strategic plan to integrate student voice in routine decision-making and school improvement efforts. However, Kahne et al. (2022) warn against using student voice in only narrowly defined ways or to focus only on “mainstream academic goals” (p. 409). Instead, they recommended that student voice be used in more broad and democratic ways.

Student voice should be elicited in a purposeful way; for example, teaching practices were examined in elementary social studies settings. The purpose was to determine if teachers used practices that elicited student voice and whether those practices were aligned with standard democratic principles (Ochoa-Becker et al., 2001). Researchers compared teachers’ authentic practices to a standard model of democratic decision making that was not initially disclosed to teachers. What they observed was teaching practices that used high levels of student-teacher respect, but teachers did not routinely engage in practices focused on open dialog or two-way exchanges with students. In one instance, researchers described a teacher providing an opportunity for students to use higher level thinking, but “only minimally democratic” (p. 267) principles to resolve a non-instructional conflict inside the classroom. When teachers applied practices that engaged students and provided ways for them to actively participate, students responded favorably. Researchers concluded that increased training for teachers and students would be beneficial and improve classroom interactions. They suggested that professional development for teachers would encourage a shift in control from “hierarchical power arrangements” (p. 269) into more democratic and facilitative practices. And further, they offered that approaches designed to elicit knowledge and experiences from students would help both teachers and students develop improved habits and expectations.

Student voice may also describe research where students actively engage in research studies. For example, in 1957, early investigators of student voice, researchers Mead and Métraux, conducted a pilot study to “really find out what all high-school students think as a group of people…about science and scientists” (Mead & Métraux, 1957). In another example, Oldfather (1995) worked with students as co-researchers over a 5-year period. Beginning in elementary school student voices were engaged as partners to examine teaching, learning, and motivation. Findings revealed that students had unique expertise about their own experiences and “students are the primary stakeholders for understanding the roots of their own intrinsic motivation to learn” (p. 132). By participating in research as partners and co-constructors of knowledge, students felt honored, listened to, and valued. And students stated they believed they could make a difference and make school a better place for others (Oldfather, 1995).

There is tremendous value in using student voices and convincing arguments have been made to promote authentic student voice in settings where students are empowered to work with clear purpose in partnership alongside adults (Kahne et al., 2022; Mitra, 2018). Studies using student voice in secondary or higher education science settings have exposed student perspectives (Brickhouse et al., 2000; MacBeath et al., 2003), and have shown students can and should take ownership of their education (Cook-Sather, 2006; Gonzalez et al., 2017; Mitra, 2018; Rudduck & Flutter, 2000). Student voice can be transformative in school improvement strategies when adults listen and act on what students have to say (Conner et al., 2015; Cook-Sather, 2006; Fielding, 2007; Fletcher, 2004; Lubelfield et al., 2018; MacBeath et al., 2003). Laux (2018) and others have argued for student voice as beneficial in empowering students to have a forum that produces a way to construct meaning and knowledge that is not solely teacher driven and set on knowledge transfer or fixed answers (Mitra, 2004; Polman & Pea, 2001).

Although it is widely accepted that effective decisions require input and active involvement from all participants, most school reform efforts are planned and carried out only by adults (Levin, 2000). When student voice has been solicited, it usually involves older students, those at secondary or higher education levels of school, not younger students in elementary grade levels (Mitra, 2018; Ochoa-Becker et al., 2001; Osborne, 2007). Gonzalez et al. (2017) conducted a systematic review of empirical research on student voice in the United States and found a majority of studies in K-12, nearly 70%, were conducted at the high school level and only 2% had been at the K-5th grade levels. There are explicit reasons for relying on more mature students to share their insights, opinions, thoughts and ideas about science education. Older students may be at a higher level of intellectual and academic development and are often more knowledgeable. They may be more articulate in descriptions and explanations, may have more thoughtful ways of telling, and may be more politically astute when reflecting on past experiences, even distal experiences (Ochoa-Becker et al., 2001).

At the secondary level, student voice topics tend to include student advocacy efforts that are socially significant. They may address broader issues, like rules or policies related to dress codes, discipline practices, cafeteria food, grading, or graduation requirements. Topics related to course content, curriculum, or pedagogical practices related to teaching and learning are often overlooked (Gonzalez et al., 2017; Jenkins, 2006; Mitra, 2018; Rudduck & Flutter, 2000).

Laux (2018) argued that the exclusion of young student voices is an outdated view that diminishes the contribution students can make. Young students can offer valuable insights into more proximal elementary experiences despite arguments that consider younger students less focused, less knowledgeable, and less verbal about learning (Mitra & Serriere, 2012). Studies also show that student's aspirations in science are often formed before middle school and are unlikely to change (DeWitt & Archer, 2015; Lindahl, 2007; Maltese & Tai, 2010). This means we should understand how young students experience science in their younger years when academic interests are still being formed.

A case study involving fifth grade girls revealed benefits of doing student voice work with young students. Researchers examined developmental assets with students as young as 10 years of age. They discovered outcomes were positively aligned with outcomes from prior research with older students from secondary settings (Mitra & Serriere, 2012) In another example, elementary students were engaged as research partners in a collaborative investigation that sought to shift the paradigm between researcher and those subjected to research (Oldfather, 1995). Over a five-year period, elementary students were actively engaged in research about what motivates them and about teaching and learning processes. When asked why students were so willing to participate, the author noted that students are key stakeholders of their own learning, care about how they are taught, and best understand exactly what motivates them to learn. Students were seen as instrumental in the research work and their voices were described as important to establishing authenticity and trustworthiness of the findings (Oldfather, 1995).

In an illustration with qualitative methods and younger students, researchers Gomez-Arizaga et al. (2016) used interviews and student drawings with third graders. Their study examined students' perceptions of science class and a new elementary science curriculum. They identified students as informants that provided clear and deep views about science experiences. In their summary, researchers noted that young students were "capable of articulating views about their learning experiences during science class" (p. 431). The authors shared that words used by students were "clear reflections of the activities in which they participated and the content knowledge involved in those activities" (p. 440).

If student voice can be so powerful at the elementary level, why is it not more commonly elicited? There may be specific reasons that qualitative research methods may present specific challenges in elementary settings. For example, access to our youngest learners may be limited and the maturity level of young students can create unique challenges for researchers to interact directly with them (Mitra & Serriere, 2012; Ochoa-Becker et al., 2001; Oldfather, 1995). It may not be common in research to ask younger students about their personal, lived experiences, but when included, it casts them into a new and different light that may reveal hidden insights about teaching and learning. Younger students are in closer proximity to elementary grades than older students and are perfectly positioned to share their insights about lived experiences in science. These insights can serve to fill gaps in understanding about elementary science and will create a more complete and comprehensive view of science learning (Furman & Barton, 2006; Gomez-Arizaga et al., 2016; Mead & Métraux, 1957; Mitra, 2018).

We can learn a lot from the voice of younger students, and new understandings can inform adults about the holistic science learning story. Student voice as research can be beneficial to educators when based on the following arguments: students are producers of school outcomes (Levin, 2000), students have direct experiences and important thoughts and ideas about teaching, learning, and school (Gomez-Arizaga et al., 2016), and students should be engaged as partners in matters associated with elementary science improvements because their knowledge and perspectives can improve implementation efforts (Jenkins, 2006; Levin, 2000; Mitra, 2004).

Data from qualitative studies can help students, science educators, and decision makers explore the often hidden, rich and textured explanations and meanings students ascribe to their lived science experiences. Student voices expose new perspectives, like what it means to be a student participant on the receiving end of mandated education. In many public-school settings, state test scores are low and improvement strategies are often based on information that excludes the voice of students. Students have unique perspectives and can help unpack test scores by shedding light on reasons for low or high-performance levels that adults had not considered.

The outcomes of student voice include situations where students openly contributed perspectives about their educational experiences. In some cases, student voices have been used to disrupt social and power dynamics in schools where policies are not serving students' needs or interests (Cook-Sather, 2006; Kahne et al., 2022; Laux, 2018; Shapiro & Gross, 2008). Often these disruptions are led by students that elect to challenge certain practices or policies. Despite evidence highlighting benefits of student voice, most schools have not adopted democratic principles and policies that embrace the rights of all students as active participants in school wide governance (Gomez-Arizaga et al., 2016; McQuillan, 2005). Rather, poorly defined or narrow interpretations of student voice may actually serve to inhibit the voice of the student (Kahne et al., 2022; Ochoa-Becker et al, 2001). Students may become frustrated or disillusioned with the process when they do not understand the purpose or feel unheard (Oldfather, 1995).

Student voice research shows promise for exposing a new side of the science story that is drawn directly from both passive and active participants, those engaged and disengaged in learning (Gonzalez et al., 2017; Jenkins, 2006; Polman & Pea, 2001). Decision makers are more informed when they fully understand the phenomena of science education from the perspective of all participants, especially the recipients of science education and those most vulnerable to decisions based on outcomes (Lubelfeld et al., 2018; Osborne, 2007; Rogers, 2005). Findings from student voice work bring forth ideas from those on the frontlines of learning. These new discoveries will illustrate what it means to be an elementary science student, will serve to increase understanding and awareness about science learning experiences during foundational years, and will inform decisions made about elementary science. Students can provide important insights and feedback on what is currently working and they can help strategize ideas for new experiences. Students can also contribute important perspectives, insights, and suggestions for improvement regarding science teaching and learning that are compatible with their interests, needs and values.

Elementary aged students have shown the ability to articulate personal views and ideas about science learning experiences and have offered critiques, opinions, and beliefs about teaching methods (Daniels et al., 2001; Gomez-Arizaga et al., 2016). We should, therefore, not overlook the value or avoid close examination of student voice in elementary settings. A review of ways student voice has been operationalized follows to help establish context, situate this study, and connect readers with further information on the topic of student voice in elementary science education.

Student voice has been examined in different ways for different purposes. These examinations have used varied methodological approaches, and analytic techniques across different contexts (Gonzalez et al., 2017; Jenkins, 2006; Laux, 2018). This broad archive of empirical evidence provides invaluable insights towards a foundation for understanding student voice in science education. Research showed ways the phenomena of science education has been studied, analyzed, and reported. I gleaned guidance and direction for this study from these resources. When student voices have been included in examination and design of science education practices, positive outcomes have been recorded (Jenkins, 2006). The next section will highlight some of the positive outcomes from student voice work after an overview of early work in student voice research.

When teachers elicit student voices in the classroom, it often prompts collaborative partnerships to improve teaching and learning (Basu et al., 2009; Daniels et al., 2001; Mitra, 2004; Polman & Pea, 2001). This approach can present opportunities for students to be repositioned into more active roles in classrooms and can inform school decisions related to advocacy, policy, or other school reform efforts (Cook-Sather, 2006; Daniels et al., 2001; Furman & Barton, 2006; Jenkins, 2006; Levin, 2000; Rogers, 2005). When student voice is elicited by teachers, new opportunities arise for students to share thoughts, ideas, opinions and perspectives about things that matter to them personally (Jenkins, 2006; Mitra, 2004; Oldfather, 1995). These practices can serve to empower students and produce data that can be used to establish more democratic forms of school governance (McQuillan, 2005).

In one example, a visionary school leader regularly engaged elementary aged students in practices that elicited student voices including school wide democratic practices and classroom level pedagogical practices (Mitra & Serriere, 2012). Close examination of the school's democratic practice focused on students' efforts to change both the school and district rules for cafeteria menu options. A small group of girls collaborated with their teacher and principal to develop a new menu that was more compatible with the religious and health needs of students. This student voice work prompted five youth development outcomes: student agency, sense of belonging, efficacy, discourse, and competence (Mitra & Serriere, 2012). When teachers elicited student voices, they encouraged the development of students' agency in science. They shared scientific concepts and helped make connections for students that led to the autonomous student actions (Brickhouse et al., 2000; Cook-Sather, 2020).

Basu et al. (2019) examined teachers elicitation of student voice in a high school setting. The students took on active roles in science class and routinely collaborated with their teachers. Outcomes involved the development of science lesson plans that included real-world problem solving and content that was of greater interest to students (Basu et al., 2009). In another study of teacher’s elicitation of student voice as pedagogy, students developed agency when they took on influential positions in a community-wide health initiative that stemmed from scientific concepts being studied in the classroom (Furman & Barton, 2006). Overall, students gained a lot of value from the teacher's elicitation of student voice. For example, collaborative classroom practices showed students and teachers negotiating topics of study (Hagay & Baram-Tsabari, 2012), and instructors created and carried out student driven lesson plans (Basu et al., 2009; Polman & Pea, 2001). Hagay and Baram-Tsabari (2012) concluded that students are capable partners that can demonstrate value through a concept called “shadow curriculum” where student interests become embedded in lesson plans and teachers entertain students’ questions outside the course curriculum.

To a lesser extent, student voice has been elicited and used in educational research. When researchers elicit student voices, it broadly offers a way to understand student perspectives, perceptions, interests, opinions, and attitudes about school and may help expose students' plans for the future (Jenkins, 2006; Gonzalez et al., 2017; Oldfather, 1995). Student voice has shown positive outcomes when used in research to describe a strategy, a process, or just as a way to engage students by connecting their speech with meaning (Laux, 2018). When students believe their voices are heard, they feel valued and legitimized (Conner et al., 2015; Mitra, 2018; Mitra & Serriere, 2012; Rudduck & Flutter, 2000).

Outcomes of student voice as research work have shown improvements in students' grades, attendance, competency, and overall interest in school (Kahne et al., 2022; Polman & Pea, 2001). Other benefits include new and unexpected meanings like transformative communication practices (Polman & Pea, 2001), strengthened learning, enhanced culture, and improved community relationships (Fletcher, 2004; Polman & Pea, 2001). Feedback from students also provides invaluable input for evaluation of programs, curriculum, or interventions (Gomez-Arizaga et al., 2016).

Another use of student voice involves both teachers and researchers eliciting student voice. In an example at a high school, interactions were observed in an earth science classroom over a three-year period. The observations involved both teacher elicitation and a researcher's elicitation of student voice (Polman & Pea, 2001). The study exposed ways collaborative exchanges between teachers and students and students and researchers could be effectively used to expose new insights, interpretations, and unexpected meanings. According to authors, mutually beneficial exchanges occur when "participants in social interaction work to create meaning that neither participant alone brings to the interaction" (Polman & Pea, 2001, p.227).

We should not undervalue the need for and importance of training teachers and students in effective ways to conduct collaborative work. Polman & Pea (2001) stressed that teachers must have the right tools to understand how to work with students in new ways. Active participation between students and teachers may involve areas that are new and lack pre-existing or shared meanings. Researchers captured classroom teacher elicitation of student voice in *rituals* noted as communication about topics that already had shared meanings. Simultaneously, researchers elicited student voice through interviews designed to extract new perspectives on science projects and other classroom events (Polman & Pea, 2001). Results showed how teacher and researcher elicitation of student voice provided new insights and was transformative. Students "accomplished projects more sophisticated than they could have originally conceived" (p.236) and balance was established in the classroom between teachers and students.

Regardless of how elicited, as pedagogy or as research, student voice work has been labeled effective in influencing outcomes of school practices in K-12 settings when student voices are elevated and activated (Conner et al., 2015; Furman & Barton, 2006; Kahne et al., 2022). However, soliciting student voice does not automatically produce benefits until interpreted, shared, and something is done with new understandings (Polman & Pea, 2001). And Kahne et al. (2022) cautioned that student voice work alone has not always produced change and can become merely *symbolic* if adults are not responsive to student voice. Similarly, (Fielding, 2004) encourages elicitors of student voice to avoid "dangers of unwitting disempowerment" (p. 304) that may serve to reinforce existing power structures within schools. Others caution usages of student voice that may position them only as "targets of educational policy and passive beneficiaries of educational process" (Conner et al., 2015).

To capitalize on student voice and realize the potential of transformational change, internal factors and cultural shifts may need to be enacted in educational settings (Fielding, 2007; Lubenfeld et al., 2018; Polman & Pea, 2001). Student voice is powerful and can be activated in many ways. For this study, student voice was elicited through research using the science autobiography to understand students' life-world experiences of elementary science.

Student Voice as Research Study

Past work in student voice research covers a variety of methodological designs, data gathering techniques, and analytic procedures. For example, elicitation of student voices may be structured and organized like when administering a science autobiography to elicit students' voices. Elicitation of students' voices could also be more spontaneous, as in a protest or activist cause to promote a particular idea, concept, or policy (Kahne et al., 2022). Data collection has been carried out in many different ways as well, using student observations, surveys, interviews, focus groups, suggestion boxes, written narrative, or drawings. In schools, a wide variety of communication approaches can be involved in elicitation of student voice. Examples include verbal conversations between students and teachers, students and administrators, or students and other adults. These conversations may be instigated by adults or by students and may take place inside or outside the classroom and conversations may be engaged as one-on-one or in group exchanges (Conner et al., 2015).

In one example, researchers examined student voice using interviews and focus groups with elementary students, teachers, and administrators to examine civic efficacy (Mitra & Serriere, 2012). In the study, students were found to experience positive developmental asset outcomes when they were involved in advocating for changes within school and district rules. In another example, elicitation of student voice was captured through written narratives that were initiated by first grade students when they wrote letters of protest to their local newspaper about the importance of citizen recycling (Ochoa-Becker et al., 2001).

Analytic approaches include quantitative, qualitative or mixed methods. One large scale panel data study used high school student records and student responses to a school district administered survey. The purpose of the study was to examine school responsiveness to student voice. Researchers found positive outcomes associated with grades and attendance (Kahne et al., 2022). Case study methodology has also been used to examine and compare elementary and secondary students' sense of agency, belonging, and competence in science education (Mitra, 2018; Mitra & Serriere, 2012). In another example, case study was used to isolate teaching practices that supported student voice in the classroom (Ochoa-Becker et al., 2001).

In 2016, Gomez-Arizaga et al. had third grade students create drawings of themselves in their science classrooms to see how they revealed their scientific-self. Researchers sought to expose the student's inner ideas, feelings, and ways of solving problems through visual representations of the science classroom. As a follow-up to the drawing activity, researchers provided students with a prompt so that students could explain their drawn renderings. Results were analyzed using a method that allowed the researchers to analyze the students' perception of a scientist (Chambers, 1983, as cited in Gomez-Arizaga et al., 2016).

Elicitation of Student Voice

Student voice has been elicited as research in a variety of ways, including interviews, focus groups, drawings, or written narratives. Van Manen (2016) advocates for written narrative in research: "if we wish to investigate the nature of a certain experience or phenomenon, the most straightforward way to go about our research is to ask selected individuals to write their experiences down" (p. 69) and allows what is talked about to be visible. Van Manen (2016) adds that protocol writing derives meaning from its Greek roots meaning original draft. He offers caution when eliciting writing because he claims, "most people find writing difficult" (p. 64) and suggests young children may present a handicap to research because they lack education and life experience. One form of written narrative that has proven successful in eliciting student voices is the autobiography.

The autobiography has been legitimized as a strategy for interpretive research, critical analysis, and understanding, and can be effectively used to capture students' voice in science education (Koch, 1990). The autobiography has also been used successfully in mathematics education research and has been named a mathography or personal math history. For example, the mathography was used in a high school mathematics setting to understand how students described and commented on individual experiences with mathematics (Gargroetzi & Lawler, 2017).

With roots as far back as antiquity, first-person autobiographical writing was more formally named in the early nineteenth century as a form of self-reflection where aspects of childhood and upbringing could be disclosed (Pascal, 1960). Calabrese-Barton, (2000) describes two important aspects of autobiography that empower both the teller and the listener. One is telling one's own contextual story and using that story as a catalyst for engaging in conversation with another. The other aspect is constructing meaningful understandings of science.

The science autobiography as a personal narrative serves to expose a student's life, attitudes, identities, and other learning experiences (Gargroetzi & Lawler, 2017). Another view of the autobiography is as a tool kit (Roth, 2000). The science autobiography is an instrument that offers a way for students to share first-hand accounts of their science experiences. Students of all ages can provide important insights into teaching and learning if they are given the time and space to do so. It has broad and historical application in the field of anthropology and has been defined as a narrative of one's life that is self-written. The autobiography has been used in science education to tell one's story and to share that story with others (Barton, 2000) and "provides a space to allow science to emerge from one's lived experience" (p. 40). Storytelling provides a mechanism for children to express their thoughts, make meaning of their lives, and allows for a sharing of lived events, as well as who students are and who they want to become (Kane, 2012). Autobiographies produce narratives that are textured with social and cultural understandings that are organically embedded in the subject's lived experiences (Van Manen, 2016). These embedded social-cultural interactions help define what and how we remember and what it means to be a self (Fivush & Haden, 2003).

To feature student voices as research, this study used a phenomenological study design to examine middle school student's reflections of elementary science. Using the science autobiography, I captured individual student reflections that were closely examined, analyzed, interpreted, and distilled to create common meanings and a more universal essence of elementary science (Van Manen, 2016). Science autobiographies provided a way to capture rich and textured explanations and descriptions that students attributed to their reflections of their lived elementary science experiences.

Theoretical Framework

As an interpretive or hermeneutic phenomenological dissertation, this study sought to describe the essence of elementary science, how it exists in the lived experiences, and how it is manifested through reflection by middle school students. The aim of the approach was not to prove or disprove, but instead to gain insight and expose meaning from the students themselves, as those having experienced the phenomenon of interest. I used the grounding philosophy and framework of Martin Heidegger (1889-1976) and Hans-Georg Gadamer (1900-2002) as the lens to examine middle school students' science autobiographies. I selected this framework because I sought to more fully understand the lived elementary science experiences directly from the students themselves (Gadamer, 1975; Heidegger, 1988).

Students are the ones that have experienced first-hand the phenomenon of interest, elementary science, and are therefore in the best position to reveal rich and detailed meanings. Through writing, students expressed their experiences of elementary science education. Using hermeneutics as the theory and methodology of interpretation, I worked to move beyond decoding the written text and applied a transparent and iterative analytic process (Miles, Huberman, & Saldaña, 2018). The process of analysis worked towards establishing a true relationship between the context and text to produce an enhanced understanding (Sheehan, 2014). The approach was suitable for this study because it provided a way to examine the varied and complex lived experiences of individual students as the source of those experiences. The results served to expose how students used reflective thinking to make meaning of their personal lived experiences. The study aimed to uncover meaning by understanding the essence of lived science experiences through an iterative interpretive process. The process involved a repeated circular movement back and forth between parts and the whole text to extract meaning.

Phenomenology has been used in architectural design because it emphasizes a personalized and inward reflection of people (Lessem & Schieffer, 2010). Architectural designs that have been created with a more personalized approach are considered more appealing and marketable to consumers. For this research study, the same rationale was used to support selection of phenomenological research as the method and philosophical framework. Teaching and learning could be more compatible and appealing for students, as consumers, if designed to reflect a more personalized approach. My underlying belief is that approaches to teaching and learning can be best designed by examining all components, including physical and human components. Students have often been absent from conversations about teaching and learning and are often positioned as passive recipients of teaching and learning practices. In order to change this tradition and improve understanding of student's needs and interests, we must first elicit and listen to their input, feedback, and perspectives. The science autobiography is a data collection instrument that provides a way to capture student voices so they may be heard and better understood (Koch, 1990). In an article on autobiography and hermeneutics, Friesen (2020) credits Dilthey (1927) as describing the autobiography as the most informative way to examine one's life (Friesen, 2020). Though this data collection method has not been used extensively in phenomenology, I believe the science autobiography is well aligned to serve the purpose of phenomenology; what Van Manen (2016) calls bringing forth speech. Writing is an authentic and direct way to have students share their lived elementary science experiences. After students write their science autobiographies, new personal insights about teaching and learning are revealed and explored through the descriptive explanations students provide.

Hermeneutic phenomenology requires the researcher to participate in ongoing personal reflection and insightfulness to create a balance between subjective and objective aspects of individual lived science education experiences (Heidegger, 1988). This approach led to rich and textured descriptions of students' lived elementary science experiences that helped extract the essence of participant meanings (Miles, Huberman, & Saldaña, 2018).

There are varied approaches to addressing the problem of subjectivity in phenomenological research. For example, Heidegger builds on the works of Edmund Husserl

(1859-1938), who believed nothing should be assumed in understanding (Peoples, 2020). Husserl opposed the use of frameworks as a way to gain pure understanding of a phenomenon of interest. In Husserl's view, humans were seen as "subjective spectators of objects" (Zahavi, 2003) and he argued for a different way of thinking that minimizes the subjective bias (Peoples, 2020; Zahavi, 2003). *Bracketing* was promoted as a process to transcend oneself, or suspend personal judgements, to get at the pure essence of something. Husserl created a way for the researcher to attempt objectivity "to become like a stranger in a strange land - kind of like an alien coming down to planet Earth for the first time" (Peoples, 2020, p. 30).

The approach I selected aligns with Heidegger's philosophy that recognizes the impossibility of pure objectivity and instead focuses on embracing one's subjectivity and using it as an integral part of interpretation and understanding. Heidegger rejects separation of consciousness, experience, and mind, and instead accepts that the researcher cannot extricate oneself from others. Heidegger asserts one should not attempt to suspend judgment because it is impossible to do as being in the same world we observe (Heidegger, 1988). The word Heidegger coined for this way of viewing the world was *Dasein*, which translated, means "being-there" and has been interpreted in slightly different ways. Generally, *Dasein* means a person's being in the world of meaning and recognizing that meaning gives significance to things we encounter or come into contact with (Peoples, 2020; Sheehan, 2014).

Gadamer, a scholar of both Husserl and Heidegger, offered new insights into Heidegger's thinking that provided a guide for this work and a way of embracing personal bias as an essential element of the process (Gadamer, 2013). He suggests ways for one to share in the work by embracing how one's own thinking and the thinking of another can be fused to create renewed awareness and understanding (Dibley et al., 2020). There is a reciprocity that occurs between researcher and participant or between researcher and text that supports hermeneutic thinking. This is not seen as a prescriptive way to gain understanding, rather, more of a description that supports being guided by the object of interest (Gadamer, 2013). Reciprocity offers a way to unlock hidden meanings and more fully understand. Unlike quantitative research where the researcher's influence or bias is intentionally avoided, the hermeneutic researcher embraces their situatedness in the research and becomes an important and intentional part of the design. There is immense value to be gleaned by recognizing this interrelationship between researcher and participant. Hermeneutics provides a mechanism for acquiring new knowledge where preconceived notions or beliefs are continually reviewed and revised so that new understandings may emerge (Van Manen, 2016).

Chapter 3

Methodology

For this study, I used an interpretive or hermeneutic phenomenological approach using the science autobiography to examine, interpret, and understand how middle school students described and explained their elementary science experiences. The hermeneutic phenomenological approach is appropriate for this study because my goal is to understand what it is like to experience elementary science. I believe this can best be accomplished by eliciting the voice of students because their experiences are not well known.

The written autobiography provided a mechanism to probe and explore the lived experiences of middle school students and to expose their inner world and extract the essence of their meaning (Koch, 1990; Gadamer, 1975; Heidegger, 1988; Miles, Huberman, & Saldaña, 2020). Friesen (2020) quotes Dilthey as saying that autobiographies are “the highest and most instructive form of the understanding of life” (pg. 100). My study used written narratives to explore students’ personal experiences in elementary science. New meanings were exposed and nuanced explanations for academic outcomes were brought forth (Kane, 2012). These findings revealed complex understandings of how students make connections with science.

I chose to work with middle school students for two reasons. First, since my goal was to capture elementary science experiences, including grades K-5, it made sense to inquire about those experiences from students soon after they completed those experiences. Within a couple of years after completing 5th grade, students' recollections of elementary experiences may be fresher and may shape their thinking and decisions about science. Students in middle school have more recent memories of their elementary experiences than older students. Some believe that time and experience may change how we view and understand things (Peoples, 2020). Second, middle school students have moved on from elementary school but are most proximal to elementary school experiences. This was an important consideration because I wanted students to feel comfortable being fully transparent in their disclosures of elementary experiences, without concern for potential repercussions. My goal was for students to be unhindered in their writing. I wanted students to honestly critique any and all science experiences, including environment, teaching and learning practices, former teachers and administrators, or other people involved in their elementary science experiences. By providing a separation of time and space, these concerns were mitigated while also preserving the integrity of students' critique through thoughtful personal reflections. To understand the essence of elementary school science experiences, students in middle school were engaged to write science autobiographies where they articulated descriptions and explanations of their recently completed elementary science experiences. Next, the research questions guiding this study will be shared.

The main research question is: What are middle school students reflections of elementary science when writing a science autobiography? The research question includes two subcomponents:

- How do middle school students describe their elementary school science experiences?
- How do middle school students explain their elementary science experiences?

The elements of these questions are: “how”, “explain”, “describe”, “elementary school” and “science.” The word “*how*” supports the idea that students will describe elementary science experiences in many ways. The terms “*explain*” and “*describe*” are used because each student has a unique lived-experience and represent the truths being sought by this study. “*Elementary school”* is used to define the timeframe inclusive of kindergarten through 5th grades and the word *"science"* is used to describe the disciplinary context of science. The word "*experiences*" means any and all science experiences, inside or outside of school. There is no expectation for what students should include or exclude about their lived elementary science experiences. In other words, students are encouraged to share experiences without being limited by what should and should not be included.

My role as both researcher and analyst allowed me to be guided by the research questions and the written words. I sought to explicate meaning by reading about and carefully considering each student's unique experiential story. The aim was to reveal the essence of those experiences and illuminate lived experiences in vivid descriptions (Moustakas, 1994). Writing was selected as the source for the experiential material for this study because "the most straightforward way is to ask selected individuals to write their experiences down" (Van Manen, 2016, p. 63). The popular expression of 'going to the source' aligns with the goal of this work which was to capture the authentic voice of students through a personal retelling of his or her own life, told in the first person.

In the next section I will provide context for my role as the researcher in this study by sharing my positionality statement.

Researcher Role and Positionality Statement

As in all research, it is helpful to acknowledge and understand our own experiences, pre-understandings, biases, and positionality. This offers a way to personally reflect on pre-existing perspectives about the research topic or area of inquiry and helps to establish interrelationship with the work to be done. This practice of bringing personal awareness to the forefront allows for new data to "assert its own truth against one's own fore-meanings" (Gadamer, 2013, pg. 282). We accept our own positionality and use it to help not hinder new understandings. I believe it is imperative that I closely examine my current understanding about elementary science, and routinely think about the lens I will use throughout the research process. As Gadamer noted, the interpreter must be guided by "things themselves," not as a one-time conscientious decision to do so, but rather as "the first, last, and constant task" (Gadamer, 2013, pg. 279). This means the researcher, as interpreter, is always moving back and forth between the "things" or data and their own subjective thinking and preconceptions about that data, to make sense of that new data. Gadamer goes on to describe being focused on the data or "things themselves rather than all the distractions that come into play during analysis. He explains that the interpreter is always "projecting" and ascribing meaning to events under analysis and this process leads to new understandings (Gadamer, 2013, pg. 280), which is the goal of qualitative analysis. This thinking aligns with Heidegger, who claims there is no prescriptive approach to understanding, but rather an approach that leads us to understanding (Heidegger, 1988).

Adults hold certain views of children's experience based on their own position in the world and teachers are trained to view children through a lens of pedagogical orientation (Van Manen, 2016). As an adult with views of children, I have disclosed my role as observer, teacher, and participant in the research, and as one immersed in the study. These views matter to both me as a researcher and to my audiences. The way I view children may be different from the way someone with different experiences may view children. I recognize the importance of relationships within a classroom as socially constructed spaces, where power dynamics help shape student thinking and what they are comfortable sharing. For example, in classroom settings, where a teacher controls most of the power and directs most of the learning, students may act as more passive recipients of learning. Over time, these power dynamics between teacher and student may produce class norms, habits, and learned behaviors where sharing of personal experiences is uncommon. In other situations, a teacher may delegate power to students over certain tasks or responsibilities to create an environment that promotes students as active participants. In this setting where more balanced power dynamics exist between students and teachers, students are empowered and contribute to matters of learning. Often, students in these settings become more involved and engaged in teaching and learning and their voice may be freely expressed.

Classroom norms and power dynamics that naturally exist in a classroom may influence a student's willingness, positively or adversely, to express personal views. When students have experienced imbalanced power dynamics in their everyday learning environment, where their voices were restricted or limited, it could influence what they are comfortable sharing in a study. My roles as researcher and stranger to the students, could carry certain preconceived notions or norms that could influence a student's willingness to expose certain experiences. For these reasons, I worked closely with the classroom teachers to establish understanding of the study purpose and the unique classroom environment. I had teachers, who already had a relationship with their students, help guide and administer the ungraded autobiography assignment. My assumption was that students would be more likely to share meaningful experiences if they understood the purpose, bought-in to the process, and had a relationship with the person administering the science autobiography.

As a later career academic with experience and interests in elementary science education, I thoughtfully conducted my research to understand how young students describe and explain their unique and lived elementary science experiences. My interest has been driven by my own curiosities and my passion for science. For example, I am curious why some 5th grade students in Texas are considered academically proficient in science, meaning they have foundational knowledge and skills and are allowed to pursue rigorous science coursework. At the same time, even in the same classrooms, other students are not considered academically successful in foundational science learning and are not encouraged to pursue rigorous science coursework. It seems that some students are not eligible for higher levels of science learning based on foundational learning experiences that occur in elementary settings.

I have personally witnessed science learning pathways being closed to students not deemed proficient in science at the end of elementary school. I have also observed a loss of interest by students when science wasn't made accessible or aligned with their interests or learning needs. Exclusive practices like these can lead to diminished opportunities for advanced science coursework in secondary settings. We know some things about elementary science, but we don't know much about how students explain and describe their lived experiences.

Over thirteen years in K-8 education, I've worked in the state of Texas as a public-school elementary and middle school science teacher, an elementary school assistant principal, and a regional administrator in a public charter system. During these years, I've taught many students, guided curriculum decisions and instructional practices, and had the opportunity to observe many classrooms and educational environments in Texas and across the country. I've talked to a lot of students over the years and learned some interesting insights. But I don't know what students really think about elementary school science because I've never asked. I'm committed to listening to what students say and the stories they choose to reveal. The goal of this study is to listen and really hear the ways middle school students describe and explain their personal lived elementary science experiences through written autobiographies. I believe words have meaning and we can learn a lot from the voices of students.

Instrumentation

For this study, the science autobiography was used to elicit students' voices through a handwritten narrative that is aligned with the study design. The science autobiography is a writing activity that encourages students to reflect on personal interactions, studies, and experiences in science (Koch, 1990) and offers students an opportunity to share the truths of their personal experiences. My rationale for selecting the science autobiography is the belief that to get at the heart of the subject, one must go directly to the source of the information, which in this study is the student. There are multiple ways to elicit a student's expression of thought and I selected handwriting. I believe handwriting represents an authentic form of elicitation because it comes directly from students and brings into view a phenomenon of interest.

I have used the science autobiography as an introductory activity with teacher candidates in my college classes. After several administrations of the science autobiography, I have learned that students prefer a more open-ended prompt that allows them to take the autobiography in their own direction. I find these open-ended prompts lead to much more expression from my students and they tend to include richer and more textured details in their writings. I learn more about my students personally and learn better ways to serve their learning needs.

The rationale for selecting students right after elementary school is that by middle school students have mastered the task of handwriting. They can actively participate in writing a science autobiography, if necessary, with support. Handwriting was the preferred method because written forms of writing are unimpeded by mechanisms of capture. For example, technology with spell check or editing capabilities could change the meaning or essence of the meaning. For this study, accommodation supports were considered and offered to ensure all students had access to participate, including electronic dictation of oral speech or typing directly into an electronic document. However, no students or teachers requested accommodations to support the writing tasks associated with the handwritten science autobiography. As in other narrative inquiry, the science autobiography offered a way to explore aspects of students' lives that have previously been hidden from view. The open-ended design of the science autobiography provided an opportunity for students to decide what constitutes meaning and then allowed them to decide the configuration of their lived science experience.

I used a writing prompt to introduce and guide students into the writing of their science autobiography. Table 1 includes samples of prompts used to elicit student voice in prior research studies. Prior research on the application and usage of the autobiography was foundational to this study and was significant in the design and rationale of the methodology.

Table 1

Sample Prompts for Eliciting Student Voice

Author Citation	Elicitation Technique	Prompt
Gomez-Arizaga et al., (2016)	Prompt for drawing interpretation	Please tell me about your drawing. I would like to know about what you made.
Gomez-Arizaga et al., (2016)	Sample interview protocol	What do you think about your science class?
Gomez-Arizaga et al., (2016)	Sample interview protocol	If you were a science teacher, how would you be teaching your class? What things would you do and what things would you not do?
Gomez-Arizaga et al., (2016)	Sample interview protocol	What do you most like/dislike about your science class?
Mitra (2004)	Interview protocol	What would you tell other schools that wanted to start a student voice group?
Mitra (2004)	Interview protocol	What would you say the role of students should be in being a part of changes at your school?
Ellsworth & Buss (2000)	Prompt for mathematics or science autobiography	What has influenced your attitudes towards the teaching and learning of mathematics or science?

After developing the instrument for eliciting student voice using the science autobiography, a rationale for participants was developed. The next section will present the approach to recruitment and participant engagement for this research study.

Participants

As with any qualitative research study, it is important to target a population that will be able to provide data that aligns with the research questions. I sought to explore and understand how middle school students explain and describe their elementary science experiences. To fulfill this objective, I needed to make sure the participants were in middle school currently and had experienced elementary science. I selected an elite private middle school in a southwestern suburban community to participate in this research study, because it was a good fit for my research questions inquiring about elementary science experiences. I used a purposive sampling technique because in hermeneutics the researcher is seeking to explore an experience and must have participants that have had that experience. I believed that this school had science instruction in all elementary grades.

The school site selected for this study is an elite independent, private, co-educational, preparatory day school and includes students in grades kindergarten through high school. The middle school target population for my study was organized into two different grade levels, 6th and 7th. Students in these grades had two different science teachers that showed interest in participating in the study. I recognized that certain characteristics of this elite private school make it different from a public school setting. For example, the selected school has high tuition, which affords certain amenities like smaller class sizes and extra resources and supplies available to students. On average, students at this school are more affluent and may have access to additional resources related to education outside of school. Those additional resources could include science experiences. I am not sure how this school's profile or status influenced the outcomes of this research. The elite status could be seen as a limitation when compared to a public school setting because there may be different curriculum, learning expectations, and resources available at this school. My assumption was that students in an elite, K-12 private school would be likely to have had elementary science experiences, which aligned with my study. Compared to a public school that could have a wider variation in science experiences for children and possibly higher transfer rates among students. A school with students that had a higher variation in elementary science experiences could make it more challenging to extract themes.

To recruit participants, I initially contacted several school leaders at public and private schools about participating in this research study. I created a contact list from personal relationships and made contact using an email invitation that was approved by the Internal Review Board (IRB). The leader of the private school expressed interest in the research study and provided a quick turnaround on my scheduling request. She consulted with middle school science teachers about participating in this research study. Soon thereafter, two teachers, one 6th grade and one 7th grade, contacted me by email to express their interest in the study. Both teachers requested that all classes of their students be allowed to participate in writing their science autobiography. As a result, I went about planning my study to accommodate the request to include all 6th and 7th grade students.

Over sampling was initially designed into the study approach to ensure an adequate sample size. However, it was not expected that sampling would include two different grade levels and nine classes of students. I looked to resources in phenomenological methods and past studies for guidelines in supporting an expanded sample size for this study. Methodological experts appear to agree on only one aspect of sample size selection. They agree that it is important. Beyond this, sample size in phenomenological studies does not follow strict guidelines. Some recommend as few as 3-15 participants (Creswell & Poth, 2016), while others offer a broader view of sampling that dismisses strict numbers, and instead suggests focusing on saturation of data as the goal (Peoples, 2020). Saturation is said to be relatively open-ended and reached when no new themes emerge from the sample. Dibley et al. (2020) suggests that sample size is inextricably linked to study design and research questions and in hermeneutic phenomenology sample size cannot be calculated explicitly. Instead, they suggest that sample sizes can vary considerably across studies and should be flexibly applied to ensure enough data is collected for the phenomenologist to address and answer their research questions. In another example, sample sizes for hermeneutic phenomenology appear more subjective and tend to follow characteristic criteria, like those determined using study purpose, method for analysis, rarity of topic related to sample size, and depth and completeness of data being collected (Dibley et al., 2020).

With broad guidelines in mind, I chose an approach for participant sample size that embraced the idea that more data is typically better. Having worked with middle school students in a classroom setting, my thought was that some students would write a lot and others would not write much. I concluded that a bigger sample was more likely to produce samples with enough writing for analysis to address my research questions. I also recognized that it was likely I would not receive back all the parent consent forms that were sent out and this would naturally reduce the sample size. Also, teachers were excited about participating in the research study, so I agreed to collect data from all students in both classrooms for a total of nine classes. I did not need to make any significant adjustments to my study design because of the larger sample size. I simply made additional copies of the parent consent forms and scheduled extra days for data collection.

The primary data source for this study was the students' written science autobiography. The science autobiography was introduced to students as a novel activity in case this was the first time they engaged in this type of writing. Other sources of data collected included: students' quick writes and science pseudonyms, and my field notes, and anecdotal journaling about the research site and research process. Procedures for administering the science autobiography and data collection in each classroom were carefully developed, carried out, and managed to ensure consistent data collection practices across the nine classrooms. In the next section, I will describe the data collection process and procedures that were carried out in early Spring 2023.

Data Collection Procedures

After permission to participate and teacher introductions were made through email, I communicated directly with the 6th and 7th grade science teachers to plan data collection procedures. I attended an introductory school visit where the 6th grade teacher met with me to discuss the research study, schedule activities, and take me on a tour of the campus. Later, the 7th grade teacher communicated by email about distributing parent consent forms and collecting data. I then confirmed the schedule for parental consent and data collection by email with both the 6th and 7th grade teachers. Parent consent forms were sent home and data collection was scheduled for the week prior to spring break, beginning on Monday, and including Tuesday, Thursday, and Friday.

In total, 117 parent consent forms were sent home and 52 completed parent consent forms were returned over three weeks. Teachers pointed out that class sizes were smaller that week before spring break since some families start their vacations early. All students present in participating classes completed their science autobiography. After students finished writing, the teacher collected all science autobiographies and determined eligibility for inclusion in the research study by matching writing samples with parent consent forms. All science autobiographies with parent consent were given to me for inclusion. The rest of the science autobiographies, those without parent consent, were held by the teacher in the classroom until the end of the data collection window. As parent consent forms were returned, they were matched with science autobiographies and kept with the teacher until I returned to the school to pick up the remaining science autobiographies. A total of 52 science autobiographies, written during the week of March 6, 2023, had parent consent, and were collected over three weeks March 6 - March 20. In the next section, I will explain the process and procedures carried out in each 6th and 7th grade classroom on the day of data collection.

I believe there is merit and trustworthiness in both standard and non-standardized approaches to data collection in research. For this study, carried out across nine different classrooms, I chose a standardized data collection procedure. I carefully designed and planned out procedures to ensure consistency across classrooms. I wanted students to understand the purpose of the study, the purpose for their science autobiography, and to have clear and uniform instructions for writing. Detailed instructions and guidance provided more consistency in how students carried out their writing. I believe that using the same procedures everywhere does not inherently make the findings trustworthy in an absolute sense, but using very different procedures in each class would likely have made the results less trustworthy. The same procedures and processes were carried out in each classroom for each of three scheduled data collection visits to the school. I also collected anecdotal field notes to enhance my understanding of the environment and to support my findings and interpretation. Notes included details about steps taken to explain and administer the science autobiography, student and teacher actions during each of the classroom writing activities, and any additional comments or questions that arose during data collection. I did not collect the students' demographic data, grades, test scores, or other personally identifiable information.

Once in the classroom, the teacher provided a brief introduction telling the students that I was from Southern Methodist University (SMU) and needed their help collecting data for my dissertation research study. The teacher told students they would be completing a writing activity on that day. I then followed the teacher's introduction with a prepared, rehearsed, but informal script so that I would stay consistent with my introduction and directions across all classrooms. The students were attentive and quiet while I introduced myself, shared the purpose for my research, and described the science autobiography and set expectations.

I explained my interest in learning more about their elementary science experiences because while we know a lot about elementary science, we don't really know much about what students have to say about those experiences. I said that students' voices are often missing from what we know about elementary science, and as a teacher and researcher, I believe students can tell us a lot about elementary science that we may not already know. I added that I believe the best way to find out what students have to say about elementary science is to simply ask. Then I said, "I want to know how you, as middle school students, describe and explain your elementary science experiences, inside and outside of school." I also told them there were no right or wrong answers and their science autobiography would not be graded. Gargroetzi (2018) recommends that teachers communicate to students in advance that their work will not be graded but encourages teachers to acknowledge the receipt of students' completed work. Students may feel safer and may tend to be more honest when not expecting a grade for their reflective work (Persson et al, 2018). I told students that their science experiences are completely unique to them, and that although others were present during those experiences, their view of those experiences could be different.

I then paused and asked students if they had any questions. I received only a few questions from students. One student asked me a personal question: “what are you going to do when you finish your PhD?” and a few other questions were related to writing the science autobiography. For example, one student asked how long their science autobiography needed to be. I used the opportunity to remind all students there was no length requirement and they would have 30 minutes to write their science autobiography. Another student asked what to do if they couldn’t think of anything to write. I shared that it was ok if they could not remember some details and to focus on what they could recall. I explained my interest in gathering as much detail as they could remember about any and all elementary science experiences. I added that strong supporting details of their experiences would provide a more complete story about those experiences.

I engaged students in the process of administering the writing activity by asking one or two students to help pass out cover sheets and pens to each student. Students seemed excited about the pen with the SMU logo they could use for writing and then keep. Students were told to fill in their name, date, grade level, and circle their preprinted teacher’s name on the cover sheet. The cover sheet included a boxed section at the top right corner that was labeled: *for internal purposes only*. This section was used after data collection to verify and track parental consent to participate in the research study and parental consent for audio recording during follow up member checking interviews.

While cover sheets were being handed out and students were filling in their information, I provided an overview of the parental consent form. I explained about confidentiality and the importance of protecting students' identity in research. I told students that I had gone through extensive approval procedures to gain permission from my university, their school administrators, and their teachers to be able to conduct research in their school. I verbally assured students that I would not disclose the name of their school, their teachers' names, their names, or anyone else identified in their writing. I also explained to students about confidentiality and protecting their identity with the use of a pseudonym.

Then to encourage students to begin thinking about science before embarking on the 30-minute science autobiography writing exercise, I had students think about science. I called this activity a quick-write. I set the timer for five minutes and asked students to write everything that came to their mind when they heard the word *science*. I said: "Let's think about science! Take 5 minutes to write down all the words that come to your mind when you hear the word science." I told students to use only words or short phrases and asked them to write in the blank space of their cover page - and to use the back side of the cover sheet if they needed extra space. Before starting, I asked if there were any questions. No one asked questions, so I set the timer for five minutes and verbally asked them to begin. While students were completing the quick-write, I walked around the classroom placing notebook paper on each table for students to use for writing their science autobiography.

After introductions and after students had filled in personal information or their cover sheet, created a science pseudonym, and completed the quick write to generate thinking about science, they were ready to begin writing their science autobiography. Because I was working with students in grades 6th and 7th, ages eleven to thirteen, I used age-appropriate language to elicit personal reflections of elementary science (Van Manen, 2016). I asked students to be honest and reflective in their writing. I explained they could write about elementary science in any way they chose and to only write what they were comfortable sharing. I reminded students that their stories are unique and others may view things differently. I added that any way they wanted to describe and explain their elementary science experiences was acceptable.

Students were reminded that the writing activity was open-ended, un-graded, and would only be viewed by me and their teacher. I also reminded students they would have 30 minutes to complete their science autobiography and to ask questions that arose while they were writing. I paused for questions, then repeated the phrase "tell me all about your elementary, kindergarten through 5th grade, science experiences, inside and outside of school by using detailed explanations and descriptions, so I'll understand exactly what it was like for you" and asked students to begin before starting the 30-minute timer.

To summarize the writing process, I used the autobiography as the primary data collection tool. I guided students so that they had clear understandings about the purpose and intention of the research. Both the classroom teacher and I were in the room during the thirty-minute writing process. Although we encouraged students to raise their hands if they had any questions, few students asked questions during writing. The few questions that arose before writing were about how to spell certain words (either I or the teacher responded that we weren't overly concerned about spelling or grammar and were more interested in their descriptions and explanations), or about what to write (we reminded students to think about ways of describing or explaining their elementary science experiences).

During writing, there were few questions, and most took on the form of asking about how much longer or how much time has passed. With these questions, the teacher reminded students to keep writing until 30 minutes had ended. Towards the end of the allotted time, some students reported being finished. When this occurred, either I or the teacher encouraged them to continue writing. We suggested they review their writing and think about additional details or ways to explain and describe their elementary science experiences. Most students wrote or drew for the entire 30 minutes allocated to writing their science autobiography. Most students filled one full page, many students filled 2 pages, and some students included drawings in their science autobiographies.

At the end of thirty minutes, either I, the students, or their teachers stapled the cover sheet to each written science autobiography as they were collected from students. The teacher then matched completed autobiographies with parent consent forms. Science autobiographies with a signed parent consent form were given to me. Science autobiographies without a signed parental consent form were kept by the teacher in case the consent form came in later.

I used the same procedure for administering the science autobiography in each of the nine classrooms to ensure consistency in data collection. The first week, I collected a total of 35 science autobiographies with signed parental consent forms. I collected an additional 17 science autobiographies with parental consent from teachers after spring break, resulting in a total of 52 completed science autobiographies with parent consent. In the next section I will explain the underlying philosophical approach and the analytic steps used to analyze the science autobiographies. The autobiography, as the primary data instrument, guided my work in answering the research questions.

Data Preparation

At completion of the data collection window, 52 student writing samples, 52 parent consent forms, and 52 science autobiography cover sheets were obtained from 6th and 7th grade middle school students. No data was excluded from the sample; every student's science autobiography was included in the analysis. To prepare for data validation, I needed to determine which students were eligible for member checking interviews. To seek permission, I provided parents with two options on the consent form: 1) I give my permission for my child to be audio recorded or 2) I do not give permission for any type of recording. Students with permission to be audio recorded were eligible for a follow up interview. It was made clear in the consent form that a child could still participate in the research study without an audio recording. I used the pre-printed boxes on the top of the cover sheet to track consents and permissions to audio record member check interviews. For the 52 writing samples with parent consent, a total of 12 parents did not explicitly consent to audio recording (3 checked no, 8 left the question blank, and 1 checked both yes and no boxes). Parental consent forms that did not show yes as a response were excluded from consideration for member checking interviews.

The next step in preparing data for analysis included making photocopies of each science autobiography and assigning a unique, alphanumeric code for tracking each science autobiography and protecting student identity. Although coding is often an arbitrary process used to protect student anonymity, in this study I coded the autobiographies twice. The second round of codes were used to protect student anonymity; the first round of codes were non-anonymous and actually played an important role in my analytic process. Therefore, I will explain this initial round of coding in detail.

During analysis, I used the alpha numeric pseudonym to easily identify a student and confirm, if they had parent consent, if they were part of the member checking, and it provided an easy way to find that particular student in my notebook of science autobiographies. The code was developed using the writing date, teacher's initial, a sequential number, and a dichotomous code, Y or N, for parental consent, for example, [F310_12YY], indicates teacher F, written on March 10, student number 12, parent consent to study, parent consent for audio recording. Student names were redacted from photocopies of each science autobiography. In its place, the unique alphanumeric code was written in the top right corner of each science autobiography photocopy. The same unique alphanumeric code was also written on each corresponding cover sheet in the top right corner so it could be matched with the original. The alphanumeric code was used when student names were needed to schedule member checking interviews.

Next, a secure database was created in google sheets to track data for the duration of the study. Then, student data was logged into the database using the following twelve column headers: unique number (random assignment that became the student number), unique alphanumeric code, student first name, student last name, date writing sample was completed, teacher name, class section (if known), grade (6th or 7th), parent consent (Y/N), parent consent for audio recording (Y/N), student generated science pseudonym, official pseudonym.

To summarize steps taken to ensure the privacy and confidentiality of all participants, the following measures were taken. First, parent consent forms were administered to parents and those returned were reviewed by the teacher and the researcher at the school throughout the data collection window. Only signed parent consent forms were collected by the researcher for analysis. As an extra measure, parent consent forms were reviewed at least twice more when filling in tracking data and again when generating the student's unique alphanumeric code.

Second, a copy was made of all student writing and names were redacted using a black pen. Photocopies of the science autobiographies were labeled with the unique alphanumeric code. Parent consent forms were also labeled with the unique alphanumeric code. Then, the original science autobiographies were stapled with parent consent forms and placed in a secure physical file for duration of the research study. Third, a secure database was created in google sheets with access only available to the researcher and researcher's faculty advisor (in case of emergency). Fourth, data was logged into the secure database using the student's name and unique numeric code. Fifth, all participating students, those with a signed parent consent, were assigned a pseudonym that was logged and used for analysis and reporting of findings to protect the identity of participants. Sixth, all written documents (science autobiography, parent consent forms, cover sheets) were maintained in a secure physical storage cabinet throughout the research study. Seventh, at the completion of the study/dissertation, the database will be deleted and all physical copies of data including parent consent forms, student's cover sheets and student's science autobiographies will be destroyed in compliance with IRB protocol and expectations.

In the final dissertation manuscript, I removed all alphanumeric codes used for identifying students and replaced them with pseudonyms created by students. This helped keep the student's identity hidden and provided a way to present students in a more humanizing way, as something other than a number. I removed any personally identifying information from each pseudonym. For example, when a student used their real name in their self-created pseudonym, I changed the pseudonym to be more anonymous. The extra step in deidentification helped ensure student confidentiality was maintained in my dissertation. Student names and pseudonyms were retained in a secure file for reference during analysis.

Analysis

The aim of this study was to extract meaning about elementary science from the handwritten science autobiographies and expose how students made sense of those experiences. Anecdotal field notes provided additional context for the classroom environment and offered a way to document students' behaviors and actions while writing their science autobiographies. The approach used to extract meaning involved a structured yet flexible examination of data. It was structured in that a systematic path was followed that aligned with sound practices for analyzing phenomenological research. The approach was flexible and reflexive because I remained open-minded and allowed the student voices to inform my interpretations. The process I used involved close examination and deep exploration of the rich and textured narratives students used to describe and explain personal elementary science experiences. This process along with prior research and my personal positionality led to interpretations of the essence of the lived elementary science experience.

Before embarking on analytic steps, I reviewed my personal position statement to bring forth my own personal biases, prior understandings, or preconceived ideas about the phenomenon of elementary science. My position statement made personal biases or judgements explicit in my mind, so they were always transparently embedded and intentional in my analytic approach. This framing supported my goal of discovering how students explain and describe their personal lived experiences from elementary science. I also revisited my personal position statement throughout the analytic process and before conducting member checking interviews to verify or challenge my personal interpretations. During analysis, I made sure to both acknowledge my biases and positionality and also remain open-minded about what students conveyed about elementary science experiences. Interpreting a student's authentic voice was a key consideration throughout data collection, analysis, and the final report of findings.

The hermeneutic framework provided a way to analyze and interpret each student's narrative. My process of analysis and interpretation can be best understood through the hermeneutic theoretical framework. Originally developed by Heidegger, the dynamic and non-linear process that was employed is called the hermeneutic circle. The approach embraces the position of me, the researcher, as a way to interpret and understand the phenomenon of elementary science (Heidegger, 1988; Sheehan, 2014). The process accepts and incorporates the researcher's own innate subjectivity and allows for interpretations that are authentic and somewhat blended between researcher and participants (Sheehan, 2014). The researcher and the phenomenon being researched interact in a way to reveal new meanings. I employed a repeating process of going back-and-forth between reading the data and reflecting on my own subjectivity, reading and re-reading each autobiography and carefully considering my interpretations. Going back and forth entailed reading each science autobiography multiple times, pausing and reflecting with each reading. I used tags to flag certain words or key phrases. I also used colored pens and highlighters to emphasize parts or to make notes in margins of the photocopied science autobiography. I repeated these steps, while also reflecting on each student's voice as I began to notice patterns and themes emerging. This process allowed the data to emerge and change during analysis (Peoples, 2020). Heidegger believed people make sense of new experiences through mental revision cycles, a sort of back-and-forth process, that blends preconceived thoughts and knowledge with new data (Peoples, 2020). The hermeneutic circle evokes new understandings through a repeating cycle until new meanings have emerged (Heidegger, 1988; Sheehan, 2014; Van Manen, 2016).

Heidegger's fundamental insight "our existence in the world is grounded in always already finding ourselves in the world" (Sheehan, 2014, p. 10) supports the idea that "the observer and observed cannot be separated" (Roth, 2000). This means that pure objectivity, which theoretically requires suspension of the researcher's positionality, is both impossible and unnecessary (Heidegger, 1988; Gadamer, 1975). As the researcher that collects, analyzes, and interprets the autobiography, I served as an active participant in the process and consciously and continually reflected upon my own subjective positionality and biases to support the process of deriving new meanings from the data. My background and how I made sense of these data may differ from what another person without those same experiences might conclude.

One example of how my positionality, and experience as an educator during the COVID-19 pandemic, shaped my interpretive process follows. As I read student accounts of COVID-19, I found slightly different versions of the same story. I was surprised that most students did not mention the COVID-19 pandemic at all; something as significant as being required to stay home and shift into an online learning environment was narrowly acknowledged. I found this surprising because I'm confident that all students were impacted by COVID-19 during their 3rd or 4th grade year. I am confident because students were required to stay at home when schools were closed during COVID-19. A person that was not a teacher during the pandemic might not be aware of the challenges related to being required to shift into an online setting.

For the small sample of students that included COVID-19 in their science autobiography, I did find some interesting statements that shaped my interpretation. For example, "Dr. Danger" reported using an app during online learning and described an assignment taking pictures and manipulating the images to change orientation. The student then shared an interesting comment related to the teacher's role during COVID-19: "In 3rd grade it was lock-down, so my science teacher had to improvise." I found it intriguing that while students were adversely impacted by COVID-19 by being required to stay home and participate in school in an unfamiliar online format, this student expressed empathy for the teacher being challenged in that same circumstance.

Other students that commented about COVID-19 mostly shared how it impacted them personally, not how it impacted teachers. From my personal experiences as a teaching assistant during COVID-19, I can relate to being that teacher trying to figure out new technology and working hard to create a seamless experience for students. I recall how some students blamed me when technology wasn't working, rather than empathizing with me as I attempted to navigate unfamiliar territory that we were all faced with during the pandemic. Another researcher without my personal experiences with teaching in an online environment for the first time might interpret the students' account of COVID-19 differently.

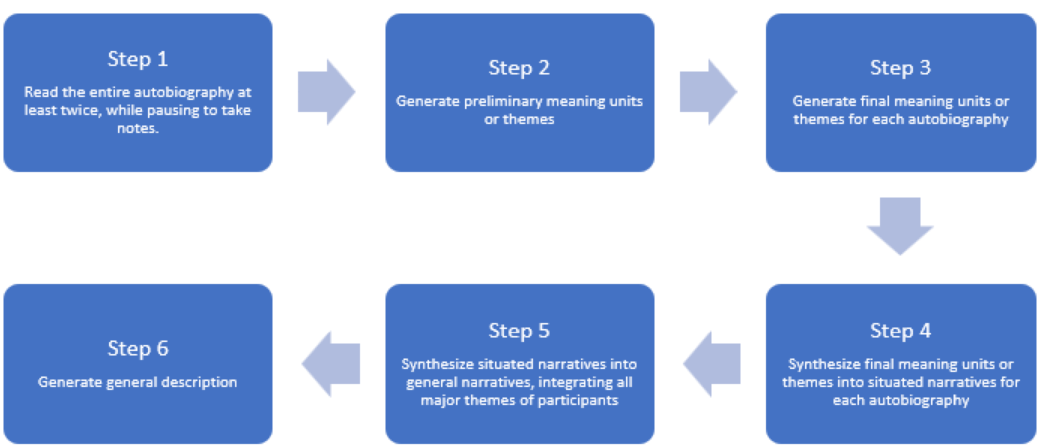
To summarize, the hermeneutic circle presented a process I could follow during analysis. This allowed me to become fully immersed, close to, and intimate with, the autobiographical data to reveal new understandings (Heidegger, 1927; Peoples, 2020). The process involved repeated readings of autobiographies and a back-and-forth iterative movement between individual parts (each autobiography) and the whole (all autobiographies) (Gadamer, 1975). Throughout analysis, parts informed the whole and the whole informed the parts (Miles et al., 2018). The hermeneutic circle helped me acknowledge presuppositions while examining data thematically.

This led to the extraction of the essences of meaning from students' personal elementary science experiences. Finally, member checking was an intentional part of the analysis where my interpretations were confirmed or refuted. Member checking also provided a way for me to examine and question my positionality to develop fresh understandings of elementary science that were extracted directly from the students' own writing (Denzin & Lincoln, 2018; Merriam & Tisdell, 2016). In whole, the analytic process led to my findings and discussion that will be shared in a later section. In the next section, I will describe the step-by-step analytic process that I used to extract meaning and develop my final interpretations.

The flow chart in Figure 1 was adapted from Peoples (2020, p. 59) and depicts the general flow in the process for data analysis where the researcher participates in an ongoing dialog with the data and prior literature. I followed this process during the analytic stage of the study and it helped extrapolate meaning from essential themes of elementary science from the student's science autobiographies. The meanings that emerged were familiar and "comprehensible and identifiable to anyone who has had that particular experience," (Peoples, 2020, p. 58) yet also different due to the uniqueness of each individual's lived elementary science experience. The process steps I followed are outlined next.

Figure 1

Data Analysis Flow Chart



Note. Adapted from Peoples (2021, p. 59)

In step one, each science autobiography was read once in a careful and reflective manner in the order it was numerically organized. My focus was on the reading of each autobiography from beginning to end, mentally concentrating on each writing like it was a story being shared with me for the first time. In doing so, I read slowly and methodically, pausing at each sentence to absorb and consider the author's intended meaning. Interpretation began with the first reading of the science autobiography when I considered the writing as a conversation between me and the student (Dibley et al., 2020). On the second round of reading, I began to closely examine each writing sample using a keen eye and sharp listening ear. At this point, I began organizing data by making notes about general impressions using colored sticky notes, pens, and highlighters to emphasize certain parts of the writing. I underlined interesting details or highlighted words or phrases that stood out and caught my attention. I attached sticky notes to writing samples as flags for further consideration during analysis and member checking. I also made notes about memorable text in the margins of each science autobiography.

Throughout this methodical process, I wondered: how are students voicing their message, and what are they communicating to me in their writing? I took time to pause, ponder, and reflect on the writing and then arrived at my own interpretations. I asked myself questions like: what is each student trying to convey through their writing? I know that words have meaning, and I closely examined each word within the context of each sentence or phrase to better understand each student's elementary science experiences. I thought about each student behind each science autobiography and wondered about them. Were they like students from my former classrooms? I also thought how wonderful it would be to meet each student and ask them more questions, to further probe into their lived experiences. This deep contemplation I went through also helped me consider which aspects of my wonderings fit within the confines of this study.

There were many other interesting details that evoked questions about student writing that I did not examine closely because they were not part of this study. For example, I did not judge or attempt to make sense of a student's writing style, grammar, and punctuation, since mechanics of writing were not predefined as a criterion of interest. As I read each science autobiography, I wondered about the students' mindset; were they engaged in helping me understand their elementary science experiences? Did the way they wrote suggest they were interested or uninterested in writing their science autobiography? Phrases like “I can’t remember anything” could be a message of avoidance or could be an indication that they really do not remember anything. I also wondered about students' memories of elementary science learning experiences. Why do students remember certain things and not others? What do students remember? Were learning experiences memorable or not, and why? As I considered answers to these questions, I focused on understanding the essence of elementary science, meaning making, and contemplating what sense could be made from these written data.

Step two involved repeated readings of each science autobiography. I noticed that new areas of curiosity or interest were brought forth. Questions like: do girls like science more than boys or vice versa? Are there differences or trends in what students say about elementary science experiences between different grade levels? How does academic performance data compare to students' attitudes towards science? What would students at other middle schools write about their elementary science experiences? I pushed myself to set these questions aside for future consideration or future research, and then revisited the research questions: how do middle school students describe their elementary science experiences? How do middle school students explain their elementary science experiences?

This process helped refocus attention on the research questions when other areas of interest emerged that were beyond the scope of this study. I continually refreshed my memory and directed myself to think more deeply about the phenomenon of elementary science. My aim was to think deeply as I mined participant stories and explored how students explained and described elementary science experiences. As I completed each reading of an autobiography, I paused to write reflective notes, asking myself, what does this mean? All the time being intentional about considering how my own preconceived ideas and notions about elementary science were influential in my interpretation and understanding. My goal was to listen closely and carefully to each student’s voice. At all times, I embraced my own subjectivity and consciously worked to set aside my own preconceived ideas, notions, and biases about elementary science. This process allowed the students' voices to be heard.

I developed preliminary understandings of elementary science; written down as units of meaning (Peoples, 2020) or themes (Miles et al., 2018; Van Manen, 1990). Themes were used as a way to capture the essence of elementary science experiences, to make sense or understand. As noted by Van Manen (1990), themes in phenomenological studies can be viewed as a way to give order and control to research but are not considered “rule-bound processes to be followed” (p. 79). Emphasis is on the idea of interpretation as a way to make meaning, or to get at the notion of students' lived experience, rather than a strictly mechanical procedure.

Meaning making began to shape my interpretations of students' lived elementary science experiences and provided a way for me to retell students' stories in a meaningful way. For example, once I recognized patterns and themes, I was able to group them together. Science content emerged as a topic that nearly every student included in their science autobiography. What appeared early on as discrete activities became connected. Using my science background, I was able to collect topical patterns into science strands. The hermeneutic circle provided a systematic approach to building understanding. Each story was reread in the same order I used for the first reading. I frequently questioned and reflected about what new insights were uncovered. Throughout this process I was always wondering if anything new or previously overlooked was present.

During step three, I used a research journal to begin creating meaning units (Peoples, 2021) or groupings as early place holders for notes about emergent patterns or themes. All science autobiographies offered insight into students' lived elementary science experience, yet some provided richer, more textured descriptions and explanations than others. This step was made easier by my intentional, slow, and methodical first reading. By now, I was already developing a deeper understanding and sense of common patterns and themes about what it means to be an elementary science student. This second time took even longer with the back and forth rhythm between the parts and whole, between the data and patterns or themes. Using a detailed reading approach (Van Manen, 1990), I examined every sentence and asked myself what that sentence revealed about the essence of the phenomenon of elementary science. I paused longer on each consecutive reading to really reflect and consider if the pattern or theme was aligned with the research questions. Then I examined if the theme or pattern was new or offered more evidence of one already identified. If not aligned with the research questions, I set the pattern or theme aside, not leaving it out entirely, but setting it aside for later consideration.

For example, ten students mentioned the impact of the COVID-19 pandemic on their science experiences. COVID-19 was a worldwide public health crisis that affected schools when they were required to close beginning in early 2020. Although the majority of students did not mention COVID-19 in their science autobiographies, those that did shared noteworthy accounts of their personal experiences. COVID-19 is not a normal part of elementary science experiences; however, it did significantly disrupt teaching and learning. Collectively, those that included COVID-19 shared that when they were sent home it impacted their learning because science experiments were difficult to complete in an online forum. After returning to school, added precautions were taken in the classrooms to ensure student safety and protection. “Chromosome” commented: “Science for me was one of my least favorite subjects in lower school. I felt that especially during 3rd and 4th grade when we had the dividers up during COVID, I felt not that much fun.” Initially, I recognized COVID-19 as important to the elementary science experience but wasn’t sure exactly how to capture the essence of that experience. Later. I decided to make COVID-19 a separate theme and category because it is important and, at least in some cases, impacted students' elementary science experiences.

I recognized that what might not seem pertinent in an early stage of analysis, might become relevant later in the analysis. I also found that taking notes about wonderings, or new questions, that arose was helpful because it allowed me to set some ideas aside to stay focused on research questions. Throughout repeated readings, I was careful to examine themes to make sure I preserved differences and did not inadvertently cluster them together. I concluded that certain recurring experiential themes were common among students and could be grouped, while other experiential themes were unique and needed to be preserved (Peoples, 2021). If the theme of pattern was new, a new group was written in the research journal. If the theme or pattern had already been identified, then notes were added to the existing group. As readings and thoughtful consideration continued, themes and groupings were revisited multiple times. I consolidated or separated groups until a cohesive set of eight categories remained. Later in the analysis, excerpts, themes, and interpretations were reviewed with students during member check interviews.

In step four, individual meanings were systematically synthesized into final categories from themes in rich and textured narrative situated within each autobiography. I worked to remain true to the essence of the elementary science experience while transparently developing narratives that explicate the themes identified (Van Manen, 1990). The process of extracting pertinent quotes from students was carried out to avoid generalization and support meaning and interpretation. Quotes lift up meaningful interpretations in a students' own voice and provide content for the narrative retelling.

I purposely avoided jumping to conclusions too quickly. For example, I carefully examined and considered each statement or phrase to ensure that what impressed me upon the first reading was noted, but not taken in isolation from other narratives. The analytic process I used provided a way for me to personally reflect on why a particular statement or phrase stood out to me. I was able to pause and question myself about why I had strong sentiments about something a student wrote. For example, when I read that a student felt as though their science learning experiences had been more shallow than then they were deep, I thought to myself, “yes! That is exactly why students are not academically ready for more challenging science content later in their academic career.” I concluded that it must be related to how students are prepared in elementary classrooms. I decided that this was evidence that science concepts are not taught deeply or thoroughly. This results in poor academic preparation rather than a strong science foundation.

Upon reflection, I realized that my interpretations are rooted in beliefs stemming from my professional experiences in education. I can relate to teachers being expected to move through large amounts of science content in limited amounts of time. Sometimes teachers are faced with moving through content quickly or skim over topics instead of teaching concepts more deeply. I have personally experienced this competing demand of quantity over quality as a classroom teacher. I also felt pressure and may have inadvertently passed that same message along to other teachers, when I served as a regional administrator. Pressure from decision makers to cover vast amounts of content seems contrary to deep learning outcomes. The added emphasis on mathematics and reading performance in some elementary schools often squeezes the time allotted for science instruction, and sometimes completely deprioritizes science.

Another area of personal experience that influenced my beliefs is the idea that elementary science teachers may not be skilled or trained sufficiently in science content. Therefore, teachers may not be equipped to teach to deeper levels required for foundational science learning. I believe these ideas are sometimes accurate based on my personal experiences. For example, I recall having difficulty finding teacher candidates that wanted to teach elementary science. These challenges were generally related to their educational background. When teachers do not possess knowledge and experience in a content area, they tend to avoid those areas for their teaching assignment. Also, I recall coaching middle school science teachers and finding that the ones that struggled most with science content did not possess strong science backgrounds. The analytic process I used supported this contemplation of thought and allowed me to make notes about the intellectual struggle I was engaged with. I acknowledged preconceptions while noting my biases and then pushed myself toward continued analysis and interpretation.

I discovered, for example, that students confirmed the notion of science content lacking depth, when they made statements like “Idocytok” who shared: “science is boring because you have to memorize a lot of things” or “Kimmberly” who wrote: “my teacher taught us very pointless stuff, from what I remember, the class was just something to fill time.” I also noted that students made counter claims about science learning depth. For example, “Georgie” reflected over elementary science experiences and concluded “everything started to click for me, overtime I learned that elementary school science gave me the building blocks to finally piece together what science means.” Another student, “Mannequin” made a similar comment “In elementary I learned so much about the basic building blocks of science that helps me in the years after that.”

In this case, my interpretation changed somewhat. Some students think of superficial learning as unfavorable because they aren’t learning content deeply. At the same time, other students may see superficial learning experiences as favorable because they can touch on many topics in the same amount of time. I was also struck by how some students did not have an opinion about how deeply they learned content. Some suggested that learning in elementary science was simply designed as building blocks, to expose them to concepts they would explore later, in high school. These different ways of viewing learning were a bit new for me and it caused me to think more about the possibilities for teaching and learning elementary science. I drew some new perspectives and understandings based on what the students wrote and the repeated readings and personal reflections allowed new meanings to emerge. I concluded that learning could be deep or shallow at different times, across different content, based on a variety of experiential circumstances. As I accepted new interpretations, I also reserved some personal beliefs and understandings about elementary science. Some that were not part of this study but would be interesting to explore further. For example, I think it would be interesting to examine students’ perceptions of science in relation to science teachers’ competencies and interests.

I relied heavily on quotes to present findings for this study, because it is one thing for me to say that students shared that they aren’t learning concepts very well, but more meaningful to read “Learner’s” words: “I also remember that we never went to in depth to the subject we would dive shallow so we could learn more.” Short phrases or statements were written under categorial headings with each student's pseudonym so that I remained focused on the words, not the characteristics of the student. In another example, I could state that some students reported that they did not like memorizing material for tests, but it is more genuine and meaningful to read what "Hard Worker" wrote: "I'm memorizing so much I don't even learn. And it frustrates me when I don't understand something." In the next section, I will explain how member checking was used to verify findings with student participants to increase trustworthiness and add credibility to this research study.

Member Checking

Member checking is a technique used by qualitative researchers to ensure data fidelity, increase rigor, and confirm the trustworthiness or credibility of research findings (Denzin & Lincoln, 2018). Merriam and Tisdell (2016) describe member checking, or respondent validation, as a way to confirm internal validity. It provides a way to check back with study participants during analysis about emergent themes or meanings to confirm the validity of the study's conclusions. The member checking process I carried out was designed to encourage mindful conversations between myself and students' written accounts of their elementary science experiences and to ensure I captured each student's voice authentically in my conclusions (Creswell & Poth, 2016; Miles et al., 2018; Simpson & Quigley, 2016).

One feature of member checking is that it serves to overcome bias when the data collector is also the analyst and the nature of understanding is co-constructed (Birt, Scott, Cavers, Campbell, and Walters, 2016). Member checking may include taking transcription reports from audio or video recordings back to participants and having them review for accuracy (Peoples, 2021). Since I used a handwritten science autobiography as my primary data collection method, I decided this aspect of member checking was not warranted.

Another use of member checking involves providing opportunities for study participants to review, reflect, and have input into interpretations so that derived meanings can be confirmed (Van Manen, 1990). Peoples (2021) argues that participants are not required to agree with results and therefore do not need to confirm or deny those results. She recommends students skip this part of member checking to avoid setting an unnecessary expectation with participants. For this study, I elected to use this latter approach to member checking for several reasons. First, since there was no need to confirm written words in the science autobiographies, I needed another way to demonstrate rigor and validate my approach. Second, and more importantly, I wanted students to review my interpretations to make sure what I understood from their science autobiographies was what they intended and meant.

Member checking interpretations also provided an opportunity to revisit my personal biases and preconceived notions about students' elementary science experiences. I wanted to make sure my interpretations were driven primarily by the student’s voice and not my preconceived ideas or notions about elementary science experiences. I carried out member checking with a sample of eligible students using ten to fifteen minute one-on-one interviews.

Students were considered eligible to participate in member checking interviews if they had parent consent to be audio recorded. Eligible science autobiographies were sorted into one of eight categories based on the primary way the student had described and explained their lived elementary science experiences. When a writing sample fell into more than one category, I selected one category as primary. From this process, one or two writing samples were randomly selected from each category. Then I closely examined each selected sample to evaluate ways the theme was described and how it related to my interpretation. Every writing sample had something interesting to offer and was included in this research study regardless of whether or not the student writer participated in member checking.

Evaluating the content of each sample was not a way to eliminate the sample from the study; instead, this was a way for me to think about how I would ask follow-up questions. For example, “Kimmberly” stated “I have always felt like science was an obligation it was never something I looked forward to (except when we made concoctions)... the things we learned in lower school were just things to fill time. Teachers, specifically the science ones, never made it a joy to learn.” I wondered what role the teacher played in shaping this student’s feelings that science was an obligation. I decided to ask this student about the role of the teacher in helping students enjoy science and what teachers might do differently to make it more enjoyable.

Another student, “Dr. Cleopatra” wrote: “In fifth grade we went to Galveston and went to a space museum and learned about space but I don’t really remember it well because it wasn’t very fun.” During the member check interview with this student, I explained that for students that wrote about the 5th grade Galveston field trip, some students enjoyed the trip and other students did not enjoy the field trip. I asked her to share her thoughts about whether this was accurate for most field trips and she agreed. She said the reason she didn’t like the Galveston field trip was because students were placed in groups and had to walk around all day reading what they were told to read. She said there wasn’t any choice and it wasn’t very fun or active. She added that when learning involved doing something it was more active and fun, and that helped her remember better. This exchange led me to think about the underlying source of the student’s dislike of the field trip. I concluded that in this case, the source was more likely related to the lack of choice during the trip, not the trip itself.

Samples with more detailed descriptions or interesting ways of explaining elementary science took priority over and replaced samples that were less rich and textured. For example, one theme that emerged early in the analysis was depth of instruction. This theme was derived from student comments about how much content they covered in elementary science versus how deeply they learned the content. I found this topic very interesting and somewhat surprising to hear from such young students. At the end of the evaluative process for writing samples, a total of seventeen 6th or 7th grade science autobiographies were selected for member checking. All seventeen included interesting ways of describing and explaining at least one of the eight elementary science categories.

Individual student interviews were scheduled with teacher input so they would be carried out during non-instructional time over the course of a week. The seventeen, fifteen minute, audio-recorded, one-on-one interviews were conducted with selected students over three days. Member checking was carried out during steps 4 and 5 while I simultaneously continued to interpret and generate meaning from the data. Member checking provided a way to further elicit student voice by providing them opportunity to offer their input and co-construct final interpretations. New insights emerged through member checking, as a "process of reflectively appropriating, of clarifying, and of making explicit the structure of meaning of the lived experience" (Van Manen, 2016, p. 77).

The next step in the analytic process involved weaving together a new story through a retelling of 6th and 7th grade students' lived experiences. In step five, the situated narratives from step 4 were written into general narratives where major themes previously identified from individual autobiographies were incorporated. Peoples (2020) describes this as an organizing event that "highlights all of the participants' meanings of their experiences" (p. 61). Van Manen

(2016) describes this process as a creative, hermeneutic process and says “linguistic transformation is not a mechanical procedure” (p. 96). In this step, I worked between the components of the autobiography and the entire autobiography to ensure the selected text addressed the research questions. In other words, I moved fluidly between the words and the whole text to more fully understand the essence of students’ elementary science experiences.

The sixth and final step in the data analysis process involved finalizing essential themes and generating general descriptions of students' lived elementary science experiences. This analysis served to “unite major phenomenological themes into a cohesive general description” (p. 62). Van Manen (2016) states that to determine the essential quality of a theme, “our concern is to discover aspects or qualities that make a phenomenon what it is and without which the phenomenon could not be what it is.” I confirmed categories through the use of student interviews during member checking by asking students if the grouping or theme I had ascribed to their science autobiography made sense. Students agreed that the groupings were appropriate and aligned with their writing.

Finally, groupings or categories of themes were put into an order that promoted a way for me to tell the middle school students' stories. I decided to first retell what students described about elementary science experiences and then share ways they wrote about how and why they learned science. A different person might elect to use a different order of telling. Even though the ordering might impact the narrative to some extent, it is appropriate because, as a researcher, I am fundamentally part of the construction of the phenomenology. I do not believe the order I selected impacted the narrative. This step is deeply important and was challenging because it became a matter of my own subjective interpretations, informed by student participants, that will determine the essence of elementary science for this study. The final descriptions and retelling of how middle school students explain and describe their elementary science experiences is unique to this study, the students, the site, and my personal interpretation.

To summarize steps taken to check my own biases and ensure the trustworthiness of the story being told about the essence of elementary science experiences, the following measures were taken. First, the science autobiography was administered using a systematic and consistent process wherein students across classrooms were provided the same introduction and instructions for writing. Next, data was collected in a structured manner that protected the confidentiality of all research participants (school, teachers, students). Then, I used the hermeneutic circle as a way to balance my biases with new meanings and understandings derived from the authentic student voice. For example, at the time I administered the science autobiography, I was not really thinking about the COVID-19 pandemic. I only started thinking about the pandemic when I noticed the first mention of it in a science autobiography. Then, as I read more and more, I discovered that several students commented about COVID-19. The accounts students gave were surprising to me because they were different from my own experiences during the pandemic. During the pandemic I did not have children at home and was not working in an elementary school. I did not expect students to share their experiences about the pandemic when writing a science autobiography, but when they did, I needed to balance their voices with my own personal experiences. This process supported my interpretations and produced results that were derived directly from the students. The data analysis flow chart (Figure 1) depicts the general process that guided me in a systematic and comprehensive approach to data analysis. This enabled me to extract and interpret meaning and avoid overly biased conclusions.

Themes generated became objects of the member checking interviews with students. These conversations were collaborative and were used to ensure authentic meanings were extracted from the autobiography. For example, I asked students to consider if what I interpreted from their autobiography is what the science experience was really like for them (Van Manen, 2016). Interpretations and meanings were reviewed by student participants during member checking to help revise my own subjective biases and to ensure authentic student voice was rendered and exposed (Peoples, 2020).

Chapter 4

Findings and Discussion

This study was carried out at a private school in a southwestern suburban community. The co-educational, K-12, school is considered an elite private school. It earns this prestigious label because the average socioeconomic status of families at this school is significantly higher than that at other local schools. I have not included other school characteristics to maintain the confidentiality of the participants in this study. I have included the voice of fifty-two middle school students who were guided to write a novel personal science autobiography. I also did not collect student demographic data or data on academic progress for this study because I wanted to avoid biased views associated with a student's characteristics. For example, it could be difficult to set aside preconceived ideas about science experiences and a student's gender or academic performance to get at the meaning of elementary science. My goal was to focus on the nature or essence of the lived elementary science experience of middle school students, regardless of their gender, academic performance, or any other defining characteristic.

In this chapter, I present the research findings and connect the findings within the hermeneutic phenomenological framework. I will address research questions to more fully understand the lived elementary science experiences of middle school students. I will use key references to salient quotes from students to support my findings. Writing samples represent different and interesting ways that students describe and explain their lived elementary science experiences.

The ways students use words to describe and explain their elementary science experiences helps frame the retelling of their writing into an authentic and plausible story about the essence of elementary science. I regarded the word *describe* as the who, what, where, and when of elementary science experiences and the word *explain* as the how and why of elementary science. I used this breakdown of keywords in my research questions as a way to extract elements for analysis and interpretation and construct meaning from each student's autobiographical data.

For this study, I utilized a hermeneutic analytic approach to understand lived elementary science experience. Students wrote about elementary science experiences in a variety of interesting ways that will be shared in this section. Students wrote about remembering, timing, setting, people, content, ways of learning, COVID-19, feelings and attitudes towards science, and some provided feedback and advice to teachers. A sampling of findings includes what students wrote about their teachers, including both favorable and less favorable experiences with their elementary science teachers. Students wrote descriptively about enjoying hands-on dissections and the connections made to human body systems. Students also shared their preference for being actively engaged in science experiences over, what they referred to as, more passive science experiences. Next, I'll briefly describe some characteristics of the writing samples, then I'll share details about the structure and flow of the sections that follow.

Writing Characteristics

The purpose of this study was not to closely examine students' writing. However, I have provided a general overview of students' writing characteristics in this section. Fifty-two students are included in the sample for this study. These students wrote approximately 70 pages in total. Table 2 shows how many pages were included and whether students included a drawing in their science autobiography.

Table 2

Characteristics of Writing

Characteristic	Frequency, *n* (%)
Less than 1 page	13 (25.0)
Between 1 and 2 pages	35 (67.3)
More than 2 pages	4 (7.7)
Included drawing	15 (28.8)

Students wrote legibly and in varying lengths ranging from a few sentences to multiple pages on the lined notebook paper provided. Only a few students chose to write as little as two sentences. The shortest science autobiography was exemplified by “Rusty” who drew a picture with a sad face and included the parenthesized phrase: “you have no clue what to write about “Rusty,” then added, “science was different in elementary school science. We played more games and in 4th grade there were a lot of legos.”

Most students, 67.3%, wrote between one and two pages of writing. Nearly every student wrote on one side of the notebook paper, and 29% of students included drawings in their science autobiography. Most of the drawings were science themed pictures. For example, “Hard Worker” depicted a person at a lab table with the caption “me making potions when I was little” and used words to describe her experiment comparing water and vinegar. She also included two captions and a conclusion to explain her illustration. The first caption read “this one is filled of water and it is about 75% full.” The second caption read “this one is about 28% full and is filled with vinegar.” The conclusion read “even though there not the same ingredients, they look the same!” In another example, “Dr. Cleopatra” included a drawing of a girl at a table holding a flask of bubbling liquid and a test tube that appears to be on fire. The student also included a drawing of a dinosaur skeleton and a rocketship.

All students wrote something in their science autobiography. They used different ways of expressing their voice in response to my inquiry focused on descriptions and explanations of their elementary science experiences. For this study, I focused on the meaning behind what was written and less concerned with how it was written. Though closely related, I did not examine or judge ways students wrote their science autobiographies. I also did not analyze drawings but have included a couple of examples of drawings.

All students used words in their science autobiographies and produced a wide variation in communication style. Students were not specifically asked to include drawings, but some students included drawings in their science autobiographies. Drawings were mostly rendered from elementary science experiences. These illustrations could have been used by students to represent something memorable that occurred during their science experiences. Illustrations could also have been unrelated to science experiences and used just as a form of doodling.

Structure of Findings and Discussion

The results of the phenomenological analysis are shared in this section. I used my own interpretations, supported by verbatim accounts extracted from each student's written words. There were multiple ways to organize themes and patterns because students had varied ways of describing and explaining their elementary science lived experiences. I chose to focus on categories that represented the most prevalent themes and patterns that emerged from the analysis. This was not done in an attempt to produce an amalgamation of those experiences;

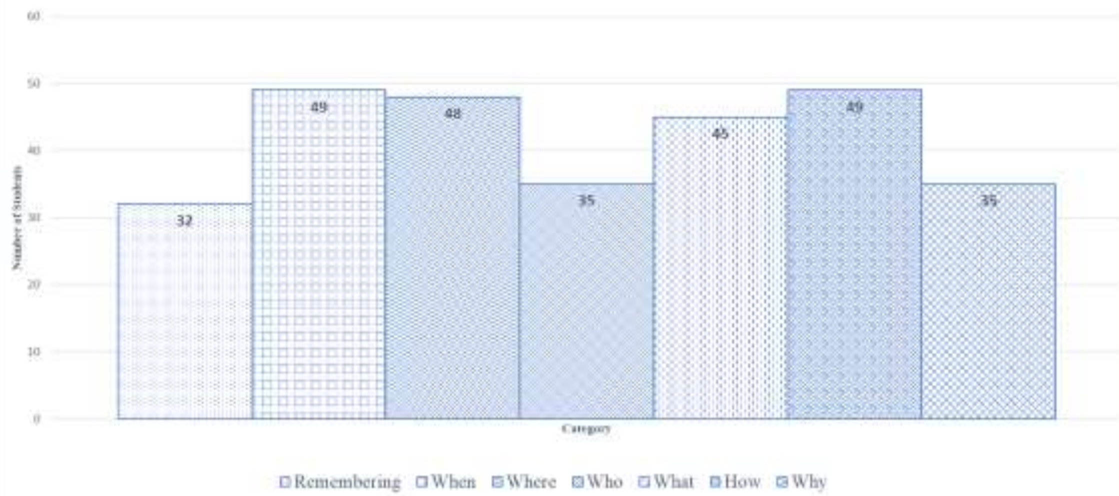
instead, I wanted to give shape and a retelling structure for the essence of those lived elementary science experiences. As Van Manen (1990) noted, determining the essential qualities or essence of the phenomenon means to “discover aspects that make a phenomenon what it is, and without which the phenomenon could not be what it is” (p. 107).

I organized categories in a way that presented the essence of elementary science, the lived elementary science experiences as told through the autobiographical science stories of middle school students. One of the first things that drew me into students' elementary science stories was how students used the word “remember” in the context of describing and explaining elementary science experiences. What students wrote about remembering will be shared first. Then, I will share the descriptions and explanations students used to share their elementary science experiences, categorized into common themes based on my own interpretation. Categories of *descriptions* include when and where science experiences occurred, who students described as memorable in their elementary science experiences, and what content and skills were learned in elementary science experiences. Categories of *explanations* include how and why elementary science experiences were carried out. Lastly, I include some additional insights drawn from students' voices across two categories: what students shared about their feelings and attitudes towards elementary science experiences, and feedback or advice students offered teachers.

The following categories resulted from a systematic and comprehensive qualitative review and analysis of student voice. I used keywords in my findings and interpretations. Keywords came directly from students' writing, extracted from the ways they described (the what, where, when, and who) and explained (the how and why) elementary science. Each category was ordered as a way to create flow in the retelling of middle school students' elementary science experiences. Figure 2 provides an overview of how many students mentioned keywords or topics within a category. For example, 32 of the 52 students mentioned remembering, 35 students mentioned another person in relation to their elementary science experiences, and 49 students mentioned ways that they engaged in elementary science experiences.

Figure 2

Categories of Themes from Science Autobiographies



First, I have provided an overview of the categories selected with operational definitions. Then, each category has been described and explained in detail with support from students' quotes as illustrative representations.

1. Remembering: This frames the “what” and “how” students described and explained their lived elementary science experiences. As an overarching concept or way of telling, what and how students remember is framed with what they wrote about remembering or not remembering. What was memorable about elementary science experiences for these

students? How did students reflect and choose to present their experiences from elementary science?

2. Timing: This represents the age or grade level students chose to write about elementary science. This is another overarching concept or way of telling. Timing of elementary science is complicated by a student's memory; for example, do students only remember certain years or events? When did elementary science begin for these students?
3. Setting: Where did students experience science? Was the elementary science experience they chose to write about inside or outside of school? Was the experience part of a school-based excursion or field trip, or as part of a family outing, friend adventure, or personal exploration?
4. People mentioned: Who did students mention or describe in their elementary science experiences? Students wrote about teachers, a mother, a father, family members, classmates, a friend, a friend's parent, or a clown at a friend's birthday party.
5. Content: Two areas emerged around science content, topics and skills.
    a. Content or topics that students learned in elementary science.
    b. Specific skills students learned, developed, or practiced in elementary science.
6. Ways of learning - This category included a variety of ways students described or explained the activities they used and participated in during elementary science experiences. The list included activities, experiments, investigations, demonstrations, field trips, or family trips.
7. COVID-19: Few students mentioned the COVID-19 pandemic in their science autobiographies. Those that did mention COVID-19 spoke of the impact it had on their

access to learning when they were required to stay home or engage in school in an online format or later a highly restricted classroom setting.

8. Feelings and attitudes towards science: Most students expressed liking or disliking science and described feelings or attitudes in different ways. Some expressed how feelings and attitudes changed over time based on the teacher, the environment, the ease or difficulty associated with learning science, or their personal interest. Most students used words like fun, cool, super fun, super cool to describe their feelings and attitudes about elementary science experiences.
9. Feedback and advice to teachers: Some students offered specific advice to teachers about elementary science experiences.

Remembering

Early in the repeated readings of science autobiographies, I recognized that many students commented about remembering in some way. Students that mentioned remembering fell into a couple of different patterns. Often in the first paragraph, they either wrote that they didn't remember much or only remembered certain things. One telling account of how students may have felt torn between remembering and meeting expectations of the writing activity came from "Oscar" who wrote: "I can't remember much about elementary science but I'll try my best with what I can remember." Table 3 shows the number of times students mentioned remembering and a sample of quotes from students.

Table 3

What Students Remember about Elementary Science Experiences

Themes	Example Quotes	Frequency, *n* (%)
Remembering	"I don't think I remember anything from science until 5th grade" [Swallowtail]. "I don't remember much from elementary school science but I do remember the experiments" [Learner].	32 (61.5)

Students that didn't remember much wrote things like "Dr. Danger" who wrote: "I can't remember that much of what I did in science in 1st or 2^{nd}." In another example, "Albert" wrote: "My kindergarten through third grade science classes are not very memorable and I don't really remember them." And finally, "Dino" wrote: "If we did (science), then I just don't remember about it." "Jimmy Neutron" wrote: "elementary science experiences are hard for me to remember because I never had science when I was in elementary school." In another example, "Pea Pod' commented: "For me I don't remember too much from my elementary school science because of COVID-19." "Mannequin" wrote: "I don't remember much from science in 4th or 5th grade because we were learning virtually, so my teacher couldn't do any interactive experiments." Another student, "Science Learner" wrote about another school, "I don't remember anything I learned that year."

Students that remembered only certain things wrote things like "Pea Pod" who wrote: "Overall everything I remember in elementary school science I remember vaguely but the things I remember best are the fun projects where I got to be creative." Similarly, "Mannequin" wrote about preferring certain types of learning over other types of learning, "many interactive experiments helped many kids in my class understand the material. I would have never remembered but because we did fun experiments and it has cemented stuff like that long-term in my brain."

The two primary ways students expressed remembering led me to consider how students are aware of the presence or absence of memory. I also thought about how and when they chose to mention it in their science autobiographies. Most students used their memory of elementary science as an introduction into the telling of their science autobiography. For example, "Boron" wrote: "The first memory I have of science is my Pre-k class." Another student, "Learner" wrote: "I don't remember much." Students remember a lot or a little; for example, "Aluminum" wrote: "I remember that day like it was yesterday." "Dr. Science" wrote: "I don't really remember any experiment with him [Teacher C], I do remember science was either fun or boring, but mostly it was fun." This example illustrated that students wrote about remembering using very specific details of elementary science like a grade level, or teacher. Students described the role of the teacher and how it is related to learning science and this will be explored in a later section. With regard to a teacher's influence *on remembering*, "Dr. Aspen" stated: "I really understood everything because we weren't just talking about random stuff everyday. It was the same concept but different units."

Other students focused on particular events they found memorable. Students sometimes associate remembering with negative or positive experiences. For example, recalling a field trip "Dr. Cleopatra" wrote: "we went to a space museum and learned about space but I don't really remember it well because it wasn't very fun. I feel like when an activity has been fun and active I have remembered it well." That same student recalled detailed memorable experiences with a friend when they visited a museum and went on camping trips. Another student's memorable out of school experience entailed making connections to classroom learning. "Bex" shared how learning about the moon's influence on ocean tides became memorable when visiting the beach during summer break. She stated:

> I never really thought about the tides or why they changed or how, so when I started to learn that the sun and moon influenced the tides my jaw dropped! I thought it was SUPER cool that two things that were so far apart could influence one another. What I learned about the ocean and sun and moon changed the way I thought about them. It also made me rethink my definition of science.

The memory shared suggests that this student made a connection between classroom instruction and the real world she inhabited and suggests that this connection changed how science was thought about. Koch (2018) states that students learn better when what is taught in the classroom is related to their personal lives. In this case, "Bex" expressed that she hadn't really given any thought to how or why tides changed until she learned these concepts related to the sun, moon, and tides in the classroom. Later, while she was on summer vacation, a connection was made between what was learned in the classroom and what was observed in the natural world. The student was impressed and excited to connect what was being observed at the ocean to what had been taught in the classroom. Teachers can connect and make visible classroom learning to the real world because these factors are powerful mechanisms for remembering (Koch, 2018). The accounts from students illustrate how meaningful connections are made between the real, natural world and a student's personal life.

Another way students' described memorable science experiences was through longer range scientific discovery or classroom observations that involve changes over time. "Sister Chromitad" shared about observing a caterpillar turn into a butterfly and "seeing a lizard with a cut off tail, then we took it into the classroom and it took weeks and weeks to repair." The student described watching eggs hatch into baby chicks that grew into large chickens. The student also described observing worms, an ant farm, and planting seeds that grew into big plants. Another student, “Dr. Aspen” recalled learning about plants “My second grade year was fun, I learned about plants and all about them. We planted plants and watched them grow until they died.”

This student’s account of learning science over time reminded me of learning progressions. This way of learning in science is recommended as an integral part of teaching and learning in elementary science. This way of learning produces deeper understandings of core science concepts (Koch, 1990). Learning progressions are well aligned in elementary classrooms and I’ve had direct experiences using this approach to teaching and learning. I have found that students in elementary classrooms benefit from these experiences to observe and consider how living things change over time. This connects all of science to the natural world and helps children construct deeper scientific understandings.

One student described their elementary science experiences through the personal changes that transpired. “Guy” wrote: “through elementary school all the way to middle school a lot of things have changed with learning and my thought processes.” This student’s account of how thought processes changed from elementary to middle school could be attributed to the fact that the student became older during this time period. While the student was growing older and maturing, new thought processes emerged naturally. As most children age, their brains are changing and developing. This student may have simply become aware of what is considered expected growth and development. The student also wrote that “a lot of things have changed with learning,” which indicates the student has recognized that learning is different in middle school compared to elementary science. My interpretation is that this student’s account of changes is due to what naturally happens as a human grows older and is involved in learning experiences. It seems reasonable to assume, for example, that in middle school I am different than I was in elementary school; I have grown older and I have experienced new learning. The student is older now and has continuously participated in a structured school setting where science teaching and learning has transpired and evolved.

Students wrote about levels of difficulty varying over time and how each year different subject areas became “my biggest enemy” or “my favorite class.” “Guy” ended the science autobiography by stating “science is back on my good side thanks to a great teacher.” One student, “Dr. Aspen” shared an unpleasant experience with a teacher that was memorable: “3rd grade I really do not remember, I only remember the teacher calling me out on something causing me to fail an assignment that was a big grade.” This student identified the teacher as influential in how elementary science experiences were perceived, experienced, and remembered in both positive and negative ways.

To summarize, one interpretation of students and remembering is this: when students describe and explain elementary science experiences, they choose to tell their story by first qualifying their experiences as remembered or not. This way of prepositioning writing about elementary science experiences with a qualifier of remembering could be an example of what Weatherall (2011) calls epistemic hedging, a practice that “shows less than a full commitment” (pg. 334) on the part of the teller. It could also mean that students are fully committed to remembering their elementary science experiences but either did not have elementary science experiences or the elementary science experiences they did have were not memorable. The point here is that there are different ways to interpret this idea of remembering. The purpose of this study is to focus on what students said and not to attempt deriving meaning about the deeper cognitive processing that occurred around remembering. Teachers can learn a lot from students about what constitutes memorable learning. Students seem to remember learning experiences when they are actively participating or engaged in experiences they find interesting. One way to better understand what students find memorable is to ask them for their input. Another area that students wrote about remembering was the social and emotional aspects of the teacher and student relationship. Student remember certain teacher actions that leave them feeling bad or good. Teachers need to understand these aspects of teaching and learning and the best way to obtain this information is through the student's own voice.

In the next section, the ways that students described their elementary science experiences are shared. Table 4 provides an overview of the themes that were created from many ways students described their elementary science experiences. Themes are represented with sample student quotes pertaining to the when, where, who, and what of elementary science experiences.

How Students Describe Elementary Science

Timing. Students related their science experiences to particular time periods or when these experiences occurred. Students mostly referenced grade levels in their autobiographical writing, rather than their age. Maybe students consider science as something that occurs in school so that they automatically relate science experiences with the grade level when it occurred.

Students wrote about certain time periods for elementary science and they used grade levels, ranging from kindergarten to current (6th or 7th grade). They may have referenced specific grade levels in school, such as: 3rd grade, 4th grade, or 5th grade as being memorable because of certain activities or events. They may have referenced a certain meaningful event, as in when they talked about the COVID-19 pandemic occurring during their 3rd or 4th grade years.

Table 4
Ways Students Described Elementary Science Experiences

Themes	Example quotes	Frequency, *n* (%)
Timing (age, grade level)	"I got my start in science when I first started at this school" [Dr. Science].	49 (94.2)
	"Pre-K through 3rd grade I was at a Montessori school. We didn't really do any science stuff there. If we did then I just don't remember about it" [Dino].	
Science Setting	"Out of all science experiences I have done whether they were inside or outside of school, I have done many" [Science Susi].	48 (92.3)
	"We had science in online learning. Then we came back to school and our homeroom teacher taught us science" [Dr. Science].	
	"I remember going to the Perot Museum and learning all about science like volcano experiments" [Chopsticks].	
People mentioned	"When I met [teacher A] it seemed as if my world changed. She was one of the best teachers I have ever had" [Phospholipid].	35 (67.3)
	"My mom would always show me cool experiments and why science is important" [Chopsticks].	
Content and Skills	"In 5th grade we went over the solar system, volcanoes, oceans and Newton's Laws" [Acla].	45 (86.5)
	"In kindergarten we did simple experiments, I remember we did a will it sink or float? Experiment with simple objects" [Birdy].	

Many students described lower school as either including science or not including science. One student, “Thinking Cell” shared: “I do not think we learned that much about science in 2nd or 3rd grade.” Another student, “Swallowtail” wrote that she didn’t remember much about science before 5th grade; “Every class from beginners to 4th grade was just a blur of writing.” She added “I wouldn’t know because it was so boring I never really paid attention.”

Others talked about being at a different school for elementary grade levels. For example, “Birdy” stated “I went to a different school before (this school). My experiences from science in both schools are very different. In kindergarten we did simple experiments…but our main focus was never specifically science, it was always math and reading." Several students shared that science began at this school. "Dr. Science" wrote: "I got my start in science when I first started (at this school)." "Dr. Cleopatra" had a similar statement: "My experiences in science during school mostly started when I came to (this school). Before that I went to (another school) and they didn't teach us any science." Another student, "Dino" wrote that "Pre-k through 3rd grade I was at a Montessori school. We didn't really do any science stuff there. If we did, then I just don't remember about it." Statements about science not really starting until coming to this school indicated to me that some other schools may not have as strong a focus on science for younger students in elementary grades. If students had science in earlier grades at other schools it appears those experiences were not particularly memorable. Based on the responses from students that had attended this school for all their elementary grades, it seems possible that this school has a higher emphasis on science in comparison to other schools students attended. It could also mean that other schools teach science in different ways that are not as explicit to students. For example, some schools embed science learning into other content areas in an integrated approach. When students did not mention science from lower elementary grades it could mean they did not receive explicit science instruction, it could mean they did not remember science from early elementary grades, it could simply mean they chose to focus on other grades, or it could mean something else.

Some students offered their own opinion about why science was not taught to earlier grades. "Dino" wrote "Now that I'm older, I kind of understand why they didn't teach us that much science. This is because science is a complicated subject and the teachers probably thought science would be too hard for our young minds to comprehend." Another student, "Swallowtail" shared similar thoughts, “we might not have done much (science) because little kids aren’t very good at experiments, but I feel like we could have done something to make the class more enjoyable.” One student, “Science Learner” referenced a teacher at another school when she wrote “she would always give the older classes fun experiments. The fun experiments she did were never for us because we were too young.” These two students expressed that science is not really designed for young children. One student claimed science was “too hard for our young minds to comprehend” and that sentiment just does not align with how I was trained. The other student seemed to agree when stating “little kids aren’t very good at experiments.” As if young students are not ready for science instruction. I found these accounts of why science is not taught in elementary school to be in contrast to what I believe. I wonder where these misconceptions about science came from. My experiences in elementary schools tell me that young children are capable of learning age-appropriate science. In public schools in Texas, students are required to learn science beginning in kindergarten. It would be interesting to ask these students follow up questions about how that arrived at those conclusions about teaching and learning science. .

In another example about the purpose of elementary science, “Learner” wrote “I think the goal of elementary school and middle school science is to help you choose which science you want to study in high school.” This student has the perspective that elementary science is designed to expose students to many different topics in science during elementary. The reason suggested is to help prepare students for high school where science is organized into smaller strands. This makes sense with how science is typically carried out in public schools and it sounds like this is how science progresses at this school. I wonder if students are prepared for the rigors of high school science when some suggest they have not experienced much elementary science. If the goal of elementary science is to prepare students for high school, then doesn't it make sense that all students would have the same science experiences?

Middle school students have different ideas and thoughts about when elementary science is taught; some believe science is reserved for older students, because young children are not developmentally ready to learn complex content. Others think science is taught at some schools and not others and suggest that science may be left out because some schools focus on other content or subjects like mathematics and reading.

Setting. Students mostly wrote about science experiences that were connected with school. Experiences affiliated with school occurred inside the classroom, outside the classroom but still at school, on a school organized field trip, on to a lesser extent, in an online learning platform while at home during COVID-19. Students also mentioned science experiences that were not associated with school; for example, a lesson learned at home, a friend's party, on a family vacation, at a museum, or other outing. School settings were not always explicitly named; rather students mostly said things like "Oscar" who wrote: "in my 3rd grade class" or "Chopsticks" who wrote: "in lower school science." Another way students labeled settings included "Science Susi" who wrote: "out of all science experiments I have done whether they were inside or outside school, I have done many." One student, Dr. Duffensmarts" mentioned using "trash found outside" for an egg drop competition, so it can be assumed they went outside, but the student did not go into detail about how they went about collecting the trash from outside. In another example, "Science Learner" wrote about the class going outside with the teacher and learning about science, saying "she would take us outside and teach us about trees and leaves."

Field trips were mentioned by several students and were described as mostly positive experiences, but a FEW students wrote about not enjoying a field trip. One student, “Dr. Danger” recalled:

> One of my favorite science field trips so far in my life is Galveston. It was my first real science trip and we learned so much! I remember driving to Galveston. It was a 3 hour drive and we stayed at a place called Camp Spark. The next day is when everything happened. We went to so many places, we went to an oil rig and we learned about really cool things. I remember going to a space museum and seeing so many cool things. We had a lot of free time during the trip.

Another favorable comment came from “Leboult,” who wrote:

> We took a field trip to Galveston, Texas. We also had a stop in Houston, and in Houston we toured NASA. This was not only really cool to experience and see rockets, but it was also cool because at that time we were learning about gravity and rockets have a lot to do with gravity.

These two students wrote about enjoying the field trip to Houston, which appears to be an example of a tradition at this school. They each provide specific reasons why they enjoyed the field trip and these were things that it seems most students would enjoy.

In contrast, “Doctor Cleopatra” wrote favorably about other science experiences but expressed not enjoying the field trip to Houston, stating: “we learned about space, but I don’t really remember it well because it wasn’t very fun.” In the member checking interview with this student, I inquired about why the experience “wasn’t very fun” and the student said “we were told where we had to go and what we had to look at, I would rather look at what I want to explore." I thought it was unusual that one student would write about not enjoying an overnight field trip, while other students wrote about the same trip as an enjoyable experience. I was pleased to gain clarity from the student during the member checking interview and this helped with my interpretation. The student was able to share that the unfavorable part of the trip was being told what to do and where to go; not the trip itself. This reminded me of an assigned field trip I used to take with my class of 5th graders. Each year we took the class to a particular museum. Before going, we were given a tight timeline and a very prescribed list of what we could go see while in the museum. I recall that many of my students lamented about not being able to explore further inside the museum. I understood the administrative side, but I still wondered why we couldn't take some time on the field trip to allow students to explore other areas that were of interest to them. This makes me think how beneficial it would be for students to routinely share their thoughts, opinions, and interests in teaching and learning science.

Other students wrote about science experiences that occurred in ways that were not directly associated with school. For example, "Night Hawk" wrote about how his dad had sparked his interest in science: "The biggest thing that exposed me to science was when my dad taught me about Newton's Laws and physics. This sparked an interest in me to discover how things happen." The student shared advice he would give his younger self, stating, "Science is not just in labs, it is the base of all things, … there is no limit to science." My interpretation for this student's account is that his dad taught him about a science concept and it sparked his interests in science. It sounds like the experience really opened the student's eyes to the world of science. I think the student's final remark is powerful; he shared that science has no limit. It could mean the student recognizes that science is everywhere and has made the connection that science can be explored, inside or outside of school. This also tells me that for students at this school, elementary science is not reserved for elementary classrooms. This may or may not be true for students that attend different schools.

Another student, "Science Susi" shared about having science experiences at a friend's home for a birthday party where a clown was the entertainment. At the party, Doctor Doughnut, the clown, thrilled and amazed the children with science activities. The student remarked "after that moment I realized how fun and interesting science is. I also learned you do not need to be in school to learn science."

These two examples show me that students are exposed to science in their everyday lives and they recognize these experiences as science learning, regardless of where it occurs. It's important for teachers to understand the many ways their students are learning science. This provides an opportunity for students to share their personal science experiences within the classroom. I think this is something teachers could incorporate into instructional strategies. Teachers can embrace influences that occur outside school because all experiences impact learning. Teachers are not the only instructors for science and should encourage any and all ways student interest is sparked. It is empowering for teachers to lift up these external science lessons as highly valued and bring them into the classroom. This school may be unique in that students may be exposed to more science learning external to the classroom (affluence buys opportunities that may not be available to lower SES students). However, I believe all students have science experiences in their "real world" (lives outside of school) but they may not recognize those experiences as such. It is my belief that when connections are made and learning is made visible to students, both inside and outside of classroom experiences, students may be motivated or inspired to explore science connections independently. The science autobiography offers an easy way for teachers to learn this invaluable information by eliciting the voices of their students.

Several students wrote about science experiences they had during camping trips where they explored animals and collected rocks and fossils. One student, "Birdy" wrote that she received limited science instruction in her classroom but enjoyed repeated annual field trips to the Dallas Arboretum where they participated in hands-on science experiences. The student shared that she had taken a liking to learning science, but "unfortunately my school didn't have much to offer for what I could learn about science." The student added "We would talk about what we learned on the Arboretum trip at school but then we would quickly go back to only learning math and reading." She said her mother started taking her back to the Arboretum when they had free time "so I could see, experience, and learn about science outside of school." A couple students mentioned participating in a non-school sponsored camp during the summer months. "Pea Pod" was one of those students and remarked that the experience was not memorable: "I remember doing a STEM camp the summer before 3rd grade, I don't remember anything about that except I think we grew a lima bean in a cup." This tells me that students may experience science outside of school that is not memorable. The student did not elaborate on this experience so it cannot be determined why the only thing remembered was growing the bean in a cup. It could be that the student did other things at the camp that were not considered associated with science and therefore were left out. Maybe the student did not enjoy the camp and it was not memorable or maybe it was something else.

"Bex" shared an experience that connected classroom learning with real world context when on summer vacation with the family. The student wrote about observing ocean tides and thinking about how tides are related to, and influenced by, the sun and the moon. She was impressed that "it was SUPER cool that two things that were so far apart could influence one another." This student made a clear connection between the ocean and the tides. I think it is important that students have access to these real world scenarios in connection with their classroom learning. It is great that this student took a trip to the ocean and was able to see it live. There are other ways to bring the outdoors into the classroom; especially for places that are not geographically local.

In another example, another student wrote about an outing with a family member to participate in a "new competition" at the natural history museum. "Dr. Duffensmarts" didn't specify which museum but did provide details about designing "the ultimate parachute" and "destroying everybody" in the egg drop competition. Another student, "Chopsticks" referred to the Perot Museum as "my favorite memories" because it was "so much fun to learn all about science and all the cool things like dinosaurs and space." Students enjoy taking advantage of science museums in the community and students seem to have fun discovering science, wherever it takes place. Next, I'll summarize the different science settings students described in their science autobiographies.

Students recalled and described different places or contexts where elementary science experiences occurred. Students didn't necessarily name a particular location at school, so I inferred that the location for science learning was in a classroom. Others named particular settings or locations: inside or outside the classroom, on school sponsored field trips, in online learning during COVID-19, at home, at a friend's home, on vacation, or on other outings like summer camp or museums. Some students expressed dissatisfaction with their elementary science setting. For example, "Science Learner" shared that being at home during COVID-19 made learning science difficult. Most students liked elementary science settings and, in some cases, made it explicitly clear how the particular setting had deepened their understanding about key science content. For example, one student traveled to the beach and made a connection between the ocean tides and the moon. I wonder, what factors most positively influence a student's ability to enact deep cognitive thinking about science content where they are able to translate learning to real world applications? This student shared something I would not know without reading the science autobiography. Even during summer break students are making real world connections. It seems that when students learn science concepts well, they are able to translate that learning to other settings or make better connections with the real world. I do not think this concept is unique to this school. All teachers play an important role in helping move learning along by being aware that students are exposed to science all the time, everyday. Teachers can bring student's external science experiences into the classroom by finding the time and space for student voices.

People Mentioned. Nearly 70% of students mentioned a person in their science autobiography. Students may have referred to the person by name, title, or role - for example, my dad, a friend, or a teacher. People were named as having influenced science experiences, were named as collaborators or participants in science experiences, or were simply mentioned in name, title, or role. Students sometimes provided features or characteristics of a person named while at other times they described the role a person played in their science experiences. People may have been presented as influential in learning science in either positive or negative ways. Table 5 shows the people that were mentioned in some way by students in their science autobiographies.

Teachers were, by far, the most often mentioned in students' science autobiographies. Nearly 60% of students mentioned teachers by name or title. It is no surprise that students would mention a science teacher when reflecting on their elementary science experiences. It is plausible that students would associate elementary science with science classrooms since the word elementary often is used synonymously with school. Also, when factoring in that the science autobiography was administered in a science classroom at a school, it makes sense that the association was clear to students. Teachers are leaders in classrooms, so it makes sense to me that they would be the number one person identified by students in their science autobiographies.

Table 5

People mentioned in elementary science experiences

Person named	Example quote	Frequency, *n* (%)
Teacher	"I had [teacher A], she was so kind and was good at controlling our class" [Science Learner].	31 (59.6)
Parent	"The biggest thing that exposed me to science was when my dad taught me about Newton's laws and physics. This sparked an interest in me…" [Night Hawk].	10 (19.2)
Friend or friend's family	"I just remember that I had a blast making play-dough with my friends" [Macy].	4 (7.7)
Other	"It was an experiment I will never forget. It's all because of Dr. Doughnut!" [Science Susi].	1 (1.9)

Next named, in order of times included across science autobiographies, was a parent. Parents, mentioned by 17% of students, were identified as either mom or dad. Roughly 8% of students mentioned family members or friends in their science autobiography. Finally, one student mentioned a birthday party guest that inspired a passion for science during elementary years. A sample of students' accounts of people mentioned will be shared in this section. I will begin with teachers because they were mentioned most often.

Teachers. Students had a lot to say about their teachers. Teachers can learn from students different ways to adjust instructional practices or develop personal interactions with students. A few references to classroom teachers were negative, but the vast majority were positive, if not glowing! Students wrote about teachers as generic individuals whose name they could not recall, or they wrote about personal attributes or pedagogical practices related to a particular teacher. This distinction is important when considering what constitutes a positive teacher status; was it the teacher's personal attributes, the fun activities they carried out, both, or something else? Different scenarios were represented in students' accounts of their elementary science teachers. Table 6 shows a sample of teacher mentions and provides a breakdown as to whether the mention was positive or negative, and whether it was associated with a teacher's personal attributes or pedagogical practices.

Students wrote positive things like: "Guy" who wrote: "science is back on my good side thanks to a great teacher, my teacher was nice." In another example, "Oscar" shared: "[Teacher B] was very similar to [Teacher A], a very joyful person and someone who understands me a lot." Or in a more descriptive account, "Phospholipid" shared: "when I met [Teacher A] it seemed as if my world changed. She was one of the best teachers I have ever had." The students described arriving at a new school and being introduced to [Teacher A]. The student expressed, "Her personality was amazing and all of her classes were amazing. The student goes on to list the varied activities carried out in that classroom, including "the projects we did were fantastic." This student shares that [Teacher A] is retiring and will be missed, adding "I really started to realize I was going to miss her a lot. We had created so many good memories." Students associate positive experiences with teachers that care about them personally. Teacher descriptions led me to understand that students have positive perceptions about teachers based on their pedagogical practices and personalities or personal attributes, including how teachers made them feel. It can also be said that students associate negative experiences with teachers based on their pedagogical practices and personalities, or attributes, including how teachers made them feel.

Table 6

Teacher Valence by Characteristic

	Example Quotes	
Teacher Characteristic	Positive Valence	Negative Valence
Personal attributes	"We had a really nice teacher, [Teacher A]" [Thinking Cell]. "[Teacher A], who by the way is awesome! taught us about clouds, planets, space, and animals" [Dr. Cleopatra]. "I remember how fun the teacher was and how cool the classroom was" [Mitosis].	"It got really frustrating because [Teacher] wasn't helpful either" [Science Learner]. "I didn't really like science then, [Teacher] kinda made it boring" [Dr. Science]. "I felt like I didn't need to try…because my teacher, she always wanted to get me in trouble and didn't want to help me get better" [Guy].
Pedagogical practices	"One reason my thought for science changed, because the activities we did in [Teacher A] class were very engaging and made me think outside the box" [Chromosome]. "[Teacher B] does labs we can do interactively and that helps remember the things we learn" [Dr. Cleopatra].	"In kindergarten, I don't remember much science because the teachers were focused on teaching us how to read and write and shapes and letters and very basic math" [Chopsticks].

Using an example of a less favorable memory associated with unnamed teachers, "Kimmberly" expressed teachers did not appear to care:

> "Now, when I went to ask teachers to help me provide the evidence and scientific studys, I was just pushed to a corner, just some other thing to deal with. But through my life I feel like my science teacher never helped me because she didn't believe in me, she was not willing to give me her support. This really discouraged me. For her I was just a stupid little private school girl. But what she didn't know is I have experienced things that I could have never learned in a classroom. In school we are never taught real world skills or experiences and thats what puts a break on our creativity."

In this scenario the student appears to be attributing her discouragement to the teacher's actions of not helping. The student writes that the teacher did not believe in her and that left her feeling that the teacher thought of her as stupid. The student also shares that she learns science outside of the classroom. It's not clear if the student imagines that this is what the teacher thinks about her, or if this was once verbalized by a teacher.

Even without a reciprocal response from the teacher, I believe the mention warrants consideration. The student indicates that she enjoys science, just not in the classroom, a feeling she apparently associates with the teacher's actions. The student's account may not be a perception shared by other students, but it does stand out as a motivation to lift up all voices so that no student has adverse feelings. It makes me wonder if this scenario would have played out differently if "Kimmberly" had been given opportunities to share her voice and be listened to during elementary science. This last example was one student's negative experience in elementary science that was associated with a teacher.

In the next scenario, another student recalls a negative experience with a teacher but seems to have a different outcome.

This experience was reported by "Science Learner", who shared:

> The teacher was very hard to work with. I didn't really like that class. I don't remember very much of it, but we did do slime experiments and a rocket experiment. I remember making a toothbrush move with a battery and wires. I didn't like that year very much. I remember dreading going to science.

In this case, the student describes the teacher in a negative valence without elaborating on what constituted "very hard to work with." When I examined the phrases "very hard to work with" and “I didn’t really like that class,” combined with “I remember dreading going to science” it seems that the student is attributing a dislike of science to the teacher and not the activities that are listed.

The student didn’t specifically write about liking or disliking the activities referenced. However, my interpretation is that this student’s dislike of the teacher resulted in dreading science class, despite seemingly engaging science activities. The same student then goes on to describe a more favorable experience with a different teacher the following year. This led me to conclude that students can move on from a less favorable experience in science class. The negative experience with the first teacher was memorable for this student but did not seem to leave a permanent dislike of science. In other words, I believe in the resiliency of young students to experience negative events or situations and to overcome them when they are replaced with more favorable experiences. Alternatively, the first student portrayed a lasting negative impression of classroom science attributed to how classroom teacher actions were imprinted in her memory. The second student portrays a bad experience but was left with a more favorable outcome of science. Even though both students had negative experiences associated with teachers, the second student was able to overcome that impression of science the next year with a different teacher. I do not know from this data why one student appeared to be more resilient than the other with overcoming a negative teacher experience. It could be associated with the intensity of the negative experience; for example, it is plausible that a more impactful experience would be more difficult to overcome than a less impactful experience. Another possibility is that the first student never had a more positive teacher experience and used the negative experience to rationalize her feelings towards science in general. In the second scenario, the student acknowledged the negative experience but moved on to more favorable memories of science experiences. Two students, “Kimmberly and “Science Learner,” wrote about negative elementary science experiences related to a teacher’s personal attributes yet seem to have had different outcomes. We don’t know if the teachers mentioned are the same or different because it was not shared. Either way, the important takeaway is that teachers can learn a lot about teaching and learning from the voice of students when they are given the opportunities to share.

In another excerpt from “Kimmberly,” she provides additional reasons for not liking lower school that are associated with teachers pedagogical actions:

> Throughout my years, I have never been asked what would you like to learn? Now, I am very curious and I like to know everything but the things we learned in lower school were just things to fill time. Every teacher, specifically the science ones, never made it a joy to learn, often the things I often wondered/cared about were never discussed in class. I always wondered why teachers told us to ask questions but half the time they didn’t really want to answer us.

This account seems to suggest that this student has had numerous experiences with teachers not including students in teaching and learning practices. I believe this because she says “throughout my years.” She also wonders why teachers ask students to ask questions but don’t always answer those questions. It seems to me that some of these comments in isolation are relatively simple to solve through ongoing classroom dialog. It’s not clear if students at this school have routine opportunities to inquire about instructional practices or offer input into those decisions. Another student, “Student Alpha,” wrote about not liking a teacher but still expressed positive science experiences in elementary science: “we had a teacher named (Teacher D) who I did not like. We did do some very cool things though.” It seems like it would be difficult to learn from someone you did not like. However, this student’s account indicates that a student may tolerate a teacher’s unfavorable personality if they enjoy the science experiences or activities. Another idea is that perhaps this student had other, unnamed coping mechanisms or supports that alleviated the impact of the teacher relationship on learning science.

Some students wrote about teaching and learning without naming a person, but it is clear they are referring to pedagogical practices. “Kimmberly” reported “Now I have never loved science and I think that’s because of the way I was taught,” adding, “In the beginning it was [Teacher B] who taught us very pointless stuff from what I can remember. I think the class was just something to fill time.” Another student, “Dino” wrote: “So I think that science is a complicated subject, but if you teach it correctly, it isn’t that complicated.” In another example, “Swallowtail” wrote: “I wouldn’t know because it was so boring I never really paid attention.” Then “Idocytok” summarized science in the following manner: “When I think of science I think of a nice teacher but a boring subject. I think science is boring because I don’t like researching or memorization because I don’t understand it even if I am taught by the world’s best and knowledgeable scientist.”

Students associated personal feelings towards science with teachers, while other students focused on acknowledging relationships between science complexity, teaching, and understanding. Students also remarked that science is boring or difficult to understand when memorizing or doing research. Other students wrote favorably about doing research “Lysosome” wrote: “animal research projects were interesting and fun.”

What these statements tell me is that pedagogical practices matter to students. Even difficult concepts can be made easier or understandable with what “Dr. Duffensmarts” referred to as a “good way to teach science.” Students either like or dislike particular approaches to learning. Students want to learn meaningful science content and they prefer to learn science in ways they like. My conclusion is that students like having a choice in what and how they learn. Schools typically have standard curriculum in place that is set by a school district in the case of public schools. I do not have experience with how curriculum decisions are carried out in private schools. I imagine, however, there are decision making groups in private schools that drive curriculum decisions. Even with certain decisions predetermined, schools usually have some levels of flexibility or autonomy built into classroom practices that incorporate student needs and interests.

In most schools teachers have some ability to adjust and adapt pedagogical practices to support their learners. Teachers can use student voices to better understand effective ways to reach their students. Input from students helps teachers understand students' personal interests and preferences for teaching and learning elementary science. Student voices can also be used to advance other school goals like building democratic dispositions which some argue is a student's right (Fielding, 2007; Fletcher, 2004; Laux, 2018; Lubelfeld et al., 2018; Ochoa-Becker et al., 2001; Rudduck & Flutter, 2000).

Not all students that mentioned a teacher shared a name. However, one named teacher consistently stood out as exceptional. [Teacher A] was named in ten "about 32%" of science autobiographies that mentioned teachers. One student, "Phospholipid" referred to [Teacher A] as "one of the best teachers of all time!" Another student simply wrote "We had a really nice teacher, [Teacher A]. One more detailed favorable comment about [Teacher A] came from "Science Learner:"

> My favorite year was in [elementary]. I had [Teacher A] she was so kind and cared about us, and was good at controlling our class. She had animals in the room that made the classroom even better. That was such a good year. I enjoyed it so much.

Students also wrote about [Teacher A]'s classroom, using characteristics like having animals. Several students mentioned classroom pets, "Newton" wrote: "[Teacher A] had fishes, a bunny called cinnamon, a bearded dragon, a salamander, and chickens. I really enjoyed playing with the bunny and I found the bearded dragon entertaining." Another student, "Cytoplasm" remarked about having fun with classroom pets because you could play with them in class, but added "they could be distracting."

It was revealed that [Teacher A] was frequently named as students' favorite across both grade levels, to the point of students comparing other teachers to [Teacher A]. I gained the impression that [Teacher A] was a renowned science teacher that most students had experienced. Most students would have had [Teacher A] because she taught in the upper elementary grades. Students commented about [Teacher A] as one class they always looked forward to and one that was filled with interesting explorations, investigations, animals, and experiences that were memorable and shared with enthusiasm. Here are some other comments students made about [Teacher A]. "Chromosome" had written about lower school as "boring" but was pleasantly surprised when upper elementary and middle school turned out to be different. This student described observing a petri dish filled with bacteria in a lower elementary grade: "at the time it didn't feel fun and just felt like a slideshow." The student continued with "I reason my thought for science changed because the activities we did in [Teacher A]'s class were engaging and made me think outside the box." This really speaks to how much an influence a teacher can have on a student's perception of science. The student reported one example that was not fun "just felt like a slideshow" which I interpret to mean the students did not like slideshows. Then "Chromosome" attributed a change in attitude towards science that was associated with a teacher who "made me think outside the box." Teachers have many ways to push students to think deeply or outside of the box. It is not clear if [Teacher A] elicited student voices but it is clear that the teacher, who had the students observing a petri dish, could have learned something from how the student described learning experiences in that classroom.

Teachers have opportunities to routinely elicit student voices in classrooms by asking students for their input or feedback. The science autobiography is an inexpensive and efficient tool that helps teachers elicit student voices. The impact can be significant for both teachers and students in any school setting.

Parents. Ten students mentioned parents, mom, or dad in their science autobiographies. When a parent was mentioned, sometimes it was with context and detail and other times it was a brief mention. Sometimes students wrote about parents in general. For example, "Leonard" wrote about making oobleck[1] during science class and expressed "This was a really fun experience because we got to make it then play with it and take it home to home to show our parents!"

Students wrote specifically about moms. For example, "Chopsticks" said "In lower school my mom would help me. One time before a quiz about ears and I didn't know a lot and I would always forget." and added "my mom would always show me cool experiments, and why science is important." In another example, "Dr. Cleopatra shared: "My mom is a teacher and she always tells me to read, which isn't a problem. I love reading, but I read about ancient egypt a lot and that led me to read about rocks and bones. So I learned a lot about that." This same student added that her mother "made me and my sister research animals." One student, "Guy," shared

[1] Oobleck is a substance that is a suspension and can take on the physical properties of a liquid or a solid. It was made famous by the children's story, Bartholomew and the Oobleck (Dr. Seuss, 1949, as cited in Koch, 1990).

about a turning point in science that occurred causing a shift from a less favorable to a more favorable relationship because of something the mother made the student do:

> I had trouble in science even though it was my favorite class, till summer that year I hated science. I didn't really like science that year because we had to do work that wasn't science, like worksheets that didn't relate to science. After my mom made me go to some science thing that summer so I really enjoyed it because there were all these cool inventions like volcanoes.

"Birdy" recalled not having many science experiences at school during early elementary grades but did learn about science on a field trip to the botanical gardens. "Birdy" shared, "My mom saw how much I liked going there so she would take me on weekends or whenever we had free-time so I could see, experience, and learn about science outside of school."

In another example, "Roan" simply stated "My mom is a biologist, scientist," but added no more context for the mention.

Students also wrote about dads. "Pea Pod" shared a moment her dad was involved with science. While learning about the solar system, the student created a diorama using styrofoam balls to represent the planets, saying: "I remember I was so proud of it my dad even sent a picture of it to my grandma." Another student, "Kimmberly" wrote: "My dad and I have attempted to write a book about studys about how people learn better at night." In another example, "Dr. Duffensmarts" described participating in an egg drop competition at school and then taking the model developed at school to a natural history museum for a new competition. "So me and my dad took 3 days to make the ultimate parachute." The students shared details about how they created their parachute, then added “Then we put it to the test. We destroyed everybody!”

Students seemed genuinely excited to share science learning and accomplishments with parents and with extended family members. They also shared favorable comments about parents’ involvement in their elementary science experiences both in and out of school. Students also wrote about doing projects with parents: for example, an egg drop competition, a science fair, or even writing a book. Students enjoy extending science learning to other venues outside of the classroom. Sometimes students were explicit about the impact a parent had on their science, for example when “Night Hawk” shared that his dad was “the biggest thing that exposed me to science. It sparked an interest to discover how things happen.” A parent may be influential to a child’s learning when they require the child to do educational things like reading, researching, or attending a summer science camp outside of school. Sometimes those experiences are welcome, as in, something the child already enjoys. Other times the experience required by the parent may be unwelcome, but turn out productive, nonetheless. Students did not elaborate on other things parents or family members did in relation to their elementary science experiences.

I believe parents can be influential in developing a child’s interest in and attitude towards science during elementary years. My interpretation is guided by both student voices and my own role as a parent and teacher. Looking back in reflection, at my now grown children, I relate to requiring my children to participate in academic experiences they were reluctant about. I fondly recall how often a changed attitude resulted from these parenting moments. It was rewarding as a parent to observe the shift in mindset once the child realized the experience wasn’t so bad, after all. The science autobiography exposed ways students described ways parents were influential that I might have guessed or assumed. It makes sense that students would be excited to share work they were proud of with their parents. I took my children on vacations where we explored science concepts, so these family excursions were familiar to me. On the other hand, I might not have thought about a student's family sending a photograph of a science project to a family member that lives somewhere else. These student voices showed me some of the many ways they experience science and how they share those experiences with family members.

Other People Mentioned. In roughly 10% of the science autobiographies, students mentioned someone other than a teacher or a parent. In these cases, students mentioned a classmate, a friend, a friend's parent, a family member, or a clown from a friend's birthday party. "Macy" recalled an experience in lower elementary school:

> I also remember having a really fun time in science in second grade. I remember that we got to make play-dough. I think it was supposed to represent something but I can't really remember. I just remember I had a blast making play-dough with my friends .

Similarly, "Georgie" said: "Science to me was a break from reality to see and to do cool things with my friends." In another example with a friend, "Dr. Cleopatra" described meaningful science experiences completed outside of school with a friend. During these out of school experiences, "I learned lots of science" when "me and by bff would go to this museum and explore, it taught us about rocks, fossils, volcanos, weather, and space. Her dad is a geologist so he taught her things that she later taught me." This example demonstrates how influential parents can be, even when it is a friend's parent. In this case the parent happened to be a scientist and was able to help teach new concepts. It is not important whether the learning was new or not at the time. However, it does seem important that students seemed to really enjoy learning about science with friends and family members. When teachers know these things about their students they can create new opportunities for learning. For example, teachers can build strong home and school connections to extend classroom learning. Extending beyond the scope of this work are many ways to create productive home and school science connections. These types of practices can cultivate relationships with families and represent more opportunities to extend classroom learning. I can imagine that closer connections between home and school science could promote deeper learning and replace more independent homework practices.

Other students mentioned learning science concepts outside of school that were influenced by other people. In these examples, students recall favorable science experiences they had with friends and friend's family members. Even when the science concepts that are intended for learning are not memorable, students still remember having fun or doing cool things with other students. These accounts suggest to me that science learning is social and when students have opportunities to collaborate with others, they are mostly positive. Sometimes that happens with learning outcomes that are more exploratory or less structured. For example, when making and playing with play-doh. On the other hand, there can be problems associated with group dynamics. For example, one student mentioned having trouble with a group of peers on a project and having to do most of the work on the project. This is not uncommon, because collaborative groupings can lead to imbalanced workloads among members. I think it is important that students have opportunities to share their voices so they can contribute to teaching and learning practices and are empowered to resolve conflict when adverse student interactions arise.

Family members that are not parents may be influential in a student's elementary science journey. For example, "Guy" wrote a surprising account of an elementary science experience:

> Second grade got so much harder than I ever thought, the whole year was very hard for me for some reason. I felt like I didn't need to try because my brother always said that I can just lay around all day or skip school and it wouldn't matter, so that's one reason.

In this example, it seems that a student was being misguided by an older brother, who for an unknown reason, was giving advice. I cannot be certain how these comments were intended (e.g., if comments were meant to be taken seriously by the student or if they were intended as a joke).

In one final example, "Science Susi" wrote that among the many science experiments inside and outside of school, "one I remember vividly was at a friend's birthday party when Mr. Doughnut, the science man, was a guest. He described Mr. Doughnut as a clown and "a silly man who loved to laugh." After being given "test tubes and some unknown chemicals, I was filled with curiosity and questions." The student went on to describe how impressive it was when the "elephant toothpaste[2]" experiment "bursted out of all of our test tubes. I was amazed by it and I could not believe how cool this was. I remember wanting to swim in a vat of that elephant toothpaste. After that moment, I realized how fun and interesting science is. I also learned you do not need to be in school to learn science. It was an experience I will never forget. It's all because of Dr. Doughnut." These comments were selected as examples of people that students mentioned in their science autobiographies. Similar to the analysis of different settings students described, this section supports the idea that students may learn science from many different people from teachers to family and friends. Even a clown that delivers science lessons at a birthday party can present an opportunity to learn science! Teachers can learn about different

[2] Elephant toothpaste, a substance produced from a chemical reaction causing heat producing bubbles (Zahn, 2017).

science experiences by eliciting the voice of students to learn about the many different people students are interacting with about science.

Learning Content and Skills. Learning is generally considered the primary purpose and expected outcome for elementary science experiences. So it's no surprise that students mostly wrote about learning when describing and explaining elementary science experiences. As noted previously, we know a lot about elementary science, but we don't know much about what students have to say about their lived elementary science experiences. As this study evolved, it became particularly interesting to see ways students shared descriptions of science learning experiences in their science autobiographies.

Students described the content they learned (force & motion, energy, life science, physical science, earth science, and space science) and they also explained how they learned the content (for example: project work, research, hands-on activities, or collaborative work). In some cases, students also offered their opinions or beliefs about what and how they learned. These ways that students wrote helped me organize findings into meaningful units for interpretation. This section presents findings from my analysis and provides discussion around student learning in two ways; *what* was learned (content) and *how* and *why* learning was carried out (process or skills used).

I broke down what students wrote about learning into two non-discrete categories: *what* content was learned and *how* and *why* content was learned. This breakdown aligns with research sub questions that were divided between *describing* (the what) and *explaining* (the how and why). Using this logical association, what content and skills students learned falls into *describing* and the ways students learned the content falls into *explaining*. At the end of this section, I have summarized findings, and have added a sample of the miscellaneous opinions or beliefs students also shared about their learning experiences.

Students wrote about the science content they learned as topics, experiments, experiences, activities, or events. Students sometimes provided simple lists of science topics and other times provided more descriptive phrases about the learning process. When describing the content learned, students sometimes did, but often did not, elaborate on the science concept or learning objective behind the activity being carried out.

As an example of a more detailed description, “Lysosome” wrote:

> The roller coaster would be made of a foam tube cut in half and tape. The objective would be for the marble to pick up enough force to knock down a plastic cup. You would also be given challenges like making a loop or making a hill.

The same student provided another detailed account of a volcano demonstration:

> Another one of my favorite experiences was making a soda volcano. First, we got a baking pan, then got the liter soda bottle and used paper mache to make it into the shape of a volcano. When it was time to present this, we put the minty candy into the volcano and a reaction was created with the soda and mint. We also painted the volcano and decorated it with figurines. When it was created it looked like a real volcano was really exploding!

These detailed accounts led me to conclude that this student understood the learning objectives of the activities described; to examine forces in the first account, and to observe a chemical reaction in the second account. There is another interpretation about using the classic baking soda volcano activity or demonstration because it is often paired with a lesson on volcanoes rather than a lesson on chemical reactions. This activity tends to be a poor model of how a volcano works because that actually is a more physical change in the earth rather than a chemical change (Olson, 2008) Students may remember more details about their learning experiences when they are actively engaged in the learning and have figured out or have been provided specific learning objectives. Sometimes learning objectives are aligned with curriculum standards and sometimes the purpose of science activities are less clear.

In a different detailed account of a science activity, “Cytoplasm” wrote:

> One experiment we did was where we had a balloon and string as well as a straw. We tied a balloon to a straw and taped it to the string. We let go of the balloon and the air got released. I didn’t understand why we did it and how it was affected with science, but I guess it was fun.

In this example, the student provided details about the activity and recalled it was fun. But the student does not understand why the activity was done or how it was related to science. This example led me to conclude that sometimes students remember fun outcomes rather than the science concepts being taught. I wonder if this particular student, having participated in this reflective writing activity, might give further consideration to the real purpose behind the balloon, string, and straw activity. It seems plausible that when students reflect on their experiences, they may develop deeper connections with science. It is also possible, like in the case of the volcano demonstration, that students may not know the difference between activities that are more superficial and activities that can produce deeper science connections.

In other examples, students provided only a list of activities completed. For example, “nucleus nick” wrote: “we did a coke and mentos volcano…and we did elephant toothpaste.”

One student wrote about making ice cream in a ziplock baggie during first grade. “Decarious” wrote: “we rolled this bag around a long time and out came ice cream.” Another student, “Phospholipid” wrote: “I remember we did a marble roller coaster which we did very well.” In another description of the roller coaster activity, “Biologic” provided a partial learning outcome: “In third grade we made a marble roller coaster to see who could pop the balloon. We won the whole competition, it was really a fun experience.” Again, the student remembers it being a fun experience, but does not provide details about the reason for the science activity or the science behind the outcome, popping a balloon.

I do not have information on how these or other activities were carried out in elementary classrooms referred to in students' science autobiographies, beyond what students disclosed in their science autobiographies. As a result, I cannot determine if or how teachers provided specific learning objectives for students in each setting. It is also not clear what the students were told or how they were to engage in these activities. My personal experiences in science classrooms suggest that students are usually given some type of learning objectives or purpose prior to doing an activity, but not always. This study cannot confirm or deny how science lesson activities and learning objectives are carried out in elementary classrooms these students attended in years past.

The examples provided also indicate that students sometimes write detailed descriptions of their learning experiences in science and other times they use short phrases. Even though students were asked to provide detailed descriptions and explanations, they were not instructed to include learning objectives. Sometimes students indicated they understood the objectives for learning behind the activities they mentioned, and sometimes they did not provide objectives for learning. The fact that some autobiographies included more detail than others could mean some students are more descriptive than others. It could be associated with what they remember, it could simply be their writing style, or it could be related to what the student understood about the activity they described. It is also not possible to distinguish between different students' accounts of learning experiences across different classrooms. Some students may simply be more or less descriptive in their writing style than other students. Another possible interpretation for these accounts is that perhaps science activities are more memorable than the science content or concept being taught. These findings suggest some learning activities may have succeeded in promoting a general sense of wonder or interest in science, without succeeding in promoting students' deep understanding of science concepts. If so, that is an issue teachers, administrators, and policy makers should reflect on when deciding whether and how to use certain activities. It might also be something researchers could explore. Teachers typically design lessons so that students will learn specific science content, but not always. Teachers generally establish clear learning objectives for students to understand at the beginning of a lesson. These alternate interpretations that students provided are important for teachers to know and consider as they plan lessons.

In other examples of content learned, some students produced a simple list of topics associated with various content but didn't elaborate. For example, "Benjamin" wrote:

> I remember learning about the brain in 4th grade. I also remember drawing a space ship that wouldn't sink in oobleck for a class. I also remember learning about animals and doing a project on stars in 5th grade. My animal was the goblin shark and my stars that I learned were the constellation orion. In 6th grade I remember learning about mitosis and cells and also learning about chromosomes and the diseases. If you had too many or too less of one. These are the things I remember from my elementary science.

“Science Learner” wrote: “We learned about the solar system, ocean, sky, and different areas of land.” “Leboult” also shared:

> Another time when we had a science-related gravity project was when we did something called: marble roller coaster. It had three stages and we had to learn how to build and gravitate the marble to the finish line. In another grade, we did a gummy bear dissolving experiment. It was when we put a gummy bear in different types of water. It was really cool because one gummy stayed the same, the 2nd got extremely bigger, and the third one completely dissolved to nothing.

Each student’s science autobiography offered a glimpse into more memorable science experiences from their elementary years. Some students provided detailed descriptions of activities that were carried out with specific learning objectives. Other students provide descriptions of science learning objectives with no clear learning objectives. Still other students simply included a list of science activities, and not much more. As noted in previous examples, this could mean that students sometimes do not understand the lesson purpose or science objectives behind the fun activities that are carried out. This could mean that students have not been given learning objectives, or maybe learning objectives are provided but are not understood by students. Maybe some students prefer writing about fun activities more than they like writing about science. Teachers need to know how students describe learning experiences and how well those descriptions align with the objectives for the learning experience.

As I examined the ways students described their science experiences, I noticed the emergence of certain patterns and themes among the science topics they included. I used those patterns as a way to categorize topics into science content strands so that I could make better sense of learning experiences. The science strands I chose are aligned with ways science is typically represented in public schools in the state of Texas for grades kindergarten through 5th grade. For example, various life cycles were categorized into the life science strand and electricity, sound, and light were categorized into the energy strand. These strands represented a way to both organize and communicate how students described and explained their elementary science experiences, as shown in Table 7.

Table 7

Topics Included in Science Strands

Strand	Topics Named by Students
Force, Motion, Energy	marble roller coaster, physics, Newton's laws, egg drop, Nerdy Derby, balloon zip line, electricity, magnetics, heat, sound, simple machines
Life Science	dissections, life cycles, dinosaurs, plants, human body, animals, genetics, cells, DNA
Earth Science	weather, natural disasters, oceans tides, rocks, tectonic plates, Pangaea, fossils, rain cycle, fossil fuels, clouds
Space Science	solar system, rockets, space museum, NASA, sun, moon, stars
Physical Science	density, periodic table, elephant toothpaste, oobleck, gummy lab, mentos volcano, baggy ice cream, water droplets on a penny
Other Learning	lab safety, scientific method, inventors, research, journaling, science fair, invention convention, forensic science

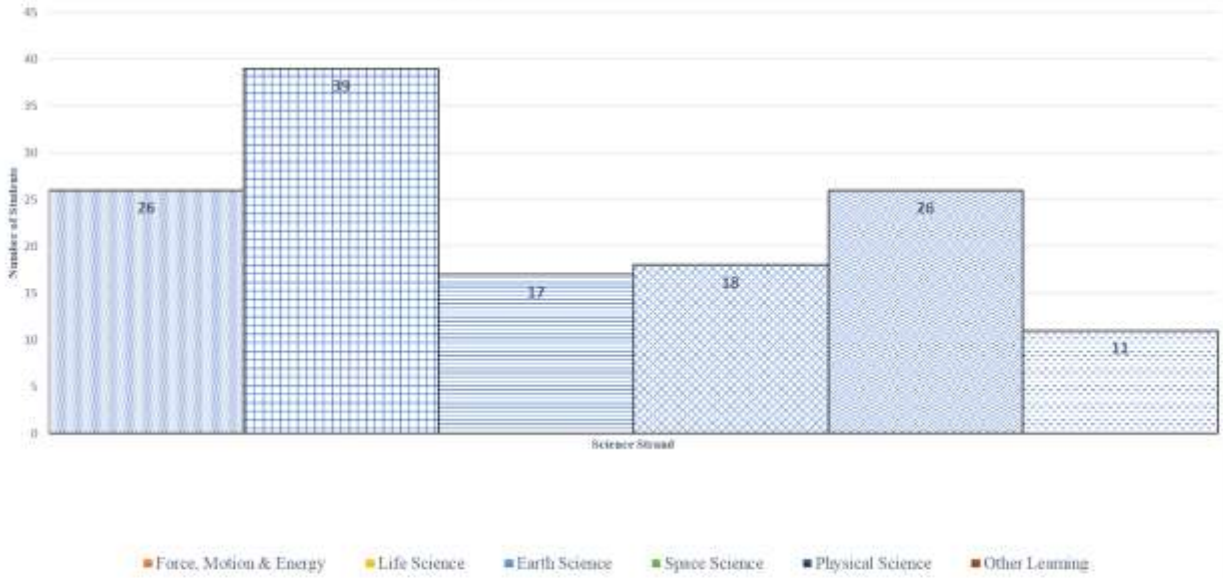
Strands were populated using an ordered process which began with reviewing science autobiographies multiple times to identify science topics mentioned. During each reading, I took note of topics being included by students with tally marks to count the frequency of occurrence. Readings were repeated until no new topics emerged. Topics represent what students wrote about science content learned. Table 7 shows all the topics that were included within each corresponding strand.

After an initial draft, a final review of each science autobiography was conducted to confirm the number of times topics were mentioned. I also used this time to identify any additional topics that were previously omitted. Data was then summarized by topics into five science strands: force, motion, and energy; life science; earth science; space science; and physical science. The final category represented students' accounts of other learning that did not align with a specific science strand. For example, lab safety, scientific methods, journaling, or science tools are examples of learning that were included in other learning. These areas of learning represent broader concepts that may transcend multiple science strands. For example, students first learn how to use a science notebook, then they use the science notebook during a scientific investigation or for some other science related purpose. Notebooks then become an artifact of learning about different strands during science experiences. A full display of topics that were clustered into each science strand and the students that mentioned them is available in Appendix A. The number of times topics within a science strand were mentioned by students is represented in Figure 3. For example, twenty students were included in the force, motion, and energy strand because twenty students mentioned at least one of the topics included in the strand:

Newton's Laws, egg drop, balloon zipline, marble roller coaster, or the Nerdy Derby.

Figure 3

Science Strands Mentioned in Science Autobiographies



The rationale for setting up strands this way was to organize topics into generally familiar science groups to create meaningful units for understanding. A graph of the science strands also provides readers with a view of the frequency of occurrence for each strand. This organization helped me isolate individual strands and consider each independently and ask questions like, what kind of topics did students mention under the space science strand? The way of organizing also helped provide context for the retelling of the elementary science story. I used the students' perspective with excerpts drawn from their own writing along with my own personal experiences in elementary science.

An example of what arose during analysis occurred after I noticed that topics related to earth science and space science were the least common among students' accounts of elementary science experiences. Since I do not know the curriculum or how it is carried out at this school, I can only assess what I do know and what the students shared. I interpreted low mentions of these two topics in a few different ways. To name a few, one idea is that earth science and space science were literally experienced less often than other strands and students therefore did not have experiences to recall. Perhaps these topics are taught at a higher grade level. It could also mean that learning about these topics was less favored by students and not an area they wanted to write about. It could even mean that the topics were just not as memorable for students. There could be other reasons for the fewer number of earth science and space science mentions by students when reflecting on their elementary science experiences.

Life science topics were the most frequently mentioned by students: 39 out of 52 students mentioned this topic. One student, "Phospholipid"], shared an inspirational moment recalled from her first day of science when the class was learning about the life cycle of a frog. "Ever since that moment I fell in love with science, when I got home, I told my mom my favorite part of the day and that was you knew it, science!"

Students identified topics they learned when describing elementary science experiences, but an even more interesting aspect of this study is how they explained these experiences. Students provided insight into how learning was constructed. Separating the topics students learned from how they learned them was challenging because they are intricately connected. Later in the next section, Table 10 displays a sample of connections between topics and how learning was constructed through engaged learning experiences. I will explain how the terms *passive* and *engaged* learning will be used to share the students' voices.

How Students Explain Elementary Science

How and Why Learning Occurred. Students recalled many different ways for learning science content in elementary or lower grades. They explained *how* they learned science content and in some cases they explained *why* they learned science content. Table 8 shows the frequency of themes and example quotes from how students explained elementary science experiences. Explanations included favorable expressions about the ways science content was learned, though in some cases, students shared unfavorable or less preferred experiences. Students sometimes shared their opinions or feelings about different ways of learning elementary science content and in some cases provided insight into why certain approaches were more impactful or desirable than others.

Table 8

How Students Explained Elementary Science Experiences

Themes	Example quotes	Frequency, *n* (%)
How I learned	"My teacher would have us all fill in notes and do presentations on creatures we chose. I remember doing activities about genetics" [Amanda]. “You would construct the cars out of wood, plastic, and nails. You could also add weights or aerodynamic pieces to the car. This was very fun and also taught us about momentum, cause and effect” [Dr. Duffensmarts].	49 (94.2)
Feedback on Learning	"I really enjoyed learning, but I wish we had days before a test to study in class or do games that helps us study" [Dr. Aspen]. “If I could offer any advice to future elementary science teachers, it would be to make the experiments memorable and impactful" [Dr. Science].	35 (67.3)

For example, “Dr. Cleopatra” shared “labs we do interactively helps remember the things we learn. This student associates interactive labs with memorable science experiences. More information on students' understandings about why certain ways of learning will be shared later under *Feedback on Learning*.

When explaining how they learned, students wrote about passive learning experiences in science, but mostly wrote about active or engaged learning experiences. Since there may be implications associated with using the term “active learning” that are not relevant to my study, I will instead use the term “engaged learning” to represent examples of experiences students referred to as active. I define engaged learning as situations where students were actively participating in the construction of knowledge or learning, either explicitly or implicity. The term “passive learning” will be used to represent examples of experiences students referred to when they were not engaged. The terms engaged learning and passive learning are not mutually exclusive and effectively coexist in most science classroom settings. For example, students may passively listen to instructions or directions before embarking on an engaged learning experience. Students may also sit passively during a science lecture where a teacher is establishing learning objectives and providing background, context and content. Sometimes passive experiences are used to transition students into more engaged learning experiences. I defined the terms engaged learning and passive learning in the following manner. Engaged learning involves students doing something more than listening, beyond what takes place as directions or instructions. Passive learning is often teacher-centered rather than student-centered and students are not actively or physically participating in learning. During engaged learning, students may be involved in a variety of activities, like observing, exploring, or investigating scientific phenomena, or completing hands-on activities. Engaged learning may also involve collaborative learning experiences. Table 10 shows sample relationships or connections between engaged learning and the topics students learned.

In contrast, passive learning is depicted as settings where students sit compliantly while being taught. During passive learning, students may listen to a lecture, observe a demonstration, memorize content, or watch a video with science related content. Students are unique individuals with their own perceptions of lived elementary science experiences. Notably, some students described or explained the same events or similar experiences in contrasting ways. For example, one student might have described something as passive and boring, and another student might have described that same activity as deeply enriching. The point here is that it is nearly impossible to assign learning experiences as either inherently engaging or passive because it depends on the way the task is enacted and how the student interprets that experience.

Students wrote about memorizing as a passive form of learning that they did not like. Students also shared examples of engaged learning experiences they found more favorable. Engaged learning sometimes involved projects completed alone or in collaboration with partners or groups. They wrote about doing investigations, experiments, and other hands-on activities while learning life science concepts. They explained how they learned through observation, sometimes over longer periods of time. They shared how models were used to demonstrate and explore science concepts across all science strands. When students described elementary science experiences, they used words that suggested engaged learning like “design, explore, or discovery.”

Students also wrote about more passive approaches to learning. As noted previously, students particularly did not like having to memorize science content. In one example, a student associated memorizing with learning, suggesting that when memorizing takes place, learning is absent. For example, “Hard Worker” wrote:

> This year it’s so hard for me to stay positive, and I’m memorizing so much I don’t even learn. And it frustrates me when I don’t understand something. My experience with science has gone down hill and as a visual learner, it’s hard when something has not been described.

In another example, “Idocytok” shares memorization as a technique to remember content learned:

> When we learned about stars we had to know the main types of stars in our solar system…we learned all the different planets by watching a video at the end of each class. We had to memorize all of the plants and know what weather was on each planet and just memorized everything about them.

The student also expressed that science is difficult because of having to “memorize a lot of things,” and remarked that “I think that science requires attention because if you zone out for even a second you could miss a whole lesson in a way.”

“Swallowtail” referred to memorizing in a similar way: “science is hard because you have to memorize a lot of things. I think science is boring because I don’t like researching or memorization.” Another student, “Anonymous” expressed displeasure with memorizing: “The only thing I hated about it was that we had to memorize all the parts and take a test on it before we dissected it.” The student also declared: “Science isn’t about memorizing what another person discovered, it’s about making our own discoveries. This is what science is all about, and I think that if everyone tried, the world would be more interesting.”

These students provide tangible evidence of their sentiments towards the act of memorizing as a passive activity. Sometimes an example was associated with engaged forms of learning, like when students memorized parts of the eye before they embarked on the hands on activity of dissection. Each student expressed their own version of what memorizing looks like and how they felt about it as a form of passive learning. Students said memorizing is hard and they do not learn when memorizing. Collectively, students may differentiate between passive and engaged learning in slightly different ways and may have different preferences for learning. One student might find an activity boring and another student may find enjoyment in the same activity. There are also some practices, like memorizing, that students consistently agreed were boring. Students made clear that they do not like to memorize information in any context, and instead prefer to engage in more active forms of learning.

Students did not mind some passive tasks that were associated with learning content or conducting research when they considered the information interesting. For example, "Fireburner" watched videos to learn about the usage of DNA to solve crimes. The student remarked "Learning about DNA was my all time favorite thing to learn. I think it's really interesting…to see how police officers and detectives use spit on items to catch criminals."

Other passive tasks like reading seemed to be satisfying for students when associated with bigger projects. For example, many students liked reading about ocean animals or constellations while doing research studies. In these situations, the purpose for reading seemed clear to students. They expressed reading as a way to acquire new knowledge. Reading may also be favorable because it can involve more choice for students. Some students also enjoyed reading about science concepts for pleasure outside of school. For example, "Dr. Cleopatra" shared how her mother influenced reading and research:

> My mom is a teacher and she always tells me to read, which isn’t a problem. I love reading, but I read about ancient Egypt a lot and that led me to read about rocks and bones so I learned about that. My mom made me and my sister research animals and I made many diagrams of where they live and things about them.

This example provided an example of a student being encouraged to read and carry out research studies on animals by her mother. The student loves reading and has opportunities to explore science activities at home. Teachers know that science is not reserved just for classrooms and they can use those outside experiences in the classroom. The information is important for teachers because it should inform teaching and learning. Perhaps a student that has experience with animal research could introduce different ways of carrying out research studies in the classroom, for example.

Middle school students at this school explicitly preferred more engaged learning experiences over more passive forms of learning science content. For example, “Gamma McGluten” wrote about preference for more active participation over writing: “It would be more useful and helps us better understand when we draw models and explain the models to your table or members, so they could all learn from each other.” This student recognized the importance of understanding when learning and expressed that collaborative work is preferable to individualized tasks.

After examining passive aspects of learning, I reviewed the many ways students described their preferred engaged learning experiences. Table 10 provides context for understanding how students explained engaged learning experiences by including a sample of associated content learned. It seemed helpful to associate what students referred to as engaged learning experiences with the science topic that were learned, because it adds context for how activities were carried out. The table shows engaged learning practices named by students, science strands they were carried out with, and example quotes from students to support understanding the lived elementary science experiences. I divided engaged learning into the practices mentioned by students: dissections, research studies, experiments/investigations/observations, projects, and models. All engaged learning practices mentioned by students fit into one of the categories.

Table 9

Connecting Engaged Ways of Learning to Content Learned

Engaged Learning	Strand/Topic Learned	Example Quote
Dissections	Life Science (owl pellets, cow's eye, starfish, earthworm, fish, sheep's heart)	"I feel like the only thing we did fun was the cow eye dissection. We were learning about the human eye and we had to find parts that were only in a human and parts only in a cow" [Chromosome].
Research studies	Life Science (animals, constellations)	"Another one of my favorite science experiences would be making a presentation about a strange sea animal" [Lysosome].
Experiments, Investigations, Observations	Life Science, Physical Science	"We got eggs and watched them grow into baby chicks then large chickens" [Sister Chromitad]. "She would take us outside and teach us about trees and leaves" [Science Learner].
Projects	All Strands	"We had a project called invention convention. We had to make up an idea and present it to the whole school" [Student Alpha].
Models	Force, Motion & Energy (electricity, magnets, light, sound, physics), Physical Science	"We constructed cars out of wood, plastic, and nails" [Dr. Duffensmarts]. "We got a battery and a tiny light bulb…to show how electricity works" [Dr. Science]. "We did model rockets and tried to see who's went the farthest" [Biologic].

Dissections

Twenty-three students in this study, 44%, mentioned dissections in their science autobiography. Those students had a lot to say about doing dissections as a way to understand the internal structure and functions of living organisms, including the human body systems. Dissection was described as a way to learn topics within the life science strand. When students described dissections, they referenced learning in relation to the human body. Students learned how to perform a dissection and then carried out dissections using different animal parts or in the case of owl pellet[3] dissection, a regurgitated mass. According to "Gamma McGluten," dissections are "an annual tradition at [this school]." Students wrote about participating in this science investigation throughout elementary grades. Some simply wrote that they had completed dissections and listed the organisms or items they had dissected, including a cow's eye, a starfish, a worm, a fish, and/or a sheep's heart. Others provided descriptive details about how they anticipated and prepared for dissection day. One student told of learning about the human eye and having to take a test before embarking on the cow eye dissection. "Bex" claimed: "I can safely say it was gross, but I found it so cool to see how science is everywhere." Another student, "Sister Chromitad" shared: "in fourth grade we dissected a cow eye, this made me not like science very much because the juicy liquid in the eye squirted at me." Most students summarized key learnings from dissections in a favorable light with positive learning experiences. Even those that were disgusted or grossed-out before or during the experience seemed to value the experience. Students made connections to other learning and saw dissections as real world science application; for example, "Leboult" wrote: "I had never dissected anything else before

[3] An owl pellet is the undigested parts of animals that are consumed by certain types of owls. Students dissect the owl pellet to discover bones that are hidden in the pellet.

and it was very cool to see what we were learning in real life." Another student, "Mitosis" had a different experience: "I remember the best part was dissecting a sheep's heart." One student, "Mannequin" provided a very detailed account of the dissection experience:

> Dreaded for as long as I could remember, so when the day came I was frozen. I wanted to run out of the classroom, down the stairs, all the way home. But I couldn't. I wanted to throw up but I had to fight the urge because I needed a good grade. Once I was done I felt so relieved because it turned out not so bad. I fought the smell and was very proud and glad I did it! And honestly, I would do it again. In science, we experiment with labs and different ideas, but that day I experimented with myself, seeing if I could make it through many more difficult things that I will have to overcome will happen. I feel like science on the day of the dissection, prepared me for that.

This student provided a detailed account about how she struggled through a difficult activity and persevered in learning. I think this is a remarkable account of how some students view dissections. Students encounter areas of science that are messy, difficult, and sometimes gross. Although the students does not specifically mention a teacher's role in this experience, teachers are instrumental in considered different ways students learn science and they help mitigate conditions that lead to unfavorable experiences.

Another interesting finding that emerged from examining dissections is the way they are carried out at this school. Animal dissections were a popular topic in the life science strand and I found meaning in the ways students described doing dissections year after year, beginning in first grade and ending in 5th grade.

“Georgie” provided a detailed explanation of how elementary science progressed throughout the grade levels:

> Everything started to click for me over time. I learned that elementary school science gave me the building blocks to finally piece together what science means. Trial and error, perseverance, and determination. Now in science class I can understand why we are doing certain experiments, how they connect with what we are learning, and what the deeper meaning of each experiment can teach me for the present and the future.

Students wrote about doing dissections in vivid ways. Students sometimes confirmed that deeper understandings were developed over time through activities like dissections that got progressively more advanced as they progressed through grade levels.

This account of elementary science tells me that over time students do understand how concepts learned produce deeper meaning and understanding. I believe this represents a good example of learning progressions because learning is sequenced in progressively deeper concepts year after year. Students wrote about dissections in ways that represented learning progressions embedded in elementary science. Students portrayed dissections as a skill, as in learning how to do dissections. Students also portrayed dissections as a way to learn about the structure and function of living organisms in the natural world. For example, “Cytoplasm” remarked: “We had to memorize all the parts and take a test on it before we dissected it.” It is interesting that activities which were seen as passive and almost universally criticized by students (e.g. memorization) were not criticized when used as small parts of a more engaging activity such as dissection.

Teachers can learn from these accounts of dissections that represent examples of learning progressions. When students participated in dissections every year during elementary science, knowledge was constructed over time and they experienced more in-depth learning. Students reported that their experiences were more memorable when learning this way. While not all schools may afford or approve scientific dissections every year, I believe a lot can be learned about learning progressions as an effective teaching strategy. Dissections are just one form of learning progressions that can shed light on how knowledge is constructed when children learn science in this manner. The key idea is that connections are made between what is being learned and learning experiences need to build from year to year. Curriculum standards are designed this way but teachers may not understand how to attend to these or offer instruction in ways that best support memorable learning opportunities for students. Teachers need to vertically align science content so that learning is less shallow and more robust from one grade level to the next.

Research Studies

Another area of life science that students wrote interesting things about was animal research studies they carried out in fourth grade. The teacher assigned students an unusual ocean animal to research and prepare a presentation about. Students shared positive affirmations about the research project. While describing the animal research project this student expressed fond memories of learning how to conduct research while carrying out the project, becoming an expert in a topic, and creating a presentation. After the student learned how to carry out research, the student applied the research skills in the strange sea animal presentation. Then the student had the opportunity to apply those research skills in a new assignment, the constellation Hercules. One example came from “Lysosome” who wrote:

> Another one of my favorite science experiences would be making a presentation about a strange sea animal. To make the presentation you would need to research and become an expert on your animal. This included things like habitat, diet, and fun facts. My presentation was on a vampire squid. Later we would have to make a presentation on a constellation. This was very similar to the presentation of the vampire squid. My constellation was Hercules. I ended up doing well on all of these assignments.

I interpreted that the student was indicating there was a transfer of learned skills, specifically doing research. My interpretation that skills are learned and transferred to different projects or assignments was validated during member checking. During member checking “Lysosome” expressed that dissections became progressively more complex throughout elementary science because they began in kindergarten with dissecting owl pellets and then dissected more complex animals with worms, starfish, and a fish. “Lysosome” student said “You kinda start on something easier then you get to the harder stuff.” Using this same idea of learning progressions, the student affirmed that research studies followed a similar progression. Other students mentioned that research skills were taught and applied across different science strands; for example, journaling, applying the scientific method, and lab safety. Research is typically taught in elementary classrooms and can be done across all content areas. One key takeaway about research at this school was the inclusion of choice in topics for research. As an example, students liked having the opportunity to select their own unusual animal for research.

Experiments, Investigations or Observations

Students included terms like “experiments,” “investigations,” or “observations” in their science autobiographies. “Professor” provided an expressive explanation of elementary science: “I have made experiences through experiments and tests, seeing what can change from those experiments." Another student, "Amanda" recalled "doing activities about genetics to figure out how many dominant or recessive genes a baby fruit fly could have." Other students wrote that the purpose for science is to explore, discover new things, and answer questions.

"Anonymous" shared how their understanding about science changed over time by actively doing science:

> Back then I didn't fully understand the term science. I thought science pertained to facts, physics, and weather. But now that I am in 7th grade, I realize that it means much more than that. Science is a word that we will never fully understand, it means to discover something, to uncover the world. However, we will never know everything but we can surely try. Everything you can imagine is science. Science isn't about memorizing what another person discovered, it's about making your own discoveries.

Comments like these tell me a lot about the students' sense of science. This student has developed a deeper understanding about science. Similarly, "Night Hawk" claimed "if I had to describe science in one word it would be why?" The student goes on to share that their interest was sparked when allowed to "actively discover how things happen."

Another student, "Sister Chromitad" shared experiences from elementary science where observations were carried out over time:

> I remember watching a caterpillar grow into a butterfly. I also remember seeing a lizard with a cut off tail, then we took it to the classroom and it took weeks and weeks to repair. In my first year of third grade we got eggs and we watched them grow into baby chicks then large chickens. I also remember having an ant farm and a bunch of worms to eat leftover food.

The same student also recounted experiences planting seeds and watching them “grow into really big plants.” Planting seeds was mentioned by “Dr. Aspen” as fun: “We planted plants and watched them grow until they died.” “Creative” also wrote about plant experiments, “planting three of the same flowers to see how the effect of using little, no, or the right amount of water affected them.”

Using live plants in the classroom is a common way teachers help students learn about the plant life cycle and enhance students' scientific observation skills. Other benefits of plants or natural environments are well documented; for example, in a systematic review, authors Mason et al. (2022), found that exposure to natural environments can help sustain cognitive functioning, in particular attention and working memory. This connection to prior literature helped inform my interpretation. Mason recently demonstrated these experiences were valuable in the short term and now I have shown that students seem to remember these experiences positively years later!

In other examples, students also wrote about learning things about the natural world. For example, “Dr. Cleopatra” shared that she would explore rocks, fossils, and minerals on camping trips with a friend and then “bring back lots of fossils to ask my friend’s dad about.” The same student described doing labs in the classroom as “interactivity that helps remember the things we learn.” A gummy lab was described as “we got to weigh gummies and put them in their cups with nothing in one cup, water in another, and salt water in the other cup.” “Birdy” shared earliest memories of science: “in kindergarten we did simple experiments, remember we did a will it sink or float experiment with simple objects.”

The same student shared about a rare science field trip and how it sparked interest in science:

> That was really our only experience learning about science and how it works. They would take us on tours to the gardens and let us learn science hands-on in rooms they had there. We would talk about what we learned on the trip at school.

These examples of learning in the natural world seem to have been memorable for students because they provided descriptive accounts of their experience in learning.

Most students referenced science experiences that occurred in the classroom or at school. Elephant toothpaste, mentos and soda, and a volcano model were popular science experiences for students. For example, one student:

> We would always do cool experiments that really interested me like elephant toothpaste where the foam shot out of the bottle. My favorite was coke and mentos though because it was so cool how the coke reacted to the mentos and wanted to escape the bottle. I remember experiments with a fake volcano that when you poured a special chemical inside it would "explode" and "lava" would come out.

Students wrote about favorite activities, experiments, investigations or observations and shared how these experiences sparked their interest or shaped their learning. Some students expressed how early or introductory science lessons led to deeper understandings in science. These accounts led me to understand that students remember learning science concepts when they are doing something they find meaningful or where they are actively engaged in learning through experiments, investigations, observations, and hands-on or interactive experiences. This matches up with personal experiences where students reported enjoying certain science experiences and also demonstrated understanding when learning was formatively or summatively assessed in the classroom. I have no way of knowing how students in this study performed on academic assessments of science learning, but I can imagine that learning outcomes are influenced by experiences.

Projects

Project work was generally associated with more favorable engaged learning experiences. Students did not always classify science learning into clearly defined terms and sometimes used terms like “projects,” “investigations,” and “experiments” interchangeably. Since these classifications are not clearly delineated, for the purpose of this study, references to “project work” are associated with learnings that students explicitly labeled “project work.”

Project work was sometimes referred to as a collaborative activity. Most students referred to collaborative work as a positive experience, but “Newton” shared an unfortunate side of group work by stating “my group partners weren’t working well so I had to do a lot of it.”

Students seemed to enjoy project work as a way to learn science content. “Pea Pod” described project work as memorable for students: “I remember some small things from elementary school science, mostly projects” and “things I remember best are the fun projects where I got to be creative.” The student went on to explain how the 3rd grade science fair project was carried out:

> We had to have a question and we had to answer it. I remember doing it off of the theory question “can an expo marker drawing float on any type of liquid” when I mean liquid, I mean milk, sparkling water, soda. I remember presenting at the science fair, I was so nervous.

Similarly, “Student Alpha” shared an experience participating in a project called Invention Convention:

> We had to make up an idea and present it to the whole school as well as parents. My invention was called the spring-a-board. It was like a board that you could put on the back of a seat in the car and bounce balls off of it.

Another student, “Chromosome” wrote about the impact of project work when exploring new discoveries, “in 5th grade my love for science grew because I had the best teacher…we did a project to learn about the ocean like all the species and all the things that have not been discovered…which makes it cool!”

Other than the one common issue that arose with individual group members doing their part, students enjoyed working collaboratively during elementary science experiences. This aligns with my personal experiences of assigning project work in classrooms. I have found that it can be a challenge to manage each student’s commitment and participation level. Students generally enjoy working with others on collaborative projects. I have found that group work and collaborative experience are more enjoyable for students because they learn from each other and can share their own ideas about learning. Sometimes students understand concepts better from a peer and sometimes students bring forth relevant learning experiences that are not part of a particular lesson and this expands learning opportunities.

Models

Students and teachers built models or carried out demonstrations of scientific phenomena for many purposes. Students and teachers also observed models when they visited museums and the space center operated by The National Aeronautics and Space Administration (NASA).

Models were used with students to represent the solar system, cell structures, or the human body, for example. Demonstrations were used to depict the water cycle, energy flow through a battery and light bulb, or to show how a science experiment was carried out. Students described an experiment where they measured how many water droplets would fit on a penny. In another example, “Roan” wrote:

> During kindergarten, I was sitting in my classroom. My teacher said that we were going to do an experiment. When she set it up, we didn’t think it would be that cool, but it turns out we were doing the volcano experiment and we thought it was the coolest thing.

“Pea Pod” remembered learning about the solar system by making “a diorama of the solar system with little styrofoam balls.”

“Science Learner” recalled a fun experiment when her teacher “set her hand on fire with soap,” adding, “she was never dangerous though.” Many students explained how they built a marble roller coaster, and some of those students provided details about how they demonstrated force and motion. In another example, “Dr. Duffensmarts”“ wrote about building a model during 3rd grade.

> We did something called the nerdy derby. The momentum would bring the cars down the tracks. You would construct the cars out of wood, plastic, and nails. You could add weights of aerodynamic pieces to the car. This was very fun and taught us about cause and effect and momentum.

In another example, the same student shared about using an engineering design process[4] in an egg drop competition. “We designed ways to protect our eggs from breaking using trash found outside. For multiple days we built, took apart, and redesigned our egg cartridge.”

After mentioning several other projects, “Pea Pod” shared how proud she was of herself for work done on a model of the solar system, an experience that was memorable because “my dad even sent a picture of it to my grandma.”

“Amanda” wrote about the impact modeling to learn a concept:

> We have done tons of experiments and connected topics to other easily pictured examples. Like how if you put a shrunken down quarter in the center of a football stadium from the quarter to the outer wall would be how far the nucleus is from the 1st electron and that really helped me understand just how much room there really is in an atom.

This example is powerful in illustrating how well the model of the atom supported student learning and conceptual understanding. I also noticed that the student mentioned doing many experiments and connecting topics across examples. This indicated to me that the student recognized that doing a lot of experiments helped build skills that prepared for additional experiments across science topics.

In this section I have defined passive learning and engaged learning and have presented a variety of ways students explained learning about elementary science content. Students enthusiastically reported engaged learning experiences using expressions of approval, even when engaged learning contained an element of passive learning. Students explained many ways they

[4] The engineering design process is a cyclic process that involves steps that engineers use.

enjoyed learning content during elementary science experiences, including dissections, research studies, experiments/investigations/observations, projects, and models. Alternatively, students used less positive words when they wrote about discreet passive learning experiences. A lot can be gleaned from the experiences students shared. Students shared interesting examples of their learning. Dissections stood out in this study because they were memorable for students. Students shared many details about carrying out dissections over the years in progressive learning patterns. Many of the things I learned from the science autobiographies were not surprising because they aligned with prior research, my personal experiences, or both. Learning that students learn about and carry out dissections beginning in kindergarten was surprising. In the next section, I will share highlights of student remarks about why they learned in the way they did or their personal feelings and opinions about how they learned elementary science content. I will also share what a few students offered as feedback or advice to teachers.

Feedback about Learning

Students were not specifically asked to share feedback about learning experiences, but many did so as a natural extension of describing and explaining elementary their science experiences. Students wrote about liking or not liking some of the approaches they were introduced to or required to utilize while learning. A few students wrote about not enjoying writing; "Student Alpha" wrote: "I remember having fun, but when we had to write a 3-sentence summary of this, I was furious!" Another student, "Gamma McGluten" referred to writing in this way: "You had to journal everything that you did which was pretty boring because I never used the stuff I write." The same student offered advice:

> I think there was a much better way of learning instead of writing in your journal. Which would be more useful and helps better to understand is drawing models and explaining the models to your table or members. So they could all learn from each other.

Only a few students wrote about writing during elementary science so it is not known how many students share these expressions or have different sentiments about writing in science. These expressions of writing do however, cause me to wonder if the students are engaged in the activity or simply following directions. In other words, do students understand the purpose for writing and how it can impact learning or are they just writing because they were told? This is an area that would be interesting to unpack further with additional input from students. Teachers could work collaboratively with students to better understand what these messages mean. Teachers could also work with other teachers to break down what students wrote to more fully understand how to inform pedagogical practices.

Students wrote about cool, fun, awesome, and exciting experiences they remembered from elementary science. However, they also sometimes noted that they didn't always learn or extract meaning from their experiences. For example, "Georgie" wrote about not taking science very seriously: "I never was trying to understand the experiments or be very careful with the steps I was taking. Science to me was a break from reality to see and do cool things with my friends." Other students may have felt confused about science concepts. "Cytoplasm" shared: "I didn't understand why we did it and how it was affected with science, but I guess it was fun." Another student, "Macy" shared a similar sentiment about a science experience: "I remember we got to make play-dough. I think it was supposed to represent something, but I can't remember. I just remember that I had a blast making play-dough." In a different example, "Leonard" provided some details about the science concepts behind the experiences when explaining the process for making oobleck, but also shared being confused about oobleck:

> Oobleck is like a mixture of a solid and a liquid, it's kind of like slime almost. Whenever you pick it up and hold it in your hand, it acts as a liquid, but if you try to punch it, jump on it, or dig at it, it acts as a solid. This was a really fun experience because we got to make it, then play with it, and take it home to show our parents. I think I was in second grade so it was really confusing to me. How can something be a solid and liquid at the same time?! Now that I'm older, I still don't understand oobleck.

The way this student shared a detailed account of making oobleck indicates that students do not sometimes understand concepts fully when doing fun activities. Not understanding is not necessarily a bad thing, but in this case the student did not eventually resolve the confusion. I concluded this from the comment "now that I'm older, I still don't understand oobleck." I do not know what the learning objectives were for making Oobleck, and it is possible that the learning objectives were met when the activity was initially carried out in 2nd grade. There does seem to be a missing component related to this student's experience, specifically an opportunity to voice confusion, whether those wonderings are embedded in the learning objective or not. Even in matters that may seem trivial or unimportant it is essential that student wonderings are heard and addressed. Teachers want to know what students think, both positive and negative sentiments about learning. I believe it is important that teachers find ways to capture this information at the time of instruction through routine elications of student voices when it does not seem as critical and instead can be embraced to inform pedagogical practices.

Students will not always understand concepts being taught, but teachers need to know when students are confused and should work towards resolving those points in learning. At the same time students do not have to wait for an adult to provide all the answers. Students need to be taught to seek their own answers, to be empowered and in control of their learning.

It seems imperative that teachers build in ways for students to express their understandings or confusion so they can be resolved in a timely manner. I also think teachers can help prepare students in ways that shift the responsibility for seeking answers from the teacher to the students. Students can be empowered to reach for answers to their own questions and wonderings. Again, I believe formative assessment practices could be used to expose student wonderings, confusion, or interests in a timely manner so that these instances are used to fulfill learning concepts.

Students wrote about the presence or absence of real-life learning opportunities. For example, “Kimmberly” shared “In school we are never taught real world skills or experiences and that’s what puts a break on our creativity. You have to show what’s really going on in this world or no ones ever gonna be able to solve it.” Alternatively, “Leboult” expressed: “it was cool to see what we were learning in real life.”

Students make connections between ways they are learning and what they remember. For example, some students suggested they don’t really understand science concepts behind science activities, while others like “Learner” wrote about remembering not going into depth in science subjects, rather learning in the “shallows so we could learn more.”

This seems to represent what some consider moving quickly through content so teachers can get through more content. And I believe that practice can impact students and the ability to construct deep science foundations. However, “Georgie” offered a counter statement: “I learned that elementary school science gave me building blocks to finally piece together what science means." This last quote sounds like it comes from a student that has been empowered to use science experiences towards future knowledge. The student says elementary science provided what is needed to develop understanding about science. This student sounds like someone that is prepared to take on more advanced science topics or concepts.

In another example, "Dr. Cleopatra" provided both favorable and unfavorable examples of science experiences and then summarized feelings towards science by stating: "I feel like when an activity has been fun and active I have remembered it well." "Georgie" expressed how her understanding of science changed from elementary to middle school "something hadn't clicked yet for me and all that could fix my problem was time." This suggests to me that understanding for some students may be a process where over time concepts just naturally become clearer. One interpretation is that what this student described as finally clicking, represented a combination of development and maturity combined with teaching and learning practices that nurtured deeper understandings.

I noticed among science autobiographies students expressed liking choice in assignments and activities. In fact, when choice is absent, students may express dissatisfaction with science experiences. For example, when "Kimmberly" was referenced earlier about not being asked what she wanted to learn. It was clear she was not pleased with the lack of choice in assignments when she offered that science teachers "never made it a joy to learn" because things she was interested in "were never discussed in class." I wonder how different this student's perception would have been if she had the opportunity to share her voice during elementary science classes.

Students also seemed to prefer choice over assignments with explicit step by step instructions to follow. For example, "Idocytok" shared experiences that illustrate varying levels of choice that may exist in classrooms "We designed a course using cut in half pool noodles to make the course we had to roll down a marble and make it complete the requirements given to you on a sheet of paper." The student reported "this assignment taught us perseverance and how fast or slow a marble can go by just adjusting the height by an inch." The student goes on to describe other experiences "in 5th grade we had assigned experiments where we had to find out who/why the experiment requires those exact ingredients and why it makes it work." In another example, "Phospholipid" described feeling restricted during science class in fourth grade. "It was pretty fun in science, there was just one thing missing. We did not really have that much freedom. We had a good teacher, there was just a lack of freedom." This student could be referring to "freedom" in a variety of ways. One interpretation is that the student felt that they experienced a lack of choice in science, as in "I didn't have the freedom to choose what I wanted to study." It could also mean that the student interpreted the teacher's practice and actions as confining or restrictive because of rules and procedures, as in "there are just too many rules, this class is strict." While it cannot be inferred exactly what the student meant by "freedom," it does seem clear that the student liked the teacher and the experience, but would have preferred more freedom during elementary science.

Another student, "Fireburner" provided feedback about a game-like activity that was impactful. The student described working with partners in science stations and being introduced to a memorable activity:

> I specifically remember 1 activity, there were 8 stations and an 8 sided die. At the start we were grouped into sections, then you rolled the die and the number corresponded with an action. For example, you are now frozen in a glacier and then you rolled to see what would happen to you next. This was a great activity because it made me think in a

different way about the rain cycle and how a water drop could be stuck in a glacier for 100 million years.

In this example, the student recalls details about the activity and how it affected learning. The activity seems relatively complex and well designed because it has multiple features that appealed to students. First, students generally enjoy learning through play, playing games that introduce chance, and they like to learn in collaboration with others. “Acla” described this concept: “this was a great activity because it made me think in a different way.”

Students explain many different but also similar ways of doing and learning about science. It is clear to me that completely passive approaches to learning were not considered favorites of students. For example, students did not like having to memorize content. In member checking interviews, students were asked about memorizing parts of the eye and taking a test before embarking on the cow’s eye dissection. In reflection, students expressed understanding of the purpose behind the more passive task of memorizing that was associated with learning parts of the eye, but it was still not their favorite aspect of learning. This makes me wonder if students would be more tolerant of, and even value, passive portions of learning if teachers engaged students in conversations that reveal the purpose behind teaching and learning tasks. It seems plausible that minor adjustments to instructional practices focused on making clear the purpose behind teaching and learning practices would enhance students' understanding and science knowledge acquisition.

There are different views about how experiences are classified as passive or engaged. For example, students may consider reading and writing as more passive approaches to learning, whereas a teacher might consider these tasks as not passive because the student is expected to be reflective and mentally engaged in learning while reading and writing. One student might consider visiting a museum a passive task because they were required to follow a rigid itinerary. Another student might describe that same field trip as a stimulating form of engaged learning.

Watching a science video may be considered a passive learning approach to some students. However, a carefully selected video serves an important purpose in the science classroom when used to expose students to scientific phenomena that they could not observe otherwise, like in the example of forensic science lessons. Videos also can be useful in providing expertise on topics or content that an elementary teacher may not possess.

Despite less favorable commentary from students, some seemingly passive approaches to learning can add clarity and structure to learning and can become a valuable asset in learning. The point is there are different views of learning experiences, and seemingly passive practices may be necessary aspects of teaching and learning that are designed to enhance the quality of the learning experience - but these purposes may not be transparent to students or well understood by students. Students should be highly engaged in learning processes so they can offer their voice, their views, and perspective to make learning more compatible with their needs.

Students shared that their favored approaches for learning science during elementary years was some form of engaged learning. Students described different forms of engaged learning, all of which involved students doing something more than sitting idly. Students also favored real world connections as illustrated throughout science autobiographies. Examining all the ways students wrote about learning, nearly all involved engaged learning with real world connections. While many students did not remember much from their earliest experiences in school, some experiences that *were* memorable involved active participation or observations of science phenomena over time. It seems when students are actively engaged, they have memorable learning experiences. When students wrote about opportunities to observe things grow or change over time they expressed having more meaningful and memorable connections to science. Projects were often mentioned by students as fun, cool, inspiring, ways to learn science and as “Dr. Duffensmarts” reported” “good ways to teach science.”

Students had mostly positive comments about the ways they learned elementary science and they also commented about less preferred ways of learning. They explained their preferences for learning and declared favorites. Students wrote about classroom structures and practices and they also referred to teacher and student actions in some cases. Students tended to write more favorably about engaged learning experiences when they are doing something: either making choices, building something, exploring independently, conducting observations, doing research, or watching demonstrations of scientific phenomena.

Some students wrote about disliking directives, when they were just told what to do. Instead they preferred at least some choice in their science experiences. They didn’t mind following a prescribed approach or the scientific method to investigate science. Students wrote much less frequently about passive learning experiences. Some were explained in a positive light, like watching a video or being taught by a teacher. Other passive learning experiences like reading a book, were mentioned as not as enjoyable or memorable. Comments like these can tell us a lot about a student’s interests, likes, and dislikes.

Students at this school communicated their mixed thoughts and interpretations about passive and engaged learning. I think teachers are better informed when they engage students in sharing experiences and listen to what students have to say about teaching and learning. I also think that being transparent about the purpose for teaching and learning approaches is important because students become better prepared for learning and carrying out new experiences. It seems students dislike being forced to follow specific directions but this could change if they understood why those directions mattered and are therefore able to meaningfully weigh in. It makes sense that students and teachers would strive to be on the same page about teaching and learning. Teachers can learn much from students and can use those learnings to support instructional decisions. There is also an opportunity for teachers to be more transparent with students about instructional decisions so students have understanding. These practices can inform new approaches for teaching and learning that incorporate both engaged and seemingly passive practices into effective science learning experiences.

Another area that stood out among all science autobiographies was the detailed descriptions and explanations students provided about doing dissections. I found dissection to be a particularly interesting representation of how science can be taught and applied over time to build memorable science experiences for students. First, students learned how to do dissection in kindergarten or first grade by examining an owl pellet. I found it interesting that students began doing dissections as early as kindergarten or first grade. When I taught elementary science, I introduced owl pellets to students, but not until 5th grade. Students did not explicitly describe the details of learning how to conduct dissection, but it can be assumed they had some preliminary instructions for carrying out the owl pellet dissection. At this school, owl pellets are used as an introduction to dissection for younger learners. The dry nature of the pellets helps serve as a proxy for more invasive investigations with dissections that occur in later grades. Students wrote about moving on to dissect more advanced organisms, like a worm, cow's eye, fish, starfish, or pig's heart. This approach to dissections enables a progression of learning, year over year, as students learn a skill then apply that skill in progressively more advanced ways. Students shared vivid accounts of the emotional roller coaster they felt when faced with dissecting the cow's eye. Some of the more detailed and memorable experiences shared related to dissection.

Students seem to appreciate science more when it is presented in ways that encourage discovery and exploration. For example, one interesting aspect of learning that students acknowledged as meaningful and memorable was observing science phenomena over time, like when watching a caterpillar grow into a butterfly, planting a seed and watching it grow, or observing a tail re-grow when a lizard was found with a tail that had be cut-off. Together, teachers and children create these meaningful and memorable moments in science. Students explained elementary science experiences in many ways that include words like experiments, investigations, explorations, or discoveries. I interpreted the descriptions students provided and found essentially the same meanings. When students wrote about science experiences, they usually included adjectives like: fun, cool, awesome, and memorable.

Students also wrote about mixed emotions like feeling confused and not understanding science. This makes me wonder if students have adequate opportunities, time and space, to reflect on learning, express their thinking, and ask questions or share their own perspective and wonderings about all topics of study. When a students says “I learned X in kindergarten and I’m now in 7th and I still don’t understand,” in reference to oobleck. This information would be helpful for future science teachers to use to stimulate new learning by filling in prior misunderstandings. For example, a high school chemistry teacher could reference these earlier learning experiences and help fill in those missing pieces. First those teachers would need to be aware of prior learning gaps or misconceptions, for example. I believe the autobiography is an instrument that has broad application and utility across all content areas and all teaching and learning participants.

Teachers benefit from eliciting students' thoughts on learning experiences at the point of learning, as a reflective practice, or even as a measure of a student's prior knowledge. Students benefit through the inherent reflective practice of writing about learning. When students reflect, they may be more insightful about their own learning, they may generate new wonderings, and they may be more likely to pursue answers to lingering questions. An even more impactful outcome would be an empowered student that is motivated or inspired to seek answers to their own questions! These sound like positive learning climates where student voices are valued and used in more routine collaborative interactions between students and teachers. I imagine that students in these classrooms might feel safe to speak and express both their ideas and questions. I also believe that being listened to and valued is likely to lead students to personal empowerment and deeper learning.

Feedback and Attitudes about Science

In this section I will provide context for ways students provided feedback or their attitudes about science experiences. Students mostly liked collaborating with partners or working on group projects, but mentioned frustration when a partner or group member did not contribute to the work. Sometimes students acknowledged a favorite teacher and listed things they had been taught. They said their teacher was awesome, my favorite, and did cool things. Sometimes students referred to a teacher as someone they didn’t like and explained why. They said their teacher was not a favorite, didn’t help me, or was disorganized. Insights like these can help teachers understand student preferences for learning and should guide design of science lessons that elevate student learning, challenge students and help them develop deeper cognitive learning.

Students expressed experiences with science as favorable or unfavorable and may or may not have offered reasons for these feelings or attitudes. Most students that had memories of elementary science expressed positive affirmations towards elementary science experiences. For example, “Night Hawk” suggested:

> I feel like if I had to teach my younger self about science, I would tell him that it is not just in labs. Science is in everything and is the base of all things and that there is no limit to science. Overall I just love learning fun facts that I may never need but science makes them fun to learn.

Another student, “Chopsticks”, shared “I remember being curious and always coming home excited to tell my parents about what we did and wanting to learn more.” Another student, “Aluminum” wrote poetically about visions of elementary science:

> The sky was blooming while the sun was beaming as the light from the sun tapped the flowers making them bloom. My stomach had butterflies and I didn’t know what was yet to come. However, once I stepped into my 4th grade science room the butterflies went away.

Tquavion” wrote: “science was always a subject I loved as a kid. Science was my favorite because of all the weird but cool experiments.” This student went on to say that science became even better in 4th grade, but later in 6th grade that all changed, when:

> We had to start taking it seriously. Homework was something you had to try hard to do. Even on labs, you were graded on and that was hard, it was almost like you couldn’t have fun anymore. When that challenge came into my life science wasn’t my favorite. I was struggling, I tried to like it but I didn’t. Science from then on became a subject I just try to get a good grade in and understand what we are learning.

Students also shared their perspective of what science is or can be. “Anonymous” stated that in elementary science:

> “I didn’t fully understand the term science. I thought science pertained to facts, physics, and weather. Now that I am in 7th grade, I realize that it means much more than that. Science is a word that we will never fully understand, it means to discover something, to uncover the world…everything you can imagine is science.”

These phrases tell me student have important things to share about their learning experiences and it seems they are comfortable sharing these sentiments. I think teachers can capitalize on these messages from students by eliciting their voices and listening carefully to what is being shared.

Students also shared memories of elementary science with less favorable feelings or attitudes about science. Some students with memories of elementary science had mixed feelings or attitudes towards science, or reported that their feelings and attitudes towards elementary science changed over time. For example, “Chromosome” wrote” “Science for me was my least favorite subject in lower school…but my non-fun science ended in 5th grade.” Another student, “Biologic” stated: “My science experiences are good and bad,” meaning sometimes science is enjoyable and other times it is not enjoyable. This account of science is compatible with other students' accounts, but since this student did not elaborate on what made science “good and bad,” I cannot determine what made it that way.

Students sometimes expressed reasons for their favorable, unfavorable, or mixed feelings and attitudes towards science. Several students attributed unfavorable relationships with science to COVID-19 and being out of school or to the influence of teachers. “Chromosome” wrote: “science for me was one of my least favorite subjects in lower school. I felt that especially during

3rd and 4th grade when we had the dividers up during COVID-19." One student, "Dr. Science" shared that "we had science in online learning but it was still very boring." Suggesting that "Dr. Science" never really enjoyed science, before or during the pandemic.

One student wrote that not having science in early years made it "tough, because I hadn't had much experience learning it, unlike my peers," "Birdy" referred to transferring into [this school]. The student went on to state:

> I wish every school taught science to elementary kids, one, because it's an important subject to learn and will help you transition into middle school, second of all, because some kids are very fascinated by science and should have school resources to learn about science at a young age.

A couple of students offered feedback or suggestions for science teachers. "Boron" wrote: "If I could give any advice to future elementary science teachers, it would be to make the experiments memorable and impactful." Another student, "Kimmberly" had written that she wished every school taught elementary science. These comments made me wonder about advice students would give science teachers. I believe feedback from students to teachers about teaching and learning is invaluable and is worthy of further exploration. Feedback from students about teaching and learning is important for teachers to adapt their pedagogical practices. Student feedback is also important for building and cultivating relationships in the classroom.

Seeing Oneself as a Scientist

Although I did not specifically ask students if they envisioned a career or future in the field of science, five students (about 10% of the sample) offered their unsolicited thoughts on this topic. Table 10 shows what each student wrote about their interest in pursuing a science career. It was surprising that all five students that offered their view about careers in science dismissed the idea of pursuing science or becoming a scientist. “Hard Worker” wrote about not having interest in a science career because “I would never understand anything and I would be very stressed out,” yet expressed interest in pursuing a medical career. This student did not seem to recognize that a medical career is, in fact, a career within the field of science. This seemingly contradictory statement led me to conclude that the student has a misconception about the connection between study of medicine and science. It could be that the student has not been exposed to or developed a deep understanding about the field of science and professional career paths.

Table 10

Unsolicited Comments about Science Careers

Student #	Sample Quote
Dr. Danger	“For my future I don’t really want a science career. I want to be a sports player and live well. I have learned to enjoy science while I have it.”
Sister Chromitad	“In the future I don’t see myself in the science field because some of the things scientist do are scary or nasty in my opinion. I see myself as a sports player or a at home mom.
Hard Worker	“I would not be in the science fields because I would never understand anything and I would be very stressed out. It would not be my dream to be one, all though when I was little I always wanted to be a forensic scientist but, I have a dream to be a neurosurgeon, or an anesthesiologist, or pediatrician (probably neurosurgeon though).”
Dr. Science	“But if I wanted to continue with my science school career, I would like to learn about computer science but I don’t want to do any actual science.”
Thinking Cell	“In the future I don’t really see myself as a scientist because while I like science it’s a lot to learn and it’s hard. Science is fun this year, though.”

I do not have this school’s curriculum so am not sure when, or if, they teach science career paths. I am surprised, however, that students were not taught these connections by the end of elementary grades. It could be that the concepts were taught and this student just didn't recall learning about science career connections. Teachers should make sure to teach important connections between science and careers. They should also routinely reinforce these concepts as part of making science relevant to student's lives. Student voices will help remind teachers about what they remember and what they may still need to have reinforced in their learning experiences.

It is interesting to note that the same student wrote about enjoying elementary science "I had always loved science, year after year, it just got better and better." I wonder what happened during elementary science that this student went from loving elementary school and wanting a science career, to thinking science is too hard and not wanting a science career. "Dr. Science" shared similar sentiments about science being "a lot to learn and it's hard." "Sister Chromitad" shared the reason for not pursuing a science career: because science is "scary and nasty" sometimes.

The remaining students shared that they did not see themselves as a scientist or having a science career because they wanted to live well or be a sports player. The last reason given for not pursuing science as a career came from "Dr. Science" who wrote "I don't want to do actual science."

I think this small sample of statements about science careers is compelling. These students provide important insights about middle school students' science identities or future science plans. A conceptual framework developed to examine science identity includes four components: recognition, competence, performance, and interest (Carlone and Johnson, 2007; Hazari et al., 2010). Science identity or student interest were not explicit goals of this research study, however, I believe we can learn something from these unsolicited remarks made by students. When applying the science identity framework to students' statements, it seems that most students at [this school] possess competence and performance in science classes, yet lack recognition of themselves as a science person, and lack overall interest in science. It could be informative to ask all students follow-up questions, specifically about their interests in science careers to better understand their attitude towards science careers. I do not know how many other students may have these same attitudes about science careers. It is possible that all other students feel this same way. It is possible that only a few other students feel this same way. It is also possible that only these students feel this way and no other students feel this way about science careers. It cannot be determined from unsolicited student comments, but it is something that I think researchers or teachers could explore further. It is possible that other research exists on this topic and could be explored in a future study. This echoes the findings of prior research where it has been suggested that some students appear to reject the culture of science outright and self-select to dismiss the idea that a science career is of interest (Tobias, 1990).

Limitations

There are always limitations in research. The first among these limitations is that I am the sole and active participant in this phenomenological study. I alone carried out the study with guidance from research experts, past and present, and by using methods and techniques that enhanced trustworthiness as much as possible. For example, I deeply considered each step of the process. I carefully thought about my interpretations, based on participant input, and adjusted meanings as a result. The hermeneutic circle helped me form interpretations that are unique to me and the students whose voices they were extracted from. The meanings I have shared are the results of my thorough investigation and analysis. Although I carefully designed and carried out this study by employing practices, a more experienced researcher, or a differently prepared person, might find different interpretations herein. I have attempted to provide sufficient context so that others may read this work and understand, if not appreciate, my own way of hearing the voices of these middle school students.

I omitted specific characteristics of participants in this study to protect their identity and this presents a limitation for this study. Without certain descriptive characteristics, the reader may be challenged to draw comparisons to other schools or to other students. Readers may wonder if the findings from this study are relevant to other school settings. As an elite private school, there are characteristics that make this school different from other schools. For example, students at this school come from families that are on average more affluent than the local public schools in the area. Tuition is high at this school, though some scholarships are offered. There are certain affordances that private schools like the one in this study have over their public school counterparts. For example, this private school offers: more resources and supplies for learning, smaller class sizes, and no state testing. These differences could influence student's science experiences. Some students transfer into this school, but most students enroll in elementary and stay through high school. Being in the same school from kindergarten through high school could be beneficial to students because there is a strong sense of community and everyone knows each other. It seems reasonable to assume this could influence students' science experiences because when you are in the same school for a long time, you are usually supported by a continuum of adults and learning needs may be more transparent over time.

The facilities at this school were an obvious difference between public and private schools. Other things like security, a welcoming spirit, and staff friendliness were very similar to public schools I've encountered. I do not know exactly how study outcomes would be different in a different school type, but it is plausible that study outcomes may have been different due to the school's characteristics. For example, in a very under resourced public school is not likely to have the resources to carry out the number of dissections that this carried out. It is also likely that students that hadn't had the experience of participating in dissections would not bring it up in the first place. It is still important to study more affluent schools like the one in this study because settings where resources and materials are not scarce can also tell us a lot about teaching and learning and how it is experienced by students. A future study could examine how students at different school types describe and explain elementary science experiences.

Another aspect of this study that may be seen as a limitation is the exclusion of student level demographic data. I was intentional about not collecting student specific data because I wanted to keep the focus on the experience and interpretation, free from inherent biases associated with student characteristics. All students selected for this study had direct experience with the phenomenon of interest, elementary science. I felt it necessary to treat the data with equal weight and focus on what would yield insight for this study examining the elementary science experience. For example, this study was not about extracting meaning from what girls wrote or what boys wrote, or what students at high academic levels or low academic levels thought about elementary science. My decision to exclude student demographic data was intended to allow for readers to better understand what the lived elementary science experience was like for any student. Adding student demographic data would be interesting to consider for a follow-up study of a different type.

Another limitation of this work is that I did not have an existing relationship with students or the school where I collected data. A school leader and teachers enthusiastically agreed to participate and support the study, making it possible to collect data. But, since I had no prior relationship or association with the school, I was a stranger to the students at this school.

While I do not know exactly if or how the results were influenced, it does seem reasonable that a student's writing could have been influenced positively or negatively by the relationship between themselves and the person requesting or eliciting their voice. For example, would students have had different things to share in their writing if the teacher had administered the science autobiography? Would students have been more or less likely to share deep intimate thoughts about their learning experiences with a known individual, like a teacher, or with a stranger?

There are many ways I could have elicited student voices, but I chose a first-hand, unimpeded account rendered directly from students. I could have used another data collection method, but that would have likely produced different results. For example, if I had chosen a survey, an interview, or focus group, the results may have been different. I believe the science autobiography was an appropriate method for eliciting a student's voice at this school because it represented an authentic and direct form of expression. Since handwriting is self-reported and does not provide for follow-up questions or elaboration, I used member checking to verify interpretations from writing to increase the trustworthiness of my results. Asking students about their lived elementary science experiences sometimes elicits responses that are more about how they felt, their opinions, thoughts, or perceptions, rather than about the actual experiences. According to Peoples (2020), thoughts and opinions are not "relevant or reliable at getting at the essence of a phenomena" (p. 53) because experiences are different from thoughts and must be analyzed differently. To mitigate this issue, I set clear expectations for students when I administered the science autobiography. I asked students to use actual experiences and insightful descriptions, rather than just thoughts, feelings or opinions. Even with these directions, some students used words to describe mental states, such as their thoughts, opinions, and feelings. I separated personal sentiments about elementary science experiences and examined them apart from other themes. This allowed me to consider students' thoughts, opinions, and feelings that were shared in science autobiographies. I extracted some general themes and summary thoughts about the more social and emotional responses which I believe add value to this study. I believe students' mental cognitions are valid, important, and relevant to understanding elementary science experiences, and I think we can learn a lot from these added sentiments students shared. However, since it is not aligned with hermeneutic phenomenological study, this paper does not closely examine these aspects of students' social and emotional responses. This results in a study limitation. When we teach, we teach the whole child, and that includes the social and emotional side of learning and this side is largely absent from my analysis. I also believe that in future studies we can learn a lot about teaching and learning by focusing on how instructional practices made students feel.

I addressed limitations by carefully considering my approach, my methods, and my personal biases. Through careful examination and analysis, students' authentic voices were acknowledged, and their ways of telling were preserved and their ways of telling were reported verbatim as much as possible in order to convey the essence of the phenomenon of elementary science. This study has inherent limitations but still sheds light on the often silenced voices of students and helps to provide new meanings and understandings.

Chapter 5

Conclusion and Implications for Practice

The purpose of this study was to elicit student voices to better understand their lived elementary science experiences. I chose this topic because student voices are often missing from conversations about teaching and learning practices in elementary science settings. This study has shown that it does not have to be that way. Schools are a service organization, filled with many internal and external customers that care deeply about student outcomes. Each group of customers has thoughts, ideas, and views of how school should be carried out based within the context of their own personal experiences. Students are one group of consumers that have often been excluded from these conversations about school, specifically practices associated with teaching and learning.

In this study, I sought to understand the essence of elementary science by employing a hermeneutical phenomenological approach. Reflection on my purpose, heavily informed my analysis because it created the overarching lens from which I examined samples of data. I approached analysis of students' science autobiographies as a way of seeing each writing sample as unique and potentially holding important missing details and ideas. I believe my role as a researcher is to focus on uncovering and revealing these important hidden meanings that have been missing from our understanding of elementary science education.

Students' unique perspectives have long informed my instructional practices and processes for learning science. Personally, I have found value in eliciting student voices in adult classrooms, because there is no other way to know how my teaching and learning practices are being received and interpreted by students. I have found that when I use students' feedback to shape and guide teaching and learning, my outcomes are improved. Students have told me that they appreciate and feel valued when I enact their ideas or feedback. I am confident that younger students will also benefit from contributing to teaching and learning practices that are carried out in elementary science classrooms. Opportunities for student voice can be designed into all classrooms as a normalized and routine part of the teaching and learning process. Teachers and students will benefit with new networks of communication. One of the greatest challenges may be in convincing people in positions of decision making to prioritize time and space for students to share their voices. This work provides evidence and impetus for these conversations to occur.

This study was designed to elicit the voices of middle school students to understand elementary science experiences from their perspective. I chose a novel activity, the science autobiography, as a reflective exercise for data collection. The participants were students in nine classrooms. The setting was an elite private school in a suburban Southwestern community. Fifty-two parents agreed to permit their 6th or 7th grade child to participate in this research study. Students were instructed to write about their elementary science experiences with details and explanations in this novel, open-ended activity. They were asked to provide details like they would share with a friend that had never experienced elementary science.

Students provided a range of written responses. Some offered thick, rich and textured writing, and others offered thinly veiled accounts of their lived elementary experiences. Students wrote a few sentences or several pages, and sometimes included illustrations of their elementary science experiences. Students described the who, what, where, and when of their lived elementary science experiences. Students also explained the how and why of their lived elementary science experiences. Some students even offered their opinions, feedback, or suggestions for teachers. I made meaning by using descriptions and explanations to organize and arrange themes and patterns for interpretation. I found the students' writing to be fascinating and both familiar and new. Every student's voice was included in the analysis and results.

I came into this work with my own preconceived ideas and experiences with elementary science and qualitative research. I investigated prior literature, delved into methods, and educated myself about techniques and approaches. I poured over salient works in elementary science, student voice, and phenomenology. The hermeneutic circle helped me embrace my positionality while engaging in new learnings about elementary science that were derived directly from the students as participants in teaching and learning. The voices of fifty two middle school students have shaped my interpretations and enriched my understanding about elementary science. This study has illuminated student voices so that they can be heard.

I deeply reflected on the many ways students described and explained their elementary science experiences. Because of my own positionality, some personal accounts of elementary science were expected, some were surprising, and some were even concerning. My interpretations were influenced by personal experiences and by a vision for what elementary science can become. I believe elementary science will be transformed when all voices are included in discussions and decisions about teaching and learning. I prepared the results of this study as a way of retelling the important descriptions and explanations students shared about their lived science stories. I will share some of the highlights in this section and their implications for various audiences including teachers, students, decision makers and the research community.

In the next section, I will provide context for the findings. Then, I will explain the research findings as key implications. I will share how results can inform practitioners and others to advance the field of elementary science education. I will also share recommendations for future research.

I elicited the voice of middle school students using a novel writing activity in their 6th or 7th grade classroom. The data instrument, the science autobiography, was administered using a consistent and systematic approach across nine classrooms. Writing, rendered from the students' own hand, was considered authentic and helped bring their voice into a place of contemplation and understanding. I did not have the opportunity to ask clarifying questions or more elaborative responses during the writing activity. Instead, I used follow up interviews with a sample of students as a part of a member checking during analysis. This gave me an opportunity to check interpretations and add credibility to the study results. Seventeen students participated in member checking and were asked to consider early interpretations.

In this autobiographical reflective writing activity, I found that science for some is highly engaging, fun and memorable, and for others it is boring and forgettable. I also learned that these accounts are highly situational, what one student loathes, another student loves. Adding to the complexity of understanding, some students wrote in great detail while others wrote sparingly. Sometimes students were introspective and revealed insights about elementary science that were deep and sophisticated. Other times the students' writing was less detailed. or absent, like when they used drawings to illustrate their elementary science experiences. One illustrative example came from ”Professor” who summed up elementary science experiences in this way: “I have made experiences through experiments and tests, seeing what can change from those experiments.” This student offers an expressive play on words about elementary science and reveals to me that the student has an understanding about the purpose of elementary science as a way to investigate phenomena and learn through experiments and tests.

Most students expressed that they liked elementary science, though there were exceptions. I learned that most students acknowledged remembering or not remembering much about elementary science experiences. Students wrote about elementary science using descriptions that align with when, where, who, and what. Students also explained their elementary science experiences using ways that aligned with how and why. This way of viewing student writing aligned with the research questions, provided a convenient way to organize data for analysis, and produced a practical way to retell the story of elementary science.

Most students wrote in positive ways about their elementary science experiences, even when they had not experienced much science in school. Some students wrote about negative elementary science experiences or included both positive and negative accounts from their lived elementary science experiences. A significant negative finding was derived from a small number of students who wrote about not having had elementary science experiences because it was not taught at their school. Most students that did not have elementary science attended a different school for elementary school. This is difficult to accept because I believe it is harmful for students to not have foundational learning in science. I believe it impacts a student's access to advanced science content. It is unimaginable that schools would deprioritize early science exposure. I cannot imagine a good outcome for students that would stem from not having science experiences in early elementary settings.

Among students that stated they did not have elementary science experiences, some expressed that not having elementary science experiences was problematic when they entered upper elementary or middle school settings. They reported feeling unprepared for advanced scientific concepts that rely on foundational learning. Transfer students in particular, shared thoughts like “Birdy” “6th grade was tough because I hadn’t had much experience learning it, unlike my peers.” Another student, “Hard Worker” reported:

> When I came into the sixth grade, everything had changed. New words, new experiments, new things that I had never heard before. Words that I couldn’t pronounce. Not just science but school became so much more stressful, like I had been smushed under a rock. Nothing was like how it was before. So much more work and so much it was so overwhelming.

Students that have not been taught elementary science lack foundational learning and are often poorly prepared to advance into more complex science concepts. This could become detrimental for students wanting to pursue advanced science concepts. When science is not taught in elementary settings, teachers and students endure real consequences.

There are certainly many reasons science is not taught in some early elementary settings. For example, it could be due to a prioritization of reading and mathematics over science, as students in this study suggested. It could be that elementary teachers are missing science resources and support, students also noted that some teachers were more prepared to teach science related content than others. Maybe teachers need training in scientific concepts and instruction. Perhaps it is even related to an out-dated idea that science is reserved for older children, as “Swallowtail” revealed in writing that “we might not have done much (science) because little kids aren’t very good at experiments.” Or maybe the reason some schools do not teach science is something else entirely. Students provided several possible reasons they believe they were not taught science in elementary settings, some also offered solutions. I did not specifically ask students to share their opinions or solutions, but I am glad that several of them did. Students view the world in ways that are uniquely theirs. When we listen to students we can learn how they see the world and their place in it. We can also scrutinize their thinking and address misconceptions, like the idea that little kids are not good at science. Researchers should continue to study student outcomes in settings where science is or is not taught. It would be interesting to quantify the impact of decisions to not teach science. I know that educators want to do the right things for students, and changing existing habits can be complicated. I believe a closer examination would produce further evidence in favor of teaching elementary science to all students.

It was interesting that students seemed to be relatively resilient to obstacles in learning science that resulted from missing foundational learning. This is interesting and could be related to how learning gaps are addressed at this school, or it could be related to something else. I do not know the specific entry requirements at this school, but as a private school, students meet a variety of qualifications to enroll. So while students may have learning gaps, it is likely they meet baseline academic standards before they are accepted. I imagine the impact to students is as students reported in this study. When students had academic gaps, they worked harder by putting in extra work to get caught up. I believe this school provides many resources and strong support for students that may not be available at other non-private schools. The thought here is that even in well-resourced private schools, some students experienced gaps created by missing instruction in elementary science. These messages from students speak loudly about the need for early foundational science instruction. There are strong implications for teachers and others. A decision to cut science out of elementary grades might be more harmful in under-resourced schools.

As the ones on the front lines of teaching and learning, teachers need to understand how to plan for all learning levels, including scaffolding science content and inserting instructional supports where needed. I think students at this school had the motivation to close learning gaps. It is not clear exactly what role teachers played but it is possible that teachers would work in unison with students to close learning gaps. Teachers also need support from their leaders in the form of professional development to ensure they have the resources that can meet every student's needs. Just the simple act of acknowledging where a student resides in relation to learning trajectories can help support the students' emotional attitude towards science.

Student's access to science is not limited to schools. Students wrote about learning science in places outside of the classroom. There was no way to determine any particular patterns between students that claimed significant science experiences outside of school with those that

Students are social and enjoy sharing their experiences with each other. Teachers can capitalize on this and facilitate collaborative classroom practices that value all sources of learning. When all voices are shared, everyone learns from each other. Students learn how to communicate about science and once their learning is shared with others it can be discussed and learning can be deepened and sometimes corrected. And I believe students make better connections with the real world when their personal science experiences are shared in the classroom setting.

The concept of remembering emerged early in the analysis while I was familiarizing myself with science autobiographies. This topic raised new questions that are not readily answered by this study. For example, why do students remember or not remember an experience? What do students remember? Students wrote about remembering in interesting ways. I found that students seemed to remember fun, cool, exciting activities, but only sometimes recalled details about the science content behind the activity described. I wondered if this meant that students really have no memory of the deeper science concepts behind those activities. Or maybe it just meant that students chose to include the more engaging things in their science autobiographies. Other questions that I pondered included when students remember fun things, for example. Do they remember because they are more fun, or do fun things help them learn better? Does this mean they really don’t remember the deeper meaning that was intended for that particular activity? These questions certainly have merit and each one has potential implications for teachers and administrators. I believe that despite limited evidence from students and what and why they remembered, we should further explore how fun and exciting science experiences relate to deep science learning. Future research could investigate these questions to provide additional context for what this means to teaching and learning.

Students may or may not remember elementary science experiences. There are some reasons shared by students and there are possibly other reasons this could be true. Students that didn’t receive science instruction in school may not relate other science learning to science experiences because it was not formalized. Maybe, like some students shared, elementary science experiences were not memorable because they were boring, repetitive, or involved activities students did not enjoy, like writing. Maybe some students just didn’t recall learning experiences at the moment in time they wrote their science autobiographies. There may be other reasons students may have elected to not share their memories of elementary science on the day science autobiographies were collected.

Additional research on this topic would yield more insight. Student accounts of elementary science did, however, align with prior research about what makes learning memorable. Koch (2018) noted students learn better when classroom experiences are related to, and connected with, experiences they can relate to in their personal lives. This can be contrasted with the act of memorizing, where a relationship has not been established between content and context. Students forget what they have memorized more readily when they memorize decontextualized facts (Koch, 1990).

Students provided examples of memorable learning experiences from elementary science experiences. Teachers helped make connections with real world science. Based on those first-hand descriptions, it appears that when science content is learned, students are readily able to make real world connections with science. Sometimes this was illustrated as an intentional pedagogical practice - for example, during the series of dissections, students referred to learning progressions in the form of lessons or assessments that preceded investigations or experiments. Learning milestones were completed before taking part in the hands on dissection activity. Although students may not have been excited to participate in these preliminary learning steps, “Bex” did acknowledge the importance of doing the steps because “they got us ready for our first dissection.” When students like “Bex” described their learning experiences and how they made connections, it reaffirmed what effective classroom practices look like. These things do not happen without carefully designed instructional plans that are carried out with intentional learning expectations. This led me to understand that students may not always enjoy certain learning tasks, but they can understand the value of that task in relation to the learning objective. Next, I will provide context and implication for teachers.

Teachers are compassionate and empathetic leaders in the classroom that readily adapt to new circumstances. They are trained and expected to be proficient in all aspects of teaching and learning. They play a critical and often pivotal role in teaching and learning by creating cultural environments that are safe spaces for all learners to share their voices. When students engage in feedback and conversations at school, they open new windows of communication about teaching and learning. Attentive listening and interpretation of student voices are paramount to effective teaching. Reflection of pedagogical and personal approaches to teaching and learning, figuring out what works and what doesn't work, is what good teachers routinely carry out in school classrooms. These practices can be optimized when carried out in a supportive and collaborative school climate.

We know that learning is a socially constructed endeavor that students learn to navigate beginning at an early age. Teachers and students have a special relationship that hinges on trust, safety, and positive experiences that open the mind up for learning (Darling-Hammond et al., 2018). Similarly mistrust and negative classroom experiences, even inadvertent ones, can be detrimental to a student's learning. Classrooms are busy and teachers have a lot to manage and may at times overlook a student reaction as inconsequential or may ignore certain behaviors in honor of time constraints. These inadvertent gestures could result in what Vogt and Monroe (2021) referred to as a triggering event that weakens trust relationships. I believe this work has special meaning for teachers because they need to know about how students are feeling about learning experiences and teacher actions. For example, when we reexamine "Kimmberly" we see a student that had a bad experience with a teacher during elementary science. The event seemed unresolved for the student years later and may have led to weakened trust relationships between the student and teachers (Vogt & Monroe, 2021). The student described feeling like science teachers did not want to help her because "she didn't believe in me, she was not willing to give me her support." The student also wrote how it made her feel; "this really discouraged me. For her I was just a stupid little private school girl." I believe all teachers would want to know this information when it occurs. The student had also shared that she enjoys learning science outside of school and I wondered if she would enjoy science in school better if she felt more supported by her teacher. This particular example was quite startling and may be unique or could be common. Teachers need to find ways to routinely elicit student voices. This will help them become aware of how students think and feel about all aspects of teaching and learning, including the social and emotional aspects. I believe student voice improves classroom communication between all participants and is critically important in helping resolve negative encounters between teachers and students. It also helps build back trust in relationships where it may have been previously compromised. First there has to be an awareness that adverse events have occurred and then there must be a willingness to improve.

Students have a natural ability and affinity to learn. Teachers involvement in student learning is important and makes a lasting impression. Effective teachers provide support and create environments that inspire and motivate students to pursue learning (Johnson, 2017). This characterized role of the classroom teacher as important to learning and how students are motivated to learning was supported by what middle school students at this school had to say about their teachers. Students shared both positive and negative experiences in elementary science and some were attributed to the classroom teacher. An interesting finding was that some negative teacher experiences didn't seem to influence how students liked science in general. One student disliked a particular experience with a teacher, but that didn't seem to cause the student to dislike science. In these cases, the students showed resilience and seemed to recover from unfavorable teacher experiences. It is not known precisely what instigated the positive outcome in learning in that situation. In other cases, the negative experience seemed to be more lasting, as when "Dr. Aspen" commented that the only thing remembered from a particular grade was "the teacher calling me out on something causing me to fail an assignment that was a big grade." I don't know any more about this scenario except that this incident, a negative teacher encounter, was memorable for the student. It seems a valuable lesson could be learned by teachers and students from these experiential moments; when addressed in a timely manner. I believe conversations between teachers and students, where students are empowered to share their voice, are imperative.

I learned a lot about elementary science from the voices of students at this school. I am left with additional questions and curiosities that offer future research prospects. For example, I wonder about the factors that contributed to individual students' ability to resolve negative teacher encounters while other students' bad experiences seemed to remain unresolved. I would use follow-up interviews with students in another study to answer this question.

Another question I still have is the matter of how the routine conversations are carried out in this classroom setting. It would be interesting to measure how much time teachers in science classrooms spend speaking versus the time spent for students speaking. It would also be helpful to know how often teachers elicit student voices in daily routines. There are many ways to examine teacher and student communication and I believe the elicitation of students' voices in relation to science learning is important. Teacher and student communication related to classroom relationships. It was shown in this study that students appreciate certain ways teachers interact with them to build relationships. A future study could more closely examine these practices and determine how intentional certain practices are.

These are important questions that I have thought deeply about, have grappled with as a teacher. My interpretation of these experiences did, however, lead me to conclude that students can learn science, despite an adverse teacher experience, but not liking a teacher could have a significant impact on learning. I believe it is difficult to learn from someone you don't like, but also relatively easy to move on from a single bad encounter when the next encounter is more favorable.

Students seemed to care about teacher flexibility in science classrooms. Teachers are trained to continually adjust and adapt to changes in curriculum based on a variety of inputs beyond the classroom. Students shared examples of when a teacher's personal attributes influenced their attitude towards science. For example, when one student associated the teacher's lack of organization with poor learning outcomes in science. In other examples, students reported that teachers made learning science boring. I believe that teachers are responsible for establishing positive classroom cultures where students can routinely and respectfully express their thoughts and feelings. In these environments, issues can be addressed in a timely manner to offset lasting or even temporary negative impressions of science. Schools are places where learning transformations occur on a regular basis despite being designed as systems of conformity. Student voices should be present in all classrooms and can be used in a variety of ways. For example, when students share their voice, they offer teachers new insights that were previously hidden from view. Student voices can help us understand different perspectives about teaching and learning and can be used to disrupt the status quo of traditional models of schooling to achieve more equitable practices.

One strongly held belief guiding my work is that students are often silenced yet are an invaluable source of information for teaching and learning. Students are typically positioned as passive recipients of teaching and learning, but their views can and should enrich the conversations we have about teaching and learning. This perception of students as only on the receiving end of teaching and learning inhibits cooperation and collaborative practices. I believe students have important things to say and their input should be routinely elicited to expose their views. The science autobiography is a useful tool to open new lines of communication with students, especially about areas of teaching and learning science that are not explicitly clear. Student and teacher relationships is an area that teachers at this school, in particular, would be interested in exploring further. Teachers may already be accustomed to eliciting students' voices and must continue to provide the time and space for student voices to be shared in, what may be, new ways. Then it is imperative to listen closely to what these students have to say. In the next section I will share some concluding comments about students.

Students

Student voices can be an effective mechanism for feedback about teaching and learning (Gomez-Arizaga et al., 2016). Student voice matters and can be empowering to students. There is a plethora of research on the practices of self-reflection during learning. This is an area for future research. Students are customers of teaching and learning and are worthy of our notice. Adults must routinely provide time and space for students to share their perceptions, feedback, and ideas about their educational experiences. Then adults need to listen, so that student voices can enrich conversations and understandings and create improved teaching and learning outcomes. In this study I asked: what does it mean for students to share their voice? Students benefit in settings where their voices are valued. Student to teacher exchanges and also peer-to-peer discussions about teaching and learning practices have the potential to enhance both the individual and collective student experience. Students arguably build deeper cognitive connections as they reflect on their learning and build their own understanding in science. I hope this writing activity was meaningful for students, because they are the motivation and reason this work matters. Students have important things to say and their words have meaning. In the next section I will share implications for the research community.

Research Community

The research community includes people focused on elementary science education and includes individuals that conduct science education research, teacher preparation programs, and methodologists. Each of these groups can benefit from this work. For those that examine how children learn science, this work is important because it includes students in early foundational learning, an area that has not been well researched from students' own perspectives. For researchers interested in studying how teachers are prepared, they can benefit from this work by considering the impact of using student voice in educational settings. Research methodologists could learn about the different usages of the phenomenological approach in ways that may be less common, for example, using a science autobiography to elicit student voices in a phenomenological study.

There are also other ways researchers can benefit by extending this work into new areas. For example, future research could address the wonderings I have been left with. One particular area of interest is to conduct a follow up study with the student participants to further inquire about their interests and attitudes towards science as a career. Only five students shared their thoughts about science careers and all dismissed science as a future career. Their reasons were varied, but I believe this is an important topic for educators to understand. Specifically, do middle school students see themselves in a science career, why or why not? As noted in prior literature, middle school students have often already formed science aspirations (DeWitt & Archer, 2015; Lindahl, 2007; Maltese & Tai, 2010). It seems important to better understand students' perceptions about science careers and what shapes these early aspirations.

There are many follow-up questions that would be interesting to probe with students from this study. Asking additional questions about what students wrote across all themes would provide deeper understanding and meaning about elementary science experiences. I wonder how participation in this study impacted students or influenced their thinking about science. I would like to know whether reflecting on past elementary learning experiences had any influence on these students' understandings about science, if at all. It would also be informative to gather feedback from students about their overall experience as participants in this research study. I think it would also be very informative to conduct similar studies in other private schools or different school settings such as public or home schools. Data from other schools could be compared in a case study format for a potentially different view of elementary science.

The results are important for teachers, students, educational decision makers, and researchers because they are instrumental in determining acceptable practices and carrying them out on a daily basis. I suspect teachers want to know what students think about their teaching and learning practices and how it affects them. Which begs the question, why don’t all teachers just ask the students for their input? For this I say, it is simply a matter of normative practice. While some teachers elicit the voice of students in routine interactions, they do not always elicit feedback about teaching and learning practices in general. I do not know why this does or does not happen, it could result from how teachers are trained, it could be based on traditional power dynamics that often play out in classrooms, or it could be because of something else entirely. Research has already been conducted on varied aspects of teaching and learning. Future studies will further contribute by examining ways teacher actions encourage, support or ignore student voices in classroom settings and how those voices are used.

I believe many and perhaps most teachers want and need to know about their students, but they may not know how to elicit student voices or how to analyze and interpret what students say. Further, teachers, both experts and novices, may not understand how to use what students have to say and they also may not know how to encourage students to engage in sharing their voice. Training that targets these aspects of student voice would strengthen understanding, reinforce benefits, and support teachers that employ new techniques into routine classroom activities. Teachers and students would directly benefit from the powerful influence students' voices can bring to elementary science experiences.

School leaders and other decision makers play an important role in helping design, execute, and manage new classroom practices and procedures. They are also instrumental in determining professional development and feedback. Efforts like those mentioned: designing, executing, and managing classroom practices and procedures, would enhance communication, build positive school culture, and would bolster inclusivity among all participants and customers of teaching and learning, including students. Educational administrators are keenly interested in improving certain measures of student outcomes. Measures may not be balanced across all measures of student outcomes. I believe students' voices provide a window into measures of academic performance that are rarely seen or understood. While academic outcomes were not examined in this study, I believe there is untapped potential for improving student learning outcomes by listening and acting on student voice data.

Students matter and this work has tangible benefits. When I consider what’s in it for the students, I say the students as an empowered group can significantly influence teaching and learning in positive and impactful ways. Even very young students can be entrusted to share their feedback, opinions, thoughts, and ideas by engaging in conversations about the very practices they are subjected to. While it is, in fact, strange, that student voices have not been lifted up in a normalized way in our schools, it does not have to be this way. We already knew a lot of things about elementary science, and this study adds valuable insights and possibilities about students' lived experiences. It is my belief that when students are encouraged to share their thoughts and ideas about learning experiences, invaluable insights are revealed that have often been hidden from view. Some students shared their input when asked and their feedback is valuable to the teaching and learning process.

There are other implications for this work. Parents and guardians, or anyone else that cares about education, need to know how students perceive and process various learning experiences. They need to hear directly from students to have a more comprehensive view of elementary science. They need to know whether our school systems are working, specifically what teaching and learning practices are productive and which ones are not effective. Researchers that examine elementary science outcomes would benefit from listening to the hidden voices of the children, who attend the very schools designed to serve them. Researchers that examine methods would benefit from the use of the hermeneutic phenomenological approach and the use of the science autobiography as a source for eliciting student voice as research. This work provides an opportunity for all participants to better understand elementary science. Foundational learning is essential for students to be prepared with the knowledge and skills necessary for advanced coursework and scientific literacy.

As a summary of this section, I have presented a detailed account of this research study designed to elicit the voice of middle school students in a way that allowed them to reflect and write about their elementary science experiences. I captured the voice of students in a carefully designed approach through a systematic inquiry using the science autobiography as a data collection instrument.

Every science autobiography offered an interesting account of an elementary science experience. While differences existed between these handwritten narratives, many common themes and patterns emerged from students' science autobiographies. I focused on revealing the essence of elementary science by extracting the rich and textured language that students' presented in their writings. Using the hermeneutic circle, I was able to analyze, extract, and interpret the interesting ways students described and explained their elementary science experiences.

My overarching conclusion is that we should find ways for students to share their voices because they have important things to share about teaching and learning science. This study revealed many interesting outcomes from a targeted sample of middle school students. Students have interesting things to say because they are the recipients of teaching and learning practices. Only students can provide first-hand accounts of their experiences. Students have important insights about effective and ineffective methods of teaching and learning. Sometimes we miss valuable input opportunities from students because we have not elicited their voices. Students open up new opportunities when their voice is revealed. Student voices can shed light on strategies that work and they can shed light on counterproductive strategies that don't work. This study is not about identifying correct ways of teaching or about incorrect ways of teaching. Instead, this study was carried out to elicit the voice of students in middle school classrooms. The study was intended to capture the essence of elementary science and expose the meanings students make of their uniquely lived elementary science experiences.

As a community of educators, it seems that we should value what everyone can contribute regardless of their background, experience, expertise or age. This idea can be juxtaposed with how our students are generally treated. Students sometimes look like disenfranchised consumers of educational policies and practices. Sometimes students are treated as if, as a holistic group, they do not matter in relation to teaching and learning practices. This sends what I believe is an unintentional message that they are unimportant and their voices do not matter. We often ignore the students' voices in schools and this is simply wrong. I argue that these practices present a significant loss to educators. This study has offered new insights and tools to consult students as worthy consumers of elementary science. Voices are powerful, words have meaning, and it takes careful listening and action to change foundational learning experiences for all children.

Bibliography

Adams, T. E., Ellis, C., & Jones, S. H. (2017). Autoethnography. *The International Encyclopedia of Communication Research Methods,* , 1-11.

Alexander, R. J. (2006). Towards dialogic teaching: Rethinking classroom talk.

Armour, M., Rivaux, S. L., & Bell, H. (2009). Using context to build rigor: Application to two hermeneutic phenomenological studies. *Qualitative Social Work, 8*(1), 101-122.

Balls, P. (2009). Phenomenology in nursing research: methodology, interviewing and transcribing. *Nursing Times*, *105*(32-33), 30-33.

Barton, A. C. (2000). Autobiography in science education: Greater objectivity through local knowledge. *Research in Science Education, 30*(1), 23-42.

Basu, S. J., Calabrese Barton, A., Clairmont, N., & Locke, D. (2009). Developing a framework for critical science agency through case study in a conceptual physics context. *Cultural Studies of Science Education, 4*(2), 345-371.

Birt L, Scott S, Cavers D, Campbell C, Walter F. Member Checking: A Tool to Enhance Trustworthiness or Merely a Nod to Validation? Qualitative Health Research. 2016;26(13):1802-1811. doi:10.1177/1049732316654870

Brickhouse, N. W., Lowery, P., & Schultz, K. (2000). What kind of a girl does science? The construction of school science identities. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching,* Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 44(8), 1187-1218.

Conner, J. O., Ebby-Rosin, R., & Brown, A. S. (2015). Introduction to student voice in American education policy. *Teachers College Record*, *117*(13), 1-18.

Cook-Sather, A. (2006). Sound, presence, and power:“Student voice” in educational research and reform. *Curriculum Inquiry, 36*(4), 359-390.

Cook-Sather, A. (2020). Student voice across contexts: Fostering student agency in today’s schools. *Theory into Practice*, *59*(2), 182-191.

Cothran, D. J., & Ennis, C. D. (2000). Building bridges to student engagement: Communicating respect and care for students in urban high schools. *Journal of Research & Development in Education,*

Creswell, J. W., & Poth, C. N. (2016). *Qualitative inquiry and research design: Choosing among five approaches*. Sage publications.

Daniels, D. H., Kalkman, D. L., & McCombs, B. L. (2001). Young children's perspectives on learning and teacher practices in different classroom contexts: Implications for motivation. *Early Education and Development, 12*(2), 253-273.

Darling-Hammond, L., & Cook-Harvey, C. M. (2018). Educating the Whole Child: Improving School Climate to Support Student Success. Learning Policy Institute.

Denzin, N. K., & Lincoln, Y. S. (2018). *The Sage handbook of qualitative research*. sage.

Dewey, J. (1910). Science as subject-matter and as method. *Science, 31*(787), 121-127.

DeWitt, J., & Archer, L. (2015). Who aspires to a science career? A comparison of survey responses from primary and secondary school students. *International Journal of Science Education, 37*(13), 2170-2192.

Dibley, L., Duffy, M., Vandermause, R., & Dickerson, S. (2020). Doing Hermeneutic Phenomenologica*l Research: A Practical Guide*. SAGE Publications, Limited.

Duschl, R. A., Schweingruber, H. A., & Shouse, A. W. (2007). *Taking science to school: Learning and teaching science in grades K-8*. National Academies Press Washington, DC.

Fielding, M. (2001). Beyond the rhetoric of student voice: New departures or new constraints in the transformation of 21st century schooling? Paper presented at the *Forum for Promoting 3-19 Comprehensive Education, , 43*(2) 100-109.

Fielding, M. (2004). Transformative approaches to student voice: Theoretical underpinnings, recalcitrant realities. *British Educational Research Journal, 30*(2), 295-311.

Fielding, M. (2007). Jean Rudduck (1937–2007)'Carving a new order of experience': A preliminary appreciation of the work of Jean Rudduck in the field of student voice. *Educational Action Research, 15*(3), 323-336.

Fletcher, A. (2004). Broadening the bounds of involvement: Transforming schools with student voice. *New Horizons for Learning, Http://Www.Newhorizons.Org/Voices/Fletcher.Htm,* Friesen, N. (2020). Dilthey and Human Science: Autobiography, Hermeneutics and Pedagogy. Phenomenology & Practice, 15(2), 100-112.

Furman, M., & Barton, A. C. (2006). Capturing urban student voices in the creation of a science mini-documentary. *Journal of Research in Science Teaching, 43*(7), 667-694.

Gadamer, H.-G. (2013). Truth and Method (J. Weinsheimer & D. G. Marshall, Trans.). Bloomsbury Academic.

Gargroetzi, E. C., & Lawler, B. R. (2017). Sociopolitical mathematics teacher identity: Mathography as window. Paper presented at the *Proceedings of the Ninth International Mathematics Education and Society Conference,* 222-226.

Gomez-Arizaga, M. P., Bahar, A. K., Maker, C. J., Zimmerman, R., & Pease, R. (2016). How does science learning occur in the classroom? Students' perceptions of science instruction during the implementation of the REAPS model. *Eurasia Journal of Mathematics, Science and Technology Education, 12*(3), 431-455.

Gonzalez, T. E., Hernandez-Saca, D. I., & Artiles, A. J. (2017). In search of voice: Theory and methods in K-12 student voice research in the US, 1990–2010. *Educational Review*, *69*(4), 451-473.

Hagay, G., & Baram-Tsabari, A. (2012). Including students' voices as engagement with curriculum: Perspectives from a secondary biology course. *Canadian Journal of Science, Mathematics and Technology Education, 12*(2), 160-177.

Haste, H. (2004). Science in my future: A study of values and beliefs in relation to science and technology amongst 11-21 year olds.

Hazari, Z., Sonnert, G., Sadler, P. M., & Shanahan, M. C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. Journal of research in science teaching, 47(8), 978-1003.

Heidegger, M. (1988). *The basic problems of phenomenology*. Indiana University Press.

Jenkins, E. W. (2006). The student voice and school science education.

Johnson, D. (2017). The Role of Teachers in Motivating Students to Learn. BU Journal of Graduate studies in education, 9(1), 46-49.

Kahne, J., Bowyer, B., Marshall, J., & Hodgin, E. (2022). Is Responsiveness to Student Voice Related to Academic Outcomes? Strengthening the Rationale for Student Voice in School Reform. *American Journal of Education*, *128*(3), 389-415.

Kane, J. M. (2012). Multiple identities and the science self. *Identity construction and science education research* (pp. 27-42). Springer.

Koch, J. (1990). The Science Autobiography. *Science and Children, 28*(3), 42-43.

Kozol, J. (2012). *Savage inequalities: Children in America's schools*. Crown.

Kuhn, D., & Franklin, S. (2006). *The second decade: what develops (and how).* John Wiley & Sons Inc.

Laux, K. (2018). A theoretical understanding of the literature on student voice in the science classroom. *Research in Science & Technological Education, 36*(1), 111-129.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*(4), 331-359.

Lessem, R., & Schieffer, A. (2010). Integral research and innovation: Transforming enterprise and society. Gower Publishing, Ltd.

Levin, B. (2000). Putting students at the centre in education reform. *Journal of Educational Change, 1*(2), 155-172.

Lindahl, B. (2007). A longitudinal study of students' attitudes towards science and choice of career. Paper presented at the *NARST Annual Conference, April 15-18, 2007, New Orleans,*

Lubelfeld, M., Polyak, N., & Caposey, P. J. (2018). *Student voice: From invisible to invaluable*. Rowman & Littlefield.

MacBeath, J., Demetriou, H., & Rudduck, J. (2003). *Consulting pupils: A toolkit for teachers*. Pearson.

Maltese, A. V., & Tai, R. H. (2010). Eyeballs in the fridge: Sources of early interest in science. *International Journal of Science Education, 32*(5), 669-685.

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among US students. *Science Education, 95*(5), 877-907.

Mason, L., Ronconi, A., Scrimin, S., & Pazzaglia, F. (2021). Short-term exposure to nature and benefits for students' cognitive performance: A review. Educational Psychology Review, 1-39.

McKinnon, F. R. (2018). *The effects of STEM education on elementary student achievement*. Western Illinois University.

McQuillan, P. J. (2005). Possibilities and pitfalls: A comparative analysis of student empowerment. *American Educational Research Journal, 42*(4), 639-670.

Mead, M., & Métraux, R. (1957). Image of the Scientist among High-School Students: A Pilot Study. *Science (American Association for the Advancement of Science), 126*(3270), 384-390. 10.1126/science.126.3270.384

Miles, M. B., Huberman, A. M., & Saldaña, J. (2018). *Qualitative data analysis: A methods sourcebook.* Sage publications.

Mitra, D. (2018). Student voice in secondary schools: the possibility for deeper change. *Journal of Educational Administration,*

Mitra, D. L. (2004). The significance of students: Can increasing "student voice" in schools lead to gains in youth development? *Teachers College Record, 106*(4), 651-688.

Mitra, D. L., & Serriere, S. C. (2012). Student voice in elementary school reform: Examining youth development in fifth graders. *American Educational Research Journal, 49*(4), 743-774.

Moustakas, C. (1994). *Phenomenological research methods*. Sage publications.

Oakes, J. (1990). Multiplying inequalities: The effects of race, social class, and tracking on opportunities to learn mathematics and science.

Ochoa-Becker, A. S., Morton, M. L., Autry, M. M., Johnstad, S., & Merrill, D. (2001). A search for decision making in three elementary classrooms: A pilot study. *Theory & Research in Social Education, 29*(2), 261-289.

Oldfather, P. (1995). Songs “come back most to them”: Students’ experiences as researchers. *Theory into Practice, 34*(2), 131-137.

Olson, J. K. (2008). The science representation continuum. Science and Children, 46(1), 52.

Osborne, J. (2007). Engaging young people with science: Thoughts about future direction of science education. *Promoting Scientific Literacy: Science Education Research in Transaction,* , 105-112.

Peoples, K. (2020). *How to write a phenomenological dissertation: A step-by-step guide*. Sage Publications.

Persson, E. K., Kvist, L. J., & Ekelin, M. (2018). Midwifery students’ experiences of learning through the use of written reflections–An interview study. Nurse education in practice, 30, 73-78.

Polkinghorne, D. E. (1995). Narrative configuration in qualitative analysis. *Null, 8*(1), 5-23. 10.1080/0951839950080103

Polman, J. L., & Pea, R. D. (2001). Transformative communication as a cultural tool for guiding inquiry science. *Science Education, 85*(3), 223-238.

Rogers, A. L. (2005). *Student voice: Bridge to learning*. University of Washington.

Roth, W. M. (2000). Autobiography and science education: An introduction. Research in Science Education, 30, 1-12.

Rudduck, J., & Flutter, J. (2000). Pupil participation and pupil perspective:'carving a new order of experience'. *Cambridge Journal of Education, 30*(1), 75-89.

Shapiro, J. P., & Gross, S. J. (2008). *Ethical educational leadership in turbulent times*. Routledge.

Sheehan, T. (2014). *Making sense of Heidegger: A paradigm shift*. Rowman & Littlefield.

Simpson, A., & Quigley, C. F. (2016). Member checking process with adolescent students: Not just reading a transcript. *The Qualitative Report, 21*(2), 376-392.

Tai, R. H., Qi Liu, C., Maltese, A. V., & Fan, X. (2006). Planning early for careers in science. *Science, 312*(5777), 1143-1144.

Tenenbaum, H. R., & Ruck, M. D. (2007). Are teachers' expectations different for racial minority than for European American students? A meta-analysis. *Journal of Educational Psychology, 99*(2), 253.

Teo, P. (2019). Teaching for the 21st century: A case for dialogic pedagogy. *Learning, Culture and Social Interaction, 21*, 170-178.

Texas Education Agency. (2022). *Texas Education Agency.* https://tea.texas.gov/. Retrieved 9/16/2022, from https://tea.texas.gov/academics/curriculum-standards/teks/texas-essential-knowledge-and-skills

Tillman, L. C. (2002). Culturally sensitive research approaches: An African-American perspective. *Educational Researcher, 31*(9), 3-12.

Tobias, S. (1990). They're not dumb. They're different.: A new “tier of talent” for science. Change: The Magazine of Higher Learning, 22(4), 11-30.

Van Manen, M. (2016). *Researching lived experience: Human science for an action sensitive pedagogy*. Routledge.

VanFossen, P. J. (2005). “Reading and math take so much of the time…”: An Overview of Social Studies Instruction in Elementary Classrooms in Indiana1. *Theory & Research in Social Education, 33*(3), 376-403.

Varelas, M. (2012). *Identity construction and science education research: Learning, teaching, and being in multiple contexts*. Springer Science & Business Media.

Vogt, G., & Monroe, A. (2021). What Mister Rogers can teach us about teaching. Phi Delta Kappan, 102(8), 46-51.

Weatherall, A. (2011). I don't know as a Prepositioned Epistemic Hedge. Research on Language & Social Interaction, 44(4), 317-337.

Wegerif, R. (2006). Dialogic Education: What is it and why do we need it? *Education Review, 19*(2)

Wilson, B. L., & Corbett, D. (2001). *Listening to urban kids: School reform and the teachers they want*. SUNY press.

Zahavi, D. (2003). *Husserl's phenomenology*. Stanford University Press.

Zahn, L. M. (2017). Try This! Extreme: 50 Fun & Safe Experiments for the Mad Scientist in You. Science, 358(6368), 1248-1248.

Zen, E. -. (1990). Science Literacy and Why it is Important. *Null, 38*(5), 463-464. 10.5408/0022-1368-38.5.463

Appendix A

What content was learned in elementary science?								
	Science Strand							
Student	Dissection	Force & Motion	Energy	Life Science	Earth Science	Space Science	Physical Science	Other Learning
	worm, starfish, fish, cow's eye, pig's heart, owl pellet	Newton's Laws, egg drop, balloon zipline, marble roller coaster, Nerdy Derby	electrical energy, magnetic energy, heat energy, sound energy, simple machines	life cycles, dinosaurs, plants, human body systems, animal research, genetics, cells, DNA	weather, natural disasters, ocean, tides, rocks, tectonic plates, Pangaea, fossils, rain cycle, fossil fuels, clouds	solar system, rockets (NASA); space museum, sun, moon, stars	desity, periodic table, elephant toothpaste, ooblek, coke and mentos volcano, gummy lab, baggy ice cream, water droplets on a penny	lab safety, inventors, scientists, forensic science, scientific method, journaling, microscope, science fair, invention convention
10	X	X					X	
11	X	X				X	X	
12								
13	X			X	X	X		
14		X						
15	X			X	X	X		
16	X	X						
17	X	X		X		X		
18		X	X	X			X	
19	X	X		X	X	X	X	
20							X	
21	X	X		X	X	X	X	
22					X			
23		X		X				
24			X					
25	X			X	X	X		X
26	X	X		X	X	X	X	
27							X	
28	X						X	
29		X		X			X	
30	X	X		X				
31					X			
32		X		X	X	X	X	X
33								X
34	X							
35		X		X	X			X
36	X		X	X	X	X	X	X
37		X		X		X		
38				X			X	
39	X			X	X			
40		X						
41							X	
42	X	X				X	X	
43			X	X	X	X	X	X
44		X		X	X	X	X	
45				X				
46	X			X			X	
47	X		X				X	
48			X	X		X		
49			X	X			X	
50	X							
51								X
52				X		X		
53	X							
54								X
55	X	X	X	X	X			
56				X	X		X	X
57				X		X	X	X
58	X			X			X	
59							X	
60		X						
61				X			X	
62	X			X	X	X	X	X
Total	23	20	8	30	17	18	26	11