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My Journey as an Elementary Science Teacher: From Linear to Authentic

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MY JOURNEY AS AN ELEMENTARY SCIENCE TEACHER:
FROM LINEAR TO AUTHENTIC

A Dissertation

by

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ABSTRACT

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The purpose of this dissertation is to provide a personalized narrative of one science teacher's use of reflexive teaching as an agent of change. This dissertation is about a journey of change in instruction fostered by a change of identity as a science teacher, using the butterfly cycle as a metaphor. This dissertation narrates the identity evolution of the teacher. This study has relevance because the process utilized by the teacher provides a method of self-examination and identity construction for other elementary science classroom teachers who want to improve their science practices. This study also has relevance because it describes the process of how a classroom teacher takes ownership of self-improvement that leads to science teacher agency.

Science teacher identity and agency research has been mostly unexplored in science education, especially at the elementary level. A greater understanding of science teacher identity and agency development learned from this dissertation will provide the knowledge needed to better support novice and pre-service teachers, ultimately leading to better science educators. The nature of reflexive practice in science teaching and the development of science teacher identity and agency is the focus of this research. This paper is grounded in three main ideas: (a) self-reflexivity, drawing from the initial understanding of reflexivity (Archer, 2007; Bourdieu & Wacquant, 1992; Mora, 2011, 2012) as reflection with social and scientific foundations that leads to social change

(Mora, 2014), (b) self-study of teacher practices (Bullough & Pinnegar, 2001;Loughran, 2007; Pinnegar & Hamilton, 2009), as a rigorous way to understand the evolution of personal practice over time; and (c) metaphors to examine phenomena from a unique and creative perspective, provide structure to the data, to understand a familiar process in a new light, and to evoke emotion (Lakoff, G. and Johnson, M., 1980).

In my findings I discovered that my teaching identity is not fixed, that the journey in transforming my teaching identity from linear to authentic is endless, and the findings could be used as a starting point to introduce changes into the curricula of elementary teacher education programs for novice and pre-service teachers. This doctoral research was an empowering journey that enriched my professional life as an elementary science teacher by enabling me to examine the practices that formed my teaching identity. I hope that my newly transformed teaching identity enables me to further develop my professional practice as an assistant professor of practice, to empower the agency of my student teachers and empower readers to reflect on their own teaching identities.

DEDICATION

I would like to dedicate this dissertation to several important individuals in my life: First, to my parents who always made me feel that I could achieve anything with enough hard work, passion, and determination, thank you for all the sacrifices you have made throughout my life to help me to achieve my goals. I love you both very much.

Secondly, to my best friend Javier Balboa who passed away in July of 2020, who always believed in me and was my biggest cheerleader in life. I remember you would walk into my classroom and proudly say, "You are an amazing teacher, and you have so much to offer. Keep striving for more." Javier, you may not physically be here with me, but I know you never left my side, I know you'll be there in spirit the day of my defense, cheering me on, being proud of my continuous hard work and success in the profession that we both loved very much.

Then, to my sweet fur baby Scottie, my EVERYTHING who passed away June of 2022. Scottie, you were next to me every step of the way through this journey. You saw me write with joy and cry out of tiredness and frustration. YOU and only YOU knew what I went through this journey. Thank you, my sweet baby, for lying next to my laptop or on my lap on those long, lonely nights as I spent them writing and rewriting. We did this Scottie! We got it done!

Lastly, to my students. To my elementary and university students. You are what drives my love and passion in this profession. Because of you, I will continue on this reflexive journey to keep growing professionally, to help you gain a stronger sense of identity and agency.

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TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

CHAPTER I

INTRODUCTION

Figure 1: The Butterfly Cycle

Butterfly, butterfly, who are you butterfly pulsating through the wind? Beautiful butterfly, vivacious and conscious, stretching its wings, merging today from the mechanistic cocoon of a modern science worldview into a paradigm shift from a traditional to a transformative view. Beautiful butterfly, your landing from the air was not smooth, for it was risky and challenging, you encountered resistance. Although others have been crushed in their quest for flight, you preferred to be challenged, to shift paradigms and become a transformative agent, pushing forward in flight, to a non-linear view of science.

Why the beautiful butterfly as a metaphor? What does a beautiful butterfly symbolize in the world of elementary science education beyond being the hallmark teaching of metamorphosis and life cycles in classrooms? What defines her personally, professionally, and why? For she is morphing into an awakened science teacher, for her identity and consciousness precedes being, and not the other way around, for when one identity is shed, there is new space. And what could be more powerful than the flap of her butterfly wings? Oh, butterfly, butterfly, flying through the chaotic and restrictive education systems of high stakes testing and accountability. For curriculum, pedagogy, and the teacher need to become chaotic attractors that evoke transformation toward a new higher order of non-linear complexity that reflects authentic science. For this purpose, it was important to become a transforming butterfly, gradually emerging from the midst of mechanistic chaos, from the egg to the butterfly, on a metamorphic journey, with a clearer view of her science teacher identity.

Through her awakening process, she discovered that her identity as a teacher was not fixed, that the journey in constructing her science teaching identity was endless, and that becoming the science teacher she is today had been a continuous and cumulative process from childhood to the present moment. It is said that teachers' "own childhood histories and memories" are a part of the past experiences that interact with present circumstances to influence teacher identity" (Day, Kington, Stobart, & Sammons, 2006, p. 607). In other words, her life had not only been the chronology of isolated events, but more importantly, an interpretation and understanding of her experiences from the perspective of the wholeness of one's entire life. Understanding her life then as a coherent whole at any given point in time, brought upon an awareness shift that, in turn, shed a new light on each experience from a higher perspective of the coherent whole. When she then understood herself or even related in some way to another person's story or experience, it is then that her story then became worth telling:

> The awakening experiences lie within me. It has been an accumulation of lived experiences that confirm that I have lived in a constant state of change. For my life

> has been a multiple of inter-weavings of cycles of change at many levels, punctuated by discontinuous transitions. But in addition to these changes, there also exists in human experience another kind of transformation, a radical restructuring of the entire psyche that has been variously referred to as consciousness. A type of consciousness that only occurs in some people without their recognizing much of what is really happening and just how extraordinary this process is . . . And just like the butterfly, I too have awakened and transformed . . . (personal journal, September 2019).

My dissertation is a journey in reflexivity as a science teacher using the butterfly transformation as a metaphor. I share my experiences through self-analysis and critical reflection of my personal and professional self that led to transformation and professional growth. I provide a personalized account of the successes and challenges within my journey that evoke, rather than answer, questions, and invites the reader to imagine how elementary science education would look, if broken from the high stakes testing and accountability spell that has led to the teaching and learning of science as a mechanistic, linear process.

I chose reflexivity as it gave me the freedom to speak from the inside out as a teacher having experienced a deeper understanding of self and the changes that occurred in my science practices along my journey of teaching. Having taught elementary science for thirteen years, I experienced changes in my teacher identity and the science practices that encompassed that identity. It was that continuous voice of reasoning and awakening that paved the way for transformation for my dissertation: How did I arrive where I am as a science teacher? Why do I teach science the way I do? How does my identity guide my science practices? I describe how I took an inward glance at myself as a science teacher to really examine what I was doing in facilitating authentic science learning in my classroom. By examining how I constructed my identity, I changed and grew. My hope is that this body of work will lead the way for future discussions about how we teach science in the elementary classroom and enhance the dialogue on elementary science teacher identity and change." As Mora (2014e) posited, the ultimate goal of reflexivity, then, is not simply to reflect on practice, but to transform it for the benefit of one's community and its members. Reflexivity imbues any scientific endeavor with a solid ethical dimension as one must always keep track of the Other as an essential partner and agent of change.

The Problem

We are living and educating our students in science at a critical time in human history, a time in which many issues are global and intertwined. If there ever was a time for authentic science education in our students, it is now. Like the Sputnik satellite launch in 1957, the coronavirus pandemic gave us an opportunity to truly transform science education. As the coronavirus pandemic continues to spread throughout the globe, societies everywhere are experiencing the same shock. We are all realizing that our scientific capacities at the moment are often insufficient to do more than mourn for the loss of a loved one, in hopes for a vaccine miracle. More crucially, the COVID-19 pandemic has revealed how inadequate scientific education is among the public and among the world's leaders, few of whom have even the most basic conception of what a virus is. As teachers worldwide continue to scramble to transition to distance learning for continuous math and reading efforts, I plan to use the coronavirus as a teachable moment. I want to create lessons that not only draw on the emphasis of relevant natural phenomena, but also unique instructional opportunities to tap into students' innate curiosity about the virus and deliver instruction that draws students into developing their own questions about those phenomena, and designing experiments, models, and other activities to help them uncover answers.

We as educators hold in our hands the responsibility to help young people become active, global, critical thinking citizens of the twenty-first century who can understand that the future of their world depends on science global competence. But to do so, we must equip our students with the essential scientific understanding and skills necessary to become scientifically literate and socially responsible citizens (King, Shumow, & Lietz, 2001). Therefore, science education is extremely important for the development of a well-rounded global student, including the sustainability of the planet and all its inhabitants (Tobin, 2016). Thus, the foundation of science education needs to start as early as possible, for the primary grades have been identified as an important stage for establishing a strong K-12 science foundation (NRC, 2012). A strong early science foundation is necessary for a positive and successful secondary and postsecondary science experience, for how can we expect a high school student to understand the complexities of the higher sciences if they were never given a foundation of science education at a younger age? The idea is that students who study science early on are better equipped to handle scientific issues facing our world in the future, for example climate change and virus pandemics.

Global problems are important problems that students need to grapple with, they are also real-world problems that affect the whole of the planet, and are highly interdependent, often in non-linear ways. However, science education has engaged students in a version of science inquiry that reduces the investigation of the natural world and global problems to a fixed, linear set of steps, lacking a deep focus on learning and applying science concepts. Unfortunately, rigid representations of a single "scientific method" do not accurately reflect the complex thinking or work of scientists and solutions to global problems (Rudolph, 2005; NRC, 1996). So why are we still teaching our students that the *scientific method* is the ultimate quest for scientific knowledge as a one truth-driven discipline?

One does not need to look too far to realize that elementary science instruction continues to be ignored or approached through linear thinking, memorization and conformity, decontextualized, traditional teacher-centered instructional methods (Appleton & Kindt, 2002; Blank, 2012). This poor image of science teaching methods is reflected in Freire's (1970) banking system in which teachers are the keepers of knowledge and it is their job to deposit the information into students' minds. These images of the typical science classroom usually include a teacher standing in the front of the room next to a board full of scripted notes and print-rich diagrams for decoration. But those of us whose science classrooms and teaching looks quite different have dared to venture away from the scripted curriculum and reached a place in our teaching where we question teaching science in a traditional manner, which include long textbook scripted lessons and unimaginative linear lab experiences with expected outcomes that lead students to believe science is about a right or wrong answer. When I began to question and rethink my science teaching and learning, my teaching changed for the better in which my science classroom consisted of engaging students in learning science in more complex, relevant, and authentic ways as they conduct real world investigations.

> "Oh no, we were wrong," they exclaimed as they lowered their faces down with disappointment as their hypothesis was incorrect in their science fair project. I could tell by their sad faces that their learning thinking process was over, and it was the end of the world (personal journal, October 2019).

It hit me hard that they had been carrying the image of science as the end game of *facts* and *right or wrong answers* rather than exploration and self-discovery. Why was this happening if young children are full of questions, spawned by true curiosity rather than a desire to impress? Why are they taught that being wrong is like being incompetent?

Students need to learn that science has flexibility and is not a rigid, one-way simplistic approaches. In science, it is okay to be wrong. We need to think like a scientist by recognizing that we will occasionally (or more than occasionally) be wrong and knowing how to find out why. Science is a journey, and part of that journey is making errors and being empowered to find out more authentic solutions to real world investigations.

Figure 2: a. Students Conducting Biofiltration Experiment and b. Students Conducting Biofiltration Experiment

The journey of becoming and being an elementary science teacher had been both humbling and professionally challenging in the sense that I realized the natural curiosity I expected of my young third grade students had been suppressed by a school culture that rewards students for figuring out what the teacher wants or what is the right answer. The students had come to believe that every science lesson had a single, simple right or wrong answer, and it was their job to get that answer right. It took time to move from a traditional classroom setting, where the teacher asked the questions and the students supplied the answer, to an inquiry classroom, where my students engaged and re-engaged in their own curiosity and exploration. By doing this, I was not just helping my students skim the surface of science lessons, but dive into the messy and fascinating real-world of science.

Purpose

Real-world problems are complex and inherently multidisciplinary. Tackling such problems required not just the ability to use critical thinking or inquiry, but also the ability to choose the best approach or combination of approaches that capitalized on the strengths of each way of thinking within the science classroom. According to the National Research Council's 1998 book *Every Child a Scientist,* Carl Sagan argued that "every student starts out as a scientist." Students are full of questions, ready to suggest possible answers to their questions but most lose this curiosity as they progress through their science studies. Some argue that this is because most educators remain committed to the model of relying on the science found in textbooks, state tested curriculum frameworks, and standards documents. A type of model that consists of political power and control systems of high-stakes accountability controls from the classroom level, concentrating them in the upper echelons of the bureaucratic hierarchies of US schools, districts, and state educational agencies (McNeil 2000, Au 2009b). It is a “standardized testing, multi-billion-dollar industry" that takes over education in public schools in its year-round curriculum and continues to eliminate needed curriculum within classrooms that make schools an engaging, authentic experience (Popham, 2015, pg. 6). It gives teachers less room to teach creatively within their classroom and no longer teach children that there can be more than one answer, but rather they are teaching how to refer to the text and get the right answer, and are not learning important tools about how to be creative thinkers and debate answers (Au, 2011). As one US teacher in Crocco and Costigan’s (2007) study remarks, the test “… really shapes the way I run the class … I must cut out certain cooperative activities because they’re time consuming. It definitely affects my teaching. It’s always in the back of your mind” (p. 521). I assure you that our students and teachers want more out of science education and learning other than lessons packed with rigid content that lack the personal connection and the creative and collaborative problem solving of real-world challenges.

Several years ago, I reached a place in my teaching where I began to daydream about the idea of teacher freedom. I began to question the public education expectation to teach in a traditional manner and began researching the better ways to teach, such as authentic science. Things really started changing for me throughout my doctoral education classes when my view of authentic science started transforming and I started opening my eyes to a far deeper insight and awakening into the teaching and learning of science. The compartmentalized world of the public-school curriculum made me feel disconnected from the realities of the world. It was then that I stepped away from rigid scripted curriculum that focused mostly on success in tests, and, instead brought to my classroom a sense of wonder and appreciation for the beauty of authentic scientific learning. For me, it became increasingly critical that I tuned in to my students and rethought my approach to science education.

> I was about 8 years old when I visited a botanical garden center as a classroom field trip. As I walked the garden sights, sounds, scents, and textures came alive. I touched, smelled, and breathed in the oxygen of the very same plants that we learned about in the textbook. At the center I also got to hold and use scientific tools to collect water and took measurements of the temperature and the air quality with the help of field-scientists. It was such an amazing experience because I worked with scientists and felt like a scientist too. (personal journal, November 2019)

Imagine a science classroom that consisted of a science curriculum where learning is an art of life rather than a political trade. Where science instruction does not consist of lecturing to students who sit in rows at desks, but rather, offers every student a rich, rewarding, unique learning experience. The science classroom should not be confined to the walls of a classroom but, instead, extends into the home, the community and around the world. That memory took me back in time when I first visited the Houston Botanical Gardens as a classroom field trip. The excitement and the feelings of astonishment and bewilderment were simply unforgettable because it connected my classroom learning with my home learning environment.

One of the most vivid memories of my childhood are those that I spent outside, especially in the summer. Besides the usual outdoor playing with the neighborhood kids, one of my favorite things to do was to tend and to harvest my parent's vegetable garden. I remember my mom would wake me up early Saturday mornings to ask if I wanted to check to see if anything was ripe or if the chickens had laid eggs, and before she could finish her sentence, I was out the door, hoping to find the perfect slicing tomato and warm eggs to be included in our family breakfast. I just loved our small vegetable garden that was in our backyard, next to the chicken and duck coup. Every Saturday morning, I felt the warmth of the sun on my face and the cool dirt under my feet as I walked up and down the neatly organized rows, searching for the perfect fruit and vegetables with chickens pecking at my side. The whole time, I was distracted by the questions in my head about the beauty and power that I felt the plants and farm animals held over me. I couldn't just rely only on my sight or touch. I needed to smell and taste to determine if something was ready to pick. I don't know how long I would be in the garden because I would lose track of time. I would hear my mom's faint voice in the distance calling me to come inside.

Fast forward twenty some years, I began a gardening box on our campus. The garden box provided ample opportunity for making science inviting and relevant to students' lives by inspiring active exploration and problem solving. The garden encouraged inquiry as students used their senses for observation, reasoning, and communication skills to find answers to questions. These experiences helped improve my students' attitude toward science. Key science concepts that my classrooms explored in the garden included organisms, cycles, and basic requirements for life, plant anatomy, adaptations, food webs, decomposition, interdependence, ecological principles, pollination, and diversity of life. Students practiced and honed scientific process skills by observing, classifying, inferring, measuring, predicting, organizing and interpreting data, forming hypotheses, identifying variables, and journaling.

Figure 3: Students Working on their Garden Box

Significance

My dissertation portrays my reflexive journey to a new level of consciousness or awakening where I slowly transformed from a mechanistic, linear science worldview (the "egg") into a paradigm shift to see science as a complex, unconstrained way to understand the natural world (the "adult butterfly"). When I look at myself now as a science teacher, I question "who was I before the awakening" and "who am I becoming?" Before the awakening, I was just another novice teacher trying to find and negotiate her identity in teaching science in a school setting that highly emphasized high-stakes testing. I realized that I needed to have a deeper understanding of myself in order to evolve my science teaching identity, "my becoming" of an authentic science educator, an agent of change, contrasting language that currently dominates the public and political conversations in education about high stakes standardized tests and linked teacher assessments (Capps, Crawford, & Constas, 2012). And at last, the old paradigm of the dogmatic, mechanistic and materialist Eurocentric worldview that once dominated my classroom, began to crumble, and in its place arose a new paradigm of inquiry, an authentic critical pedagogy of science, a science teacher ready to begin the transformation from the egg (the novice teacher) to the caterpillar (awakening of consciousness) into the pupa (taking actions) and into the adult butterfly (agent of change). In order to unravel the shaping of my own science teacher identity, I examined Clark's (1996) metamorphic transformative model. According to Clark and Flores (2010), the teacher is at the center of their development and learning within this teacher transformation model. In *Metamorphosis: A Model of Identity Transformation* (1996), Clark described four stages based on the metamorphosis of a butterfly (p. 7):

1. Dormancy: characterized as a lack of self-awareness as an ethnic being and having limited contact with other cultural group members.

2. Exploration: characterized as a process in which an individual begins to reflect and explore identity and self within the sociocultural context.

3. Crystallization: characterized as a process of acquiring clarity for defining and articulating self-identity.

4. Flight: characterized as a transformative process in which individuals experience a paradigm shift developing new ways of believing, seeing, and thinking.

My own process of transformation from one state to another state was not an easy process. For we are all captivated by the beauty of the butterfly transformation, but rarely focus on the changes it has gone through to achieve that beauty. It is a very hard journey for every egg to even reach the state of the caterpillar. After that, the caterpillar may even die before even becoming a pupa or before changing into the beautiful butterfly. Just like in education a teacher may decide to quit in its early years due to its high demands and political pressures. The difficulty of this journey is evident by the large percentage of teachers who leave the profession during this induction period. Nine percent of new teachers do not complete their first year (Black, 2001), 14 percent leave after their first year (Ingersoll, 2002), approximately 30 percent leave the classroom within three years, and up to 50 percent leave within 5 years (Carver & Fieman-Nemser, 2009). This problem is even more pronounced for secondary science teachers, when compared to teachers of other secondary subjects as well as to elementary level teachers (Guarino, Sanitbãnez, & Daley, 2006; Ingersoll, 2006). But if the teacher remains in education and when it does transform into a butterfly, it is truly attractive and beautiful for everyone to see. My conceptualization of the stages of a butterfly life cycle are described.

Stage 1: The Egg (Novice Teacher)

Figure 4: The Image of an Egg from the Butterfly Cycle

The first phase as the egg is the scariest, because it is a state of dormancy (Clark, 1996), of long held beliefs and worldviews that remain static if not challenged due to the lack of self-awareness. According to (Luft, 2007), the initial years of teaching are arguably one of the most difficult periods of a teacher's development and "deserve[s] some undivided attention." This stage represents my first years teaching in public education where I struggled with limited resources, a scripted science curriculum, and lack of time due to an overloaded schedule focused on accountability requirements in mathematics, reading and writing. Due to time constraints, administrative pressures, and lack of self-awareness, I did not have time to prepare effective science lessons or to look for alternative ways to facilitate authentic science teaching and learning. There I was with student binders full of pre-made worksheets, passing on predetermined knowledge. The walls were covered with different science and scientific method posters, and I hoped that my scripted notes, lesson, and posters would help them remember the concepts long enough for the test. It is worth noting that my science teacher identity in my first years of teaching was one from the labor market. According to (Connelly & Clandinin, 1999; Clark & Flores, 2001, 2010), this stage also assists a teacher to explore one's identity by questioning "Who am I?"

> "Who am I?" Am I willing to look in that mirror, and not run from what I see? Do I know myself, or am I still living in the shadows of an unexamined life, removed from the world, removed from lived experiences and personal truth? Does my identity run like a river of water, forever changing and forever transforming, or am I barricading myself behind the podium as a faceless embodiment of a curricular requirement within an institution? How many years have I invested in the paradigm of public education, and now find myself at war with not how to let that investment go, but rather how to reshape and transform? How painful has the process been for being a faithful believer in the idea of public schooling, a part of a flock, to a harsh critic now, being alone in a paradigm? (personal journal, December 2018).

Stage 2: Larva (awakening of consciousness)

Figure 5: The Image of the Larva from the Butterfly Cycle

The second stage as the larva, represents my 5+ years of teaching science in public education and my first years in the doctoral program. In this phase the larva must eat and eat in order to grow. The larva grows by molting, shedding the outgrown skin, several times while it grows. Just like the larva I read and learned and learned some more. As I read and learned, I shed previous misconceptions and developed new beliefs around good science education.

One of the reads from my coursework that played a major facilitating point was *The Structure of Scientific Revolutions* by Thomas Kuhn (1996), and it became an open invitation to question the unquestionable, to elaborate on the trappings of being stuck in a high stakes testing place and on the possible risks of moving forward. It is a true masterpiece that transforms all intellectuals by creating a bank of opportunities for people who dare to look at themselves in a mirror and challenge their personal truths and realities. In his book, Kuhn magically transformed the way I started to think about science, revealing it as a messier, less logical, and occasionally more sordid process than what our school science teachers made us believe in. I really think Kuhn wanted me to evolve and grapple with the following question, "Do you have a good sense of science?"

If I take a good look into this question as a current science educator and scholar, I came to the conclusion that students are in school to learn what others have already discovered and even though they might experience personal discovery and learn something new for themselves, in reality, what they learned had already been known for a long time, which meant no true scientific discovery was being done. Therefore, the sad reality that remains true today is that students are not engaged in real scientific work, they witness and perform demonstrations in or about science, but they don't *do* science (Macbeth 2000). This stage is where the "aha" moment happened, standing in front of my third-grade science students during another science fair experiment realizing why I became an elementary science teacher in the first place. It was during this stage of my journey that I began to inquire and develop my inquiry questions for my future dissertation. I started developing tools and best practices to move forward and improve on my scientific teaching practices. This stage allowed for much research and reflection on my beliefs as a science teacher and my teaching science practice.

Stage 3: The pupa (taking actions)

Figure 6: The Image of the Pupa from the Butterfly Cycle

The pupa phase represents 8+ years of teaching science in public education and my mid-years in the doctoral program. See, as soon as a larva is done growing and they have reached their full length and weight, they form themselves into a pupa, also known as a chrysalis. From the outside of the pupa, it looks as if the larva may just be resting, but inside of the pupa, the larva is rapidly changing, and a lot of activity is going on because the larva is transforming into a new creature. Within the pupa, the larva is undergoing a remarkable transformation, called metamorphosis, and the new creature must eventually escape from the cocoon to complete the transformation.

This stage is where I developed the recognition that I needed to make changes in my science teaching practices and began acting. I was awakened to the sad reality that public schools are solely driven by a back-to-basics push that holds students and teachers to high levels of accountability on state and national standardized tests, "Accountability is big! Our product is our test scores" (Thorp & Townsend, 2001 p. 353). This over-emphasis on fact-based knowledge creates a weakness in students' processing and critical thinking skills (Blair, 2009). Therefore, I decided to take a leap of faith, and began implementing a garden box with my students, as an intervention to fact and test-based teaching. This individual change was a unique opportunity within my transformation journey that allowed me to have a sensorial interaction with the process (not just conceptually understand the change) but was significant to me as well (Greensfeld & Elkad Lehman, 2006) in that I adopted this new pedagogical practice, where I valued the importance and need of authentic science. It was a huge shift in thinking, habit, and practice that occurred and molded me as a better, effective science educator.

Stage 4: The butterfly (transformation – dynamic).

Figure 7: The Image of a Butterfly from the Butterfly Cycle

The adult butterfly stage represents my current teaching years in education and a recognition that my science teaching identity is not fixed and that the journey in revealing my science teaching identity is dynamic and endless. It has been a journey of emerging from a place of inner tension, a space of disaccord and dissonance, a place to experience the complicated curriculum and a pedagogy of discomfort (Boler, 1999). My science teaching and learning practices changed a lot with the passage of time during the past thirteen years. I was teaching science without any idea of the teaching and learning process, simply a transmitter of knowledge. When I finished my master's degree in science education, I had some ideas about the methods of teaching science, but it was my doctoral courses that created radical changes into my pedagogical perception and practices. There was a metamorphosis within my journey as a science teacher where I started to believe that children are born scientists and that it was my responsibility to continue that curiosity and lead them to become critical and creative thinkers, risk takers, and problem finders. My students are now eager to tackle larger problems that, like real-world issues, are messy and have more than one solution. Such genuine scenarios require that students use analytical decision-making processes and justify their choices. They have participated in many projects to help solve community-based and worldwide problems, like garden boxes and biofiltration science projects.

Teachers act as facilitators rather than conveyors of knowledge. The responsibility of the teacher relies on gained experiences and fostering student inquiry rather than on stored knowledge (Williams & Brown, 2012). I soon became the catalyst for my school. My successes sparked the curiosity of my colleagues and administrators. Not only were the students intrigued by outdoor authentic science learning, but so was the rest of the campus. The intense experience of the garden box allowed me to understand my role as an effective science teacher in a new way. I became a mentor for other teachers, a leader in professional development on my campus and others, providing those same types of experiences for teachers so they too could find the value of teaching in the garden, allowing authentic science to be their guide. We'd go out to the garden box and plant and harvest our own vegetables, and they loved to eat what we grew. We watched a bee pollinate a flower and follow that same flower through its whole life cycle. They also experienced the life cycles of butterflies and other insects when they discovered a pupa on a branch or a group of eggs hiding on a leaf. The students would spend time asking questions and journaling. They wanted to know so much about the things they were seeing and experiencing, and if I just told them, it killed their curiosity and their creativity. When teachers can let go of their norms for neatness, bringing in the children's imagination to their learning experience, the opportunities of the school garden and surrounding environment abound (Blair, 2009).

At this stage, I was able to explore and take risks in my classroom because I had already identified my strongest beliefs as to what a science classroom community should look like, feel like, and sound like, for both me and my students. Science teaching in its very essence is lifelong learning, a somewhat cyclical process that restarts with every new school year. September to June, we learn (through our successes, our failures, and our reflection of both) and we grow. But is our transformation dynamic or fixed? As what Friere (2000) would call the incompleteness, the never ending, on-going nature of identity development and transformation.

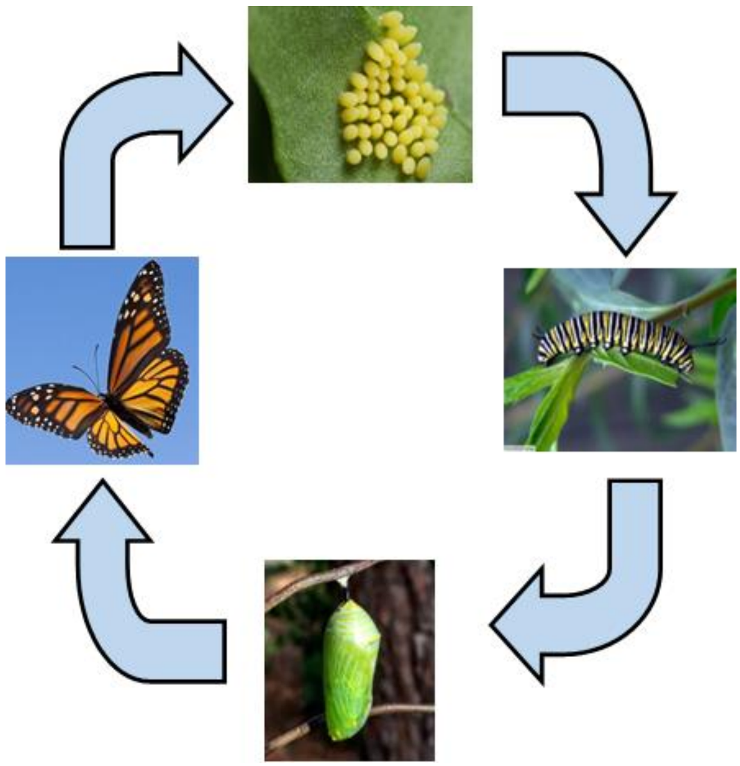


Figure 8: The Butterfly Cycle used as a Metaphor

This reflexive study will serve as a vehicle for elementary teachers who are in search of methods of examining and improving their teaching in an increasing era of accountability and a call for change in science teaching practice. In 1962, Thomas Kuhn wrote *The Structure of Scientific Revolution*, introducing the concept of paradigm shift, whereby he argued scientific advancement to be a "series of peaceful interludes punctuated by intellectually violent revolutions, and in those revolutions one conceptual world view is replaced by another" (p. 10). As it pertains to science classrooms, the revolution would deem necessary the changing of current teacher views about methods of teaching and learning science that would highlight the importance of making the student central to the implementation of science process skills. Therefore, the question guiding this inquiry is: In what ways has my experience as an elementary teacher and how I teach science influenced my identity and practice of teaching science? To reinforce the guiding question, my research process uses poetry, metaphors, and reflexivity to facilitate my development as a critical, reflective practitioner becoming an agent of change in the science classroom.

CHAPTER II

LITERATURE REVIEW

This reflexivity journey demonstrates the power of reflection in the examination of teacher identity leading to a transformation of the way I see myself and enact being an elementary science teacher. In this chapter, I provide a review of the literature in three areas that best support my study. First, I investigate the literature regarding reflective and reflexive teaching and its impact on teaching elementary science and change. I then examine the literature on identity, science teacher identity, agency, authentic science and how it is enacted in the elementary science classroom.

Reflectivity in Teaching

The roots of reflective teaching are historically evident in the works of John Dewey (1933, 1938), who maintained that reflection is an important aspect of learning from experience that leads educators to act deliberately and intentionally rather than randomly and reactively. Therefore, reflection requires a subjective glance into one's world, in this case how I teach elementary science within my classroom. As I venture off onto this subjective world, change and growth occurs, and awakens my soul to a critical consciousness with an attunement to an inner battle of constant thoughts between teaching science using prescribed curriculum and allowing my students to learn science more authentically.

According to (McKnight, 2002), reflective thinking is a multifaceted process. It is an analysis of classroom events and circumstances. By virtue of its complexity, the task of teaching requires constant and continual classroom observation, evaluation, and subsequent action. To be an effective teacher, it is not enough to be able to recognize what happens in the classroom. Rather, it is imperative to understand the "whys" "hows," and "what ifs" as well. It was through this multifaceted process that helped me to make deliberate choices as I transformed from teaching elementary science in a dichotomized, linear process to a liberated, multidimensional one. As a teacher undergoing this transformation, my past and present influence my daily classroom science practices and awareness of these influences and allow me to work on and reimagine my teacher identity with a goal of quieting my inner battle and creating an authentic science curriculum for all students to thrive in the science classroom.

After taking paradigm shifting science doctoral classes, I then found myself asking one very important question: "What is my science teacher identity?" So, I decided to look at myself as the teacher through introspection and reflection and make necessary changes so that the students in my science classroom would benefit. I soon realized that I would have to have become a reflective practitioner, one that maintains curiosity and develops the habits of inquiry and reflection to continuously move forward. This means that rather than relying on the authority of others, or unexamined and unchallenged previous practices such as the five-step scientific method, I now continually examine and evaluate my attitudes, practices, and effectiveness. When I become involved in active and deliberate reflection and analysis regarding those events, it leads to formulating new strategies for changing behavior in the classroom (Reagan et al., 2000), for professional growth, and helpful in identifying weaknesses and strengths as well as improving my practice, not just for my students to pass the STAAR (State of Texas Assessment of Academic Readiness), but rather to instill in them a curiosity and understanding of the natural world?

For the past couple of years as a reflective science teacher, I have concluded that the primary benefit of reflective practices is a deep understanding of my own teaching styles and an ability to define how I will grow toward greater effectiveness as an authentic science teacher. At an individual level, reflection has brought about an awareness of the need for change. Therefore, my reflective practice continues to be a journey, a natural process which facilitates the development of future action from the contemplation of past or current behavior and implies that as I continue to reflect on my science practices, I add any improvements I deem necessary as I continue to teach science in authentic ways.

Reflexivity in Teaching

It is important to note that there is a clear distinction between reflection and reflexivity. In the context of teaching, simple reflection may not yield all the information needed for the type of growth and learning originally advocated by Dewey and Schön. What adds to the complexity of reflection is its quality and depth. Therefore, deep self-reflections involve critical considerations of one's own understanding and are also known as "critical reflection" or "reflexivity" (Antonacopoulou, 2004; Warin et al., 2006). Engaging in reflexivity requires critical thought and careful consideration followed by action rooted in understanding, that becomes an increasingly useful tool for growth as we increase our self-awareness within the larger social, community, and ecological context that leads to an awareness of an individual about oneself, values and beliefs that impacts their future actions (Warin et al., 2006).

According to (Gilardi & Lozza, 2009), there are three principal components of reflexivity First, being aware of oneself as a professional (Warin et al., 2006), which means reflecting on one's own perceptions, strengths and weaknesses that impact his/her work. This component of reflexivity leads to questions like "How am I going to use this knowledge in the future?" The second component is having an inquiry attitude, which is a "reflective conversation with the situation" (Schon, 1983). This attitude involves a constant questioning of self-actions and learning from previous experiences. The third component of reflexivity is having an ability to work and negotiate with others (Cunliffe, 2004). This social element of reflexivity implies that individuals should be able to work with others to solve a problem (Reynolds & Vince, 2004). The development of these components of reflexivity can be facilitated by engaging individuals in reflexive practices such as journaling or responding to reflective prompts while working in an authentic learning environment (Gilardi & Lozza, 2009). The development of a professional identity such as a scientific identity helps students to value science, be motivated towards it and develop characteristics of a scientist (Hunter, Laursen, & Seymour, 2007). Moreover, reflexivity is an essential component for the development of one's professional identity (Guichard, 2005), like a scientific identity, an identity that prepares an individual to think and behave like a scientist. The concept of reflexivity facilitating the construction of one's science teacher identity is what guided this study.

Examining Identity with Respect to Science

Science has a long history of being taught and learned in ways that are contrary to how students actually learn (National Research Council [NRC], 2007). The reality is that what science is and how it works is absent from many K-12 science classrooms. The myth of the scientific method is just one example of how our understanding of good science teaching and learning has been mistakenly implemented within the science classrooms and that unfortunately continues to be directly taught in science textbooks (Abd-El-Khalick, Waters, & An-Phong, 2008. Science is messy and does not need to be neat, orderly or linear to be understood. Scientific discovery can result from a variety of approaches – experimentation, explanation, and observation, just to name a few.

If you step into many public school during the months of October and November, you will experience the greatest commandant of all, from the ten commandments of science, the 5-step scientific method. Yes, this accurately depicts the devotion to the scientific method within our elementary classrooms and schools. Even though you become mesmerized by the big and creative board displays, one factor remains common in all projects: experimentation is not a method of testing ideas, but rather as a method of producing a desired outcome. On the contrary, the main motive of a science fair should be for students to ask a question about something they wonder about, and to explore ways to discover some new understanding about that question. But, instead, because they are in competition and judged seemingly on objective performance criteria, the entire focus is on outcomes instead of processes. The questions and the curiosity become secondary to the product that students hope will impress judges as well as the general audience. Their focus is on stating their hypothesis, gathering their data, and proving their hypothesis true.

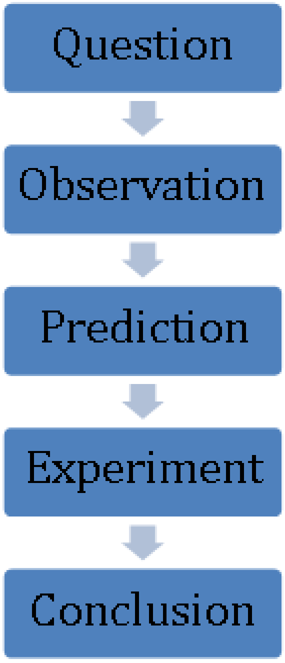


Figure 9: The Five-Step Scientific Method as part of the Elementary Science Curriculum.

There you have it; teaching science and the science fair is this cute linear process that kids see in school, and it is what publishers have done to make teaching science as simple and boring as possible. Now, what science really should really look like is a little more complex than how it is marketed by publishing companies to our children when they are in school. They're not training kids to be scientists; they're selling textbooks to teachers who are not scientists. Many of these teachers are reluctant to teach science because administration makes them overdose on math and reading to maintain test scores. How about instead of memorizing these science steps, lets focus on how science works instead.

Trying to understand that good science teaching and learning requires teachers to find out what students know and then challenge them to create meaningful understandings (Yore, 2012). Recent educational standards promote science learning that emphasizes *doing*, and not just *knowing*, science (NGSS Lead States 2013). This *doing* approach to science teaching and learning focuses on the learners' construction of scientific knowledge and encourages a deeper understanding of scientific work (NRC, 2012). Research has indicated that students learn science through emphasis on theory, explanation and models (NRC, 2007) and not on the memorization of facts and the replication of controlled experiments with expected outcomes that encourage students to believe that an experiment leads to a right or wrong answer.

Hence, authentic science teaching cannot be reduced to prescriptive techniques, but comes from the identity of the teacher as a whole person (Palmer, 1997). Therefore, looking at identity can provide insight into how people bring in and leverage personal resources, change in important or lasting ways relative to science practice, and develop agency to act in their lives and communities. Identity then with respect to science is about whether you see yourself and are recognized by others as someone who understands, uses, and does science (i.e., Gee, 2000; Carlone and Johnson, 2007). I strongly believe that this line of inquiry about elementary science teacher identity will help us ask questions that have not been asked so far about how students learn science and how teachers teach science in order to promote and ensure authentic learning experiences.

Teacher Identity

Why should educators be concerned with identity and identity construction? One reason identity is a powerful lens is because it influences how we design and teach for authentic learning. How we decide to teach a lesson is an extension of who we are. It is of critical importance that teachers understand how different experiences within their profession will impact their identities (Graham & Phelps, 2003). Gee (2000) believes that there is no such thing as a definitive core of identity because the core is never fully formed - or always tends to change (transform). This work builds on Grier and Johnston's (2009) argument that, "Teacher identity is based upon the core beliefs one has about teaching and being a teacher that are constantly changing and evolving based upon personal and professional experiences" (p. 59). In another perspective on identity, Cohen (2008) argues, "teachers' identities are central to the beliefs, values, and practices that guide their engagement, commitment, and actions in and out of the classroom" (p. 80). The literature demonstrates that past experiences affect teacher identity, which then modulates their pedagogical choices (Eick and Reed 2002). Thus, experiences shape teachers' identities (Proweller and Mitchener 2004), and teachers' identities affect their experiences as their identities influence their instructional practice.

The construct of identity has been explored and used extensively in various social science disciplines and is defined in different ways. Etienne Wenger's (1999) book *Communities of Practice; Learning, Meaning, and Identity* was the most frequently mentioned in the literature on teacher identities. Wenger provides the following definition of identity:

> An identity, then, is a layering of events of participation and reification by which our experience and its social interpretation inform each other. As we encounter our effects on the world and develop our relations with others, these layers build upon each other to produce our identity as a very complex interweaving of participative experience and reificative projections. Bringing the two together through the negotiation of meaning, we construct who we are. In the same way that meaning exists in its negotiation, identity exists—not as an object in of itself— but in the constant work of negotiating the self. It is in this cascading interplay of participation and reification that our experience of life becomes one of identity, and indeed of human existence and consciousness (p. 151)

Identity then is a continued process of social experiences, how we interpret these experiences, and how we construct our own meaning of the experiences. Therefore, an individual's identity is always in continuous development, even if a person has a relatively stable perception of "who" one is. Beijjard, Meiger and Verloop (2004) support this by considering identity to be an ongoing process of interpreting oneself as a certain kind of person and being recognized as such in a given context. In that context, according to these authors, identity can be seen as an answer to the recurrent question, "Who am I at this moment?" (p. 108).

Danielewicz (2001) also defines identity as "our understanding of who we are and of who we think other people are. Reciprocally, it also encompasses other people's understanding of themselves and others (which includes us)" (p. 10). Sachs (2001) uses the term "professional identities" where others use the term "teacher identities." She explains identities to be all the attributes that are assigned to the teaching profession by either those outside the profession or by teachers themselves. Individual professional identities are determined in the context of educational institutions and by the decisions the teachers make as these relate to teaching.

Therefore, the concept of teacher identity refers to how teachers identify themselves as teachers, including who they are as professionals, and who they strive and are empowered to become in a constant process of reflecting on their practices and experiences. Teacher identity then is not a static entity; a teacher constantly constructs and develops a reflective sense of self through looking into his or her practice and life of teaching, as a mirror (Palmer, 1997). Teachers teach who they are (Palmer, 1997); a teacher's identity is associated with his or her distinctive set of practices (Gee, 2001), such as inquiry-based, authentic science teaching. In this sense, teacher identity is intertwined with teacher practices (Enyedy, Goldberg, & Welsh, 2005). Teachers' professional identity arises out of their various types of teaching practices across contexts in which they construct holistic views of themselves in relation to students, colleagues, professional purposes, and circumstances of teaching (Beijaard, Meijer, & Verloop, 2004).

Connelly and Clandinin (1999), also view identities as the stories that teachers tell, that is teachers' stories are their identities. Teachers' identities, according to these researchers, lie in the story's teachers share about their lives in their classrooms. Like Connelly and Clandinin (1999) suggest that in sharing their stories, teachers negotiate and construct their identities. Taking into consideration these varied perspectives on identity from the literature, I then explain my understanding of teacher identities, as who each of us is in the classroom as we interact with students. Each teacher constructs his or her teacher identity as opposed to this identity being something that happens to us. We decide who we are in the classroom, and we consider who we want to become as educators. Teachers determine the beliefs that will influence their teaching practices, all while making intentional decisions about how social interactions within teaching contexts will (or will not) affect who each of us is as a teacher. In my thinking about teaching identities, I rely on Danielewicz's (2001) concept that a teaching identity involves our knowing who we are as teachers, and Connelly and Clandinin's (1999) thinking that we determine our identities in the process of creating stories about our lives in the classroom. Essential to a teaching identity is being in control of defining ourselves as teachers and an awareness of how our teaching contexts are critical to teacher identity construction.

Science Teacher Identity

Identity is truly a multidimensional, multifaceted, and complex construct receiving increasingly more attention in science education**.** Science teacher identity is important because it shapes our practice. Teaching authentic science is important to help students gain a greater understanding of how scientists actually do science (Chapman and Feldman, 2017). Therefore, the teacher must abandon the more common, albeit safer, lecture approach of passively imparting facts and assume the role of facilitator as students uncover scientific knowledge for themselves (NRC, 2000). (Carlone and Johnson, 2007) further argue that someone who has a science identity demonstrates competent performance in relevant scientific practices, has a deep and meaningful knowledge of science content, and recognizes oneself and gets recognized by others as a science person. In other words, identity construction requires the participation of others. To be the kind of person (i.e., to enact a particular identity) requires that we talk, think, use tools, value, act, and interact in ways that render who we are and what we are doing recognizable to others. Therefore, Crawford (2000) agrees with re-thinking of teachers' roles in science classrooms but extends the idea that teachers are more than facilitators, they are also active participants, collaborators, mentors, researchers, and learners.

With this new re-thinking and transformation, comes the view that science education must involve much more than teaching children discrete facts that are narrowly aimed at increasing scores on standardized tests of science knowledge (DeBoer, 2000). True scientific literacy requires authentic science learning experiences. There is a greater need to provide more opportunities for students to experience authentic science for themselves and thus to appreciate how science is done. Too often students believe that doing science is a matter of merely putting together scientific knowledge and scientific skills. We must help them to recognize the importance that doing science involves the whole person, including their creativity, their imagination, their commitment, and their persistence (Woolnough, 2001).

Science teacher identity and the practice of teaching science are interconnected. Helms (1998) argued that teachers' identity influenced curricular choices, pedagogy, and career trajectory. Melville and Wallace (2007) pointed out that the process of building a science teacher identity might determine the quality of how to implement and reform the teaching practice of science, using a case study of a non-university educated science teacher. For example, as found in Eick and Reed's (2002) study, a preservice science teacher having a weaker role identity as an inquiry-oriented teacher showed difficulty in understanding, guiding, and implementing inquiry-based hands-on instructions during student-teaching. Enyedy et al. (2006) described how practicing secondary science teachers who constructed a science teacher identity could be influenced by setting goals, knowledge, and beliefs about teaching practice to implement a new inquiry-based curriculum. This study found that science teachers implemented different strategies of curriculum and classroom practice in accordance with their own identities.

Similarly, in Moore's study (2008b), a teacher's positional identity contributes to how they teach science and interact with their students. In another study (Moore, 2008a), a social justice science teacher identity is essential for science teachers' teaching practice to improve science teaching and learning in urban classrooms. It is especially important to improve science teaching and science learning in urban classrooms because the school curriculum with an urban classroom is at a minimal level with very little student participation using outdated equipment and scripted textbooks curriculum, and teachers and students lack motivation to engage in meaningful learning activities making science having to do little to do with their personal lives (Fusco, 2001).

Research shows that these urban students must see some kind of connection between their science learning and lived experiences, and teachers have to create an environment in the classroom where such connections can be made. If science teaching is to make any difference in urban students' lives, teaching has to take place in the context of students' experiences (Barton, 2001). Since most classroom environments are different from the real-life environment of the students, teachers have a great influence on how students learn and make sense of science concepts (Lave & Wagner, 1993; Resnick, 1987)

Teacher Agency

I have seen firsthand the need and value of teaching authentic science and the role as an agent of change in elementary science education. Given the enormous pressures brought by standardized testing in K-12 public education, much emphasis has been placed on mathematics and language arts, especially in elementary classrooms. Thus, there is a greater need to recognize the value of authentic science learning rather than science being taught as a linear, step by step scientific method. Therefore, growing one's teacher agency is critical to understand how pathways through science learning become meaningful in the classroom and challenge common practices such as the scientific method, cookbook laboratory investigations, memorization, and rote learning. This dilemma prompted me to become an agent of change as a science teacher.

According to (Pantić, 2015) our ability to do our agency is influenced by who we are (our identity) and where we are (sociocultural context). Like Pantić, in developing our own sense of agency, it embraces Freire's (1970) notions of *concientización* or critical consciousness, liberation of the oppressed, and social justice. Freire (1970) introduced the concepts of critical consciousness and agency, where critical consciousness was an ability to read the world critically and agency was the ability to act in the world to change it. Therefore, agency can suggest a freedom from the constraints of educational political tyranny. The concept of agency looks for moment of improvisation, resistance, and self-determination, allowing us to consider how individuals take actions in response to specific situations or environments to change their position in a cultural world (Holland et al., 1998). Therefore, an agent of change is a person who is committed to teaching science to all students by incorporating different teaching methods, creating a less traditional, linear science classroom, and providing students authentic opportunities to learn science.

Varelas, Settlage, and Mensah (2015) define agency as “a person’s capacity to engage with cultural schemas and mobilize resources in ways that did not exist before, creating new contexts and practices” (p. 439). By exercising their agency to activate and mobilize resources, teachers can transform structures for teaching science. Moore (2008) defines agency in science education as “individuals or groups reflecting, acting, modifying, and giving significance to the teaching of science in purposeful ways, with the aim of empowering and transforming themselves and/or the conditions of their lives, students and others” (p. 591). In efforts to transform school structures that promote science inequity in elementary science classrooms, elementary teachers need to construct a strong science teacher identity to teach science.

Agency and identity are reciprocal in their relationships with one another. As we view ourselves as a teacher (our identity), the more confidence we have as an agent with the power to act. Therefore, our sense of agency in turn reinforces our feelings of identity as an effective teacher and determines the directions we take and our courses of actions within the science classroom. Considering the various perspectives of agency, for this study, agency is defined as individuals or groups reflecting, acting modifying, and giving significance to the teaching of science in purposeful ways, with the aim of empowering and transforming themselves and/or the conditions of their lives, students and others. Thus, agency is action-oriented; it is critical; it is the way that teachers use power, influence, and science to make decisions that affect positive social change in science classrooms.

Authentic Science

Science learning begins long before children enter formal education. They already carry an innate curiosity about the world and how it works prompts them to independently develop rudimentary forms of scientific investigations and design activities to find answers to their questions and solutions to their problems (NRC 2007). Therefore, high-quality, effective, elementary science education is necessary for establishing a sound foundation of learning for their later years in middle and high school, to keep instilling a wonder of and enthusiasm for science that lasts a lifetime, and in addressing the critical need for a well-informed citizenry and society (NSTA 2014), However, in many schools, elementary science instruction often takes a back seat to math and reading which are testing subjects, and receives little time in the school day, leaving science learning to a scripted, textbook curriculum.

In an investigation, a study of nine upper elementary and middle school science textbooks found most activities described as inquiry lessons were primarily simple inquiry activities that led to obvious conclusions (Chinn & Malhotra, 2002). The authors concluded that what many textbooks present as inquiry-based activities do not reflect authentic science. As a result, textbook inquiry tasks assume an epistemology that is entirely at odds with the epistemology of real science. One remedy to this problem is to provide students with authentic science experiences, in which students are allowed to experience real science that is as similar as possible to the work of scientists (Hsu et al., 2009). Authentic science, then, is defined as "forms of engagement that have a high degree of family resemblance with the real jobs of scientists and technicians in science-related fields" (Hsu et al. 2009, p. 481).

According to Buxton (2006), key elements of contextually based authentic science are (1) teaching and learning are taking place outside of the classroom that places students and teachers in the natural environment, (2) students are the originators of scientific inquiry-based questions, (3) students are given an appropriate amount of time to investigate the problem or question, and (4) relationships between students, teacher, professionals, and the community are valued. This type of scientific learning environment promotes a student-centered, higher-order inquiry-based environment that implants students into the community as important members of the community.

Therefore, science education must involve much more than teaching children discrete facts that are narrowly aimed at increasing scores on standardized tests of science knowledge (DeBoer, 2000). There is a need to provide more opportunity for students to experience authentic science for themselves and thus to appreciate the importance of tacit knowledge and the affective work of scientists. Too often students believe that doing science is a matter of merely putting together scientific knowledge and scientific skills. We must help them to recognize the importance of the affective, to realize that doing science involves the whole person, their creativity and their imagination, their commitment and their persistence (Woolnough, 2001).

Metaphors

The use of metaphors will be critical to this research in that it invoked new ways of seeing and thus of thinking for it was the process by which I viewed the world and the heart of what I thought and learned. It is stated by Lakoff and Johnson (1980) that humans live by metaphors and point out that metaphors "provide ways of comprehending experience; they give order to our lives… (and) are necessary for making sense of what goes on around us" (pp.185-186). As far as I can remember, I have been enchanted by this form of figurative language, for metaphorical expression flows freely through my veins, always helping me construct and evolve in the teacher world. To support this, Eren and Tekinarslan (2013) view metaphors as "crucial structures of the human mind" and define them as "the mental structures reflecting individuals' self-related beliefs, emotions and thoughts by means of which they understand and act within their worlds" (p. 435), in this case, their teaching worlds.

Within the teacher world, metaphors serve multiple metacognitive and meta-affective purposes; they draw out teachers' "internal thinking, reflection and emotional state", in their work contexts (Johnson et al., 2014, p. 541). As with any good educational practice, metaphors enable us to simplify the complex and reify the abstract (Eren & Tekinarslan, 2013), to position the teacher within her/his social and professional context (Pinnegar, Mangelson, Reed, & Groves, 2011), and to capture a glimpse of the future, idealized or otherwise. As such, metaphors are "improvement-aimed" (LaBoskey, p. 2004, p. 817), and have the capacity to help us grow into our 'best selves'. They also serve a purpose in "demystifying and making explicit personal knowledge so that it can be articulated to others" (Thomas & Beauchamp, 2011, p. 763), as well as to the self, thereby enhancing self-understanding (Kelchtermans, 2009).

As mentioned, metaphors are pervasive in our daily lives to conceptualize, to represent and to communicate many of our thoughts and actions (Lakoff and Johnson, 1980). According to Lakoff and Johnson (1980), a metaphor is a mental construction that helps us to structure our experience and to develop our imagination and reasoning. This means we construct metaphors to link our bodily experience of something to our more abstract thinking, and to "give shape, structure, and meaning to our imagination" (Sfard, 1994, p.47). This suggests that in fact, the whole conceptual system of how we think and act may be fundamentally metaphorical in nature. In brief, metaphors are something that are constructed by our minds that help us to present something in terms of something else and serve a variety of functions including facilitating conceptual change and facilitating changes in teacher belief and teaching practices. Tobin (1990) used metaphor as a means of conceptualizing teaching roles and guiding the practices adopted by teachers.

From this perspective, it is through metaphor that we can begin to comprehend the beliefs, reasons, and assumptions that might underlie the very behavior and phenomena we are exploring. Therefore, I used the butterfly metamorphosis metaphor within this inquiry, to represent change of appearance; a change from one form into another one, from something simple into something beautiful and complicated, the notion of developing and growing. When I started reflecting upon my own pedagogical practices in the science classroom, I realized the lacking in my teaching science practices in that my science teaching was dominated more by linear, traditional approaches, but with teaching experiences and my doctoral classes, it shifted towards a more authentic science approach. Metaphors then play an important role in this study, being an important means of describing science teacher identity. For a metaphor does not only *illustrate* the connection between identity and context, it can also aid in the *creation* of certain contextual understandings of identity, as it enables us to draw from our social realities in order to give meaning to our personal experiences (Hoskins & Leseho, 1996). It is through metaphors that we realize identity and context are inseparable, as they simultaneously inform one another.

CHAPTER III

METHODOLOGY

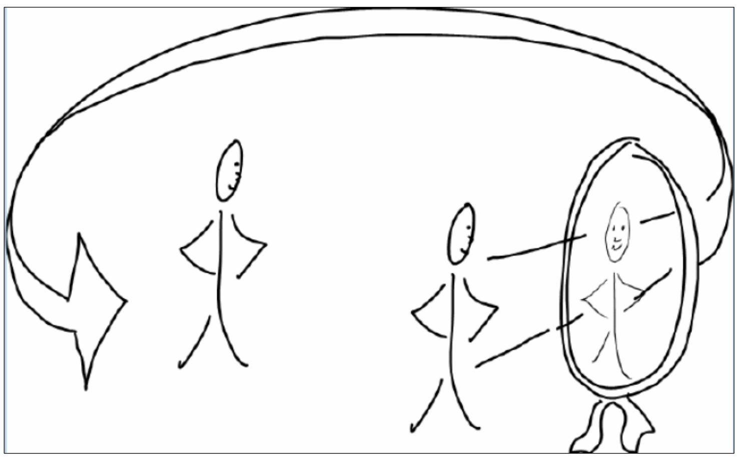


Figure 10: Mirror Image to describe Reflexivity

Mirror, Mirror, on the wall

Do you really know me at all?

While you reflect the layer people see,

Please realize there is more to me.

For flesh alone cannot speak for me,

For there is an authentic story that lies within me…

(personal journal, June 2022).

One day, while conversing with one of my committee members over my written work, I had a realization that I was not bringing all of myself to my writing. Her words resonated in my head for weeks. “What do you fear?” She made me realize that I was not showing in my writing an in-depth process of my becoming my science teacher identity. Rather, I was following a formula that I had constructed in my mind of what science teacher identity might have meant. The true problem was that I was not really connecting to my writing, finding my voice, or allowing myself to be true to the process by which I’ve become the science teacher I was hoping to portray. Thus, the question arose: why do I hold back parts of myself as I write about my science teacher identity or even the path that constructed my identity? Why has it been a lifelong struggle to understand myself, my ontological standpoint, and my epistemological framework? It seemed that all was blended in space and time from the origins deeply rooted in the values and beliefs of the colonized, Western world. I struggled to understand myself, only to be caught up in an educational and social system, obsessed with linearity, prescribed curriculum and standardized testing, sadly supported with superficial knowledge. As her words and my thoughts came crashing down on me like furious lightning on a rainy day, my carefully constructed cocoon of my world shattered into a million pieces. I stood there in front of a two-way mirror, with a naked soul, vulnerable and afraid, but with a sense of relief in finally facing the hidden truths of my fictional stories that I called my life. For the very first time I was forced to look into a two-way mirror requiring radical honesty with myself. For many years, I had created an idealized version of myself, a certain version of myself that I only wanted the world to see. I now find meaning in Frerier’s words that say “I cannot be a teacher without exposing who I am” (Friere, 2000). And so, the process of “writing the self into being” begins.

I began a vulnerable journey of introspective self-inquiry into the fragments of my identity and how I became the person and science teacher that I am today, a real transformation of exposing myself to vulnerability. I make visible to the reader and myself my thoughts and lived experiences that have facilitated my being in and out of the academic setting. Thus, this is how I begin the initial encounter with reflexivity, a path used to explore and explain the methods and processes that a researcher will use to attain a higher level of awareness (Freshwater, 2001). This new higher level of awareness required me to come at learning in a new way, as it jerked me out of the monotonous of my made-up comfort zone, that was holding me back as a human being and as an authentic science teacher. For when we immerse ourselves in the exercise of reflexivity, it becomes one of the most important factors in the process of curriculum change.

Reflexivity is concerned with deconstructing and reconstructing who we are, our identity and our voice. In order to deconstruct and reconstruct, I needed to get a wider perspective on what experiences had been influential in my life, so I began compiling a list of truly critical, life-changing experiences that forced me to break the silence and reclaim my voice. Therefore, this dissertation is, in part, my narrative of my journey as a science teacher. I offer it with humility, hoping that others see the vulnerability in writing one's truth. My wish is that perhaps my story will help elementary teachers facing similar challenges and contradictions around teaching science and spark a desire for further contemplation about that person's self in relation to the rest of the world. I hope it provides insight into what I believe is a co-constructed experience of science teacher identity development and understanding of self as we navigate our way as elementary educators.

Reflexivity (An Evolving Methodology)

> Caminante, no hay camino. (Traveler, there is no path.) Se hace camino al andar. (The path must be forged as you walk.) - Antonio Machado

This line from the famous Spanish poet Antonio Machado captured the spirit of my research process and the theories that emerged from that process. Initially I set out, on what I thought would be a solo path or no path at all, to soon realize that this path was not to be walked alone, it was socially co-constructed. In the process of looking back at one's path over the construction of their science teacher identity, there always lies a potential pitfall, which is to leave the experience of this path as nothing but a contemplation, or even nothing at all. In my dissertation journey, I sought to understand who I was as a science teacher, and ways in which my practice enables a process of authentic teaching and learning. In doing so, I engaged in a process whereby I situated myself at the center of my research inquiry. By placing myself and my own science practices under the microscope of my inquiry, I engaged with reflexivity.

Therefore, the chosen research approach for this study was a self-study practice, which we can understand "in relation to teaching and researching practice in order to better understand oneself; teaching; learning; and, the development of knowledge about these" (Loughran, 2004, p. 9). Thus, self-study of practice falls within the realm of self-reflexive methodologies of research that allow the researcher to examine their own practice in order to learn more about that practice and, in some way, improve it. Sandra Weber pointed out that

> Self-study is often a multipurpose endeavor that simultaneously involves research, teaching, learning, and evaluation. The design of any self-study usually centers on

key questions such as: What am I really doing/teaching? What influences my practice?

How does my teaching affect others? How might I improve what I do? How might I view things differently? How can I make a difference to others? (2014, p. 8)

By looking at the research from a critical perspective, it helps science teachers recognize that doing research has implications and help them engage in the necessary critical consciousness, or *conscientização* (Freire,1979; Mora, 2014b) to promote research as a true agent of change and not just a mere intellectual practice. Therefore, as I continued this self-reflexivity process, I kept returning to the following questions: “How did I arrive where I am as a science teacher? “Why do I teach science the way I do?” “How does my identity guide my science practices? Reflexive thinking then is having the ability and commitment to look inward and to see what some people refer to as a “standpoint.” Where do I stand? From where did I start? Why do I think the way I do? Therefore, reflexivity involves reflecting on the way in which research is carried out and understanding how the process of doing research shapes its outcomes (Hardy et al., 2001). In contrast to the programmatic and universal of education, the reflexivity research process invites teachers to pay conscious attention to the nuances and detail of their lived experiences. This requires teachers to look beyond the smooth surfaces of the system, and, furthermore, to problematize their own agency. One of the key critical questions of my study was, "Who am I as a science teacher?" I felt that a part of attempting to answer this question lay in what the data could teach me about myself (or selves). In order to gain an even deeper understanding of this, I needed to look closely at the ways in which my students and colleagues responded in our conversations. Having come to a more nuanced understanding of the workings of my science practice, and to a clearer sense of who I was as a science teacher, I was able to move on to a consideration of the educational effect of my practice. To be reflexive was to recognize that I was active in shaping my surroundings and begin critically to take circumstances and relationships into consideration rather than merely reacting to them and help review and revise ethical ways of being and relating in our world.

As Mora (2014e) posited, “The ultimate goal of reflexivity, then, is not simply to reflect on practice, but to transform it for the benefit of one’s community and its members. Reflexivity imbues any scientific endeavor with a solid ethical dimension as one must always keep track of the Other as an essential partner and agent of change.” Reflexivity occurred when I stepped back from my own reflection, considered my own thinking, and then acted toward my new goal, I myself identified as it related to the current endeavor. When the teacher then acts on her reflections, her thinking and actions become reflexive. Reflexivity, whether as a personal or collective endeavor, is always social (Archer, 2007; Schirato & Webb, 2002) and scientific (Bourdieu & Wacquant, 1992). In addition, reflexivity must always lead to a change in the practices (Bourdieu, 1992, Mora, 2014e). In my own research and proposal for an authentic science education, I used reflexivity (Mora, 2014) to ground my ideas on the need to deeply understand one’s reality, contexts, and participants as an obligatory step before engaging in change. What I propose, then, is a transformative process of reflexivity in research for the best science education practices.

My Transformative Stages of Reflexive Practice

Why should teachers be able to think and process reflexively? Because in an ever-increasingly constrictive and prescriptive teaching climate, it is crucial that educators think outside the box, question what they already know about their practice, and deliberate deeply on what they do, why they do it, and how they can improve it, what our schools need are reflexive educators who are poised to think nimbly, act with fluidity, and exert a willingness to “teach against the grain" (Cochran-Smith & Lytle, 1993) of institutional mores and practices. It seems reasonable, then, to explore ways that prompt educators to re-conceptualize, challenge, and ultimately transform their practice (Hargreaves, 2003) by leveraging the same intellectual capital that professional teachers have been using to think about their practice for decades (Schoen, 1983).

The work of Paulo Freire (1972) was instrumental in drawing attention to this need for critically reflexive practice in science education. He suggested that traditional pedagogies are often emphasized at the expense of critical pedagogies and that we need to redress the balance. Freire argued that traditional pedagogies encompass the banking approach to learning where teachers deposit information with students who learn to see the world in objective ways and separate knowing and being. Freire (1972) suggested that a critical pedagogy is one that transforms reality and unites critical thinking and dialogue to develop a more humanistic approach to learning, one that puts a self-conscious being able to think critically about the impact of his or her actions firmly at the center of learning. Thus, being reflexive can be a transformative process that develops transformative forms of the best teaching and learning science practices.

It is with such an understanding of a transformation process in mind that I shall show how the notion of a reflexive praxis can transform science teaching and learning by focusing on my own praxis. In this section then, I offer an account of practicing reflexivity at different stages of my research process. I begin by describing the stages of my own progress from liner to authentic science teacher, as the rest unfolds. Therefore, reflexivity, like the scientific method, is not meant to be linear and definitely not composed of a blueprint that is drawn up in advance and set in stone, it is a plan that evolves and can even be scrapped if necessary. Reflexivity, then, is continuous and lacks an end point, and can be viewed as evolving in stages, to describe how a teacher's evolution is not necessarily linear.

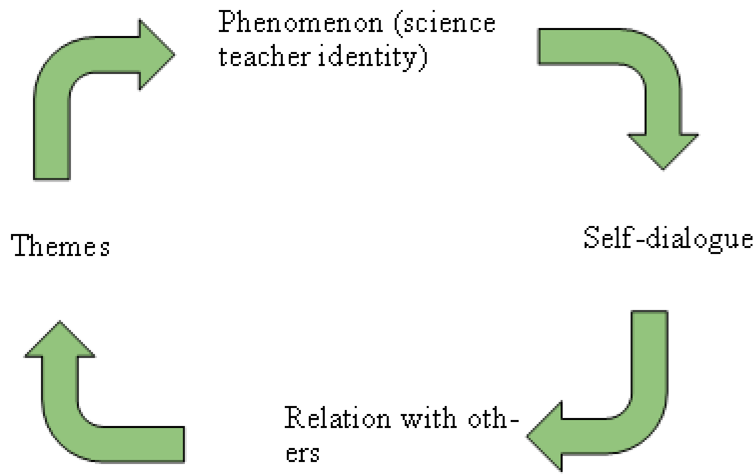


Figure 11: Reflexivity described through Evolving Stages

The first stage involved the discovery of an intense interest in a phenomenon that had important personal implications for the researcher and social meaning. In this stage, I immersed myself in self-exploration to discover tacit knowledge, which led to my research question (Moustakas, 1990). The moment of self-exploration and self-awareness happened in my journey as a doctoral student when I was learning more about authentic science. Something, for which I did not yet have a name, started bothering me while I was engaged in my doctoral classes. The process of listening to my professors, while conducting observations and reflections for this study, made me reflect on my own experience as a science teacher. This left me pondering over the following questions: How did I arrive where I am as a science teacher? “Why do I teach science the way I do?” These questions, along with my central research questions on the concept of science teacher identity, continued to probe me. It was then that I consciously started practicing reflexivity during the research process. The reflexivity process began with that question through which I was able to look at my science teaching life more critically, my past, present, future and the different roles I had played. Who was I before, now, and where was I going? These roles are of particular interest in the phenomenon of reflexivity for me for it was the opportunity to develop and identify one's voice (the ability to question, to speak out, to share and tell) and the creation of a critical voice, one that starts to question the truths that come from experiences. These lived experiences pushed me forward into action. I had to go further. I needed to journey into my own experience but with a view to engaging with the phenomenon more widely to consider its social implications in the following phases of my research. Where did I want to go? What was holding me back? Would this process help me to find out?

In the next stage, I became one with the topic and lived with the question. Living the question involves self-searching and following your intuition, listening to clues and hunches (Moustakas, 1990). Moustakas refers to this as getting "inside the question" through an immersion in the experience, which is open-ended and self-directed. In self-dialogue, the researcher converses with the phenomenon, allowing the phenomenon to speak directly to one's own experience, to be questioned by it, so that multiple meanings can then be uncovered. The process involves not only the intellect but also emotion, with the researcher attempting to understand the phenomenon in its wholeness and unique patterns of experience (Moustakas, 1990). My self-dialogue, between a younger teacher self and the older teacher self as a form of reflection. I used this format to find the rhythm or essence of the dialogue, to enter a deeper understanding and to allow more questions and answers to emerge. Moving beyond self-dialogue and bringing in an outside voice, I probed what was beginning to emerge. Further, this exchange was not just about me.

In the next stage, I moved away from the intense immersion with the question and became more detached from it. This period is a time for inner workings of the tacit dimension and intuition to work below the surface and to clarify understanding and perhaps, also to extend it beyond immediate awareness (Moustakas, 1990). This put a distance between myself and the phenomenon, as I took a more objective stance, defining and breaking down the more theoretical aspects of reflexivity. It was through the dialogue with my students and colleagues that helped me see things from different angles, to seek new perspectives and to go beyond. As reflexivity was co-constructed communally (Gergen, 2009), we acknowledge the importance of relationship and despite this first phase of research focusing on my own story, my experience of reflexivity is relational. It involved (and cannot be separated from) my audience (students and colleagues) and our ongoing dialogue. Gilbert and Sliep (2009) discuss the process as dynamic and iterative, influenced by our interaction with others. In this way, my journey was shaped not just by my own self-reflection but also by a dynamic process of relation with others and in the context of my research. Through each lived experience and dialogue, I made new connections, I started to tie the threads of my experiences together, my personal and professional self, as a reflexive researcher.

In the next stage I explored the themes emerging into awareness that were not directly present as part of the researcher's consciousness, and which reveal new insights. The themes that emerged for me begin with the need to acknowledge the becoming of my science teacher identity, including the developmental stages I have been through and the shape these took. Generally, the process of placing our life in context and reflecting on our own and others' positions (past and present) is a time for us to question our thought processes and those of others around us. What did I take from the experiences of my science teacher identity journey, what parts of me are who they used to be? To take this further, I also needed to question how this understanding will make a difference. Why was this important? How does it have an impact on my research and on my profession? Through deeper reflexivity, I began to recognize the uniqueness of my own and others' experiences and began to build a more complete picture of the phenomenon (Moustaks, 1990).

What evolved was an unfolding analysis to clarify meaning and expose new knowledge that has surfaced during the reflexive process. In this way, reflexivity is viewed as going beyond a self-reflective process that is passive, to one that is active, dynamic, interactional, and nonlinear. It challenged and probed and allowed me to become more aware of what constructed my science teacher identity.

Description of Participant

This research study is about exploration, not about proving the research questions right or wrong, therefore I am the primary participant in this study. This study was constructed from my experiences and how they impacted my science teacher identity. I am a 37-year-old Hispanic woman who is a teacher and soon to be an assistant professor of practice. These are just a few of my identities that shape my story.

Data Sources

One of the goals of my dissertation is to encourage teachers in our education system to challenge their own ideas about best practices in science teaching so that they are not merely reproducing other peoples' ideas but are leading the profession into innovative, creative, authentic science teaching and contribute to the understanding of how science teachers' construct their science identity and provide evidence for the importance of authentic science learning in the classroom. With this in mind, data collection tools vary greatly in research and studies and therefore, to ensure proper validity Feldman (2003) developed four criteria upon which data collection are based:

> "(a) provide clear and detailed descriptions of how data is collected and what counts as data, (b) provide clear and precise descriptions of how the representation of the

data is constructed, (c) provide multiple sources of data, and (d) provide evidence that the research produced change and added value to the body of knowledge for the profession." (pp. 27-28)

Feldman's (2003) criteria will facilitate the underpinnings of the data collection in my study. There will be two primary data sources. The first will include journal entries that (1) record experiences and memories, (2) present practitioner and/or classroom experiences, and (3) reflective practitioner experiences. The second data sources are from lesson plans, school curriculum, and school information. Throughout the years that this study took place, I kept two different sets of data. The first data source is a reflexive journal to facilitate and capture reflection-in-action (thinking while doing the task) and reflection-on-action (thinking after the task (Schon, 1983). Since starting my doctoral program in 2017, I have written several journal entries, sometimes before and after each class, and one summary journal entry encapsulating the entire week or even at a coffee shop conversing with my dissertation committee members. These journal entries reflected my thoughts on science lessons, science teaching methods, student observations, and life experiences. The majority of the data came from my writings which started in September 2019 and remains a continuous process. The second data sources are my lesson plans, school and district curriculum. This includes lessons from 2008 to present that include traditional lecture, 5-E model, scientific method driven school science fair, and authentic science lessons. These lesson plans were analyzed to determine how science is taught during the year, including before and after STAAR testing, to what extent the scientific method was part of 5-E lessons, and school wide science fairs. This will allow me to reflect on my metamorphic journey and science teacher identity.

Data Analysis

Through a non-linear process, I traveled through reflexivity like a scavenger hunt rather than a charted course. As such, the data analysis for this study followed the flow of experience rather than a linear progression through time. In handbooks for qualitative research, data analysis is described as a process, whereby data are coded, and themes are generated (Saldaña, 2016). Data analysis and the generation of themes therefore are not merely happening but are formally constructed to make meaning and sense of data (Morgan, 2018). Therefore, the analytical process needs to become more reflexive. Reflexivity is therefore not navel-gazing, but a conscious, interpretative process that links the researcher's conscious choices throughout all stages of the research process. The analysis then are not mechanical stages within research, but creative processes that allow to engage with and in the data. Therefore, I made the conscious decision to engage in an analytical process that would combine active meaning making with metaphorical representation, elements that I also rely on in my data collection.

My teaching and learning science practices have changed significantly during the past thirteen years. When I graduated with my bachelor's degree in elementary education, I had some ideas about methods of teaching science like applying Bloom's taxonomy to science skills and content. After my M.Ed. Degree in science and mathematics, I was inspired to go through a paradigmatic shift, from a more traditionalist and behaviorist approach to a modern, constructivist, and inquiry-based approach. Later on, during my doctoral courses in science education, I experienced another awakening and paradigm shift, from a linear, mechanistic to a broader view of science that is multifarious and authentic. In this way, I can claim that there have been pedagogical metamorphoses in my identity construction as a science teacher.

A teacher can really change their pedagogical practices with time and context after several years and instances of awakening. I think that such awakening and changes in the practices of teaching and learning from behaviorist to constructivist or traditionalist to modernist and postmodernist constitute a pedagogical metamorphosis which is parallel to that of a philosophical butterfly metamorphosis. Therefore, I link my pedagogical practices from the early days until now, and find myself asking "How did I enter into the process of metamorphosis? What was my pedagogy like then and what is my pedagogy like now? Therefore, all data were analyzed in three cycles of 1) identifying patterns, 2) emerging themes, and 3) identifying my evolving science teacher identity using a metamorphosis of butterfly metaphor analysis (Clarke, 1996; Denzin & Lincoln, 2011). A description of this process follows. I would like to show the stages of the metamorphic process in my teaching of science from the beginning of my teaching until today. I have developed an instrument that will be used as a reflexive analytical tool, explained in my findings, to explore my thirteen years of elementary science teaching (Table 1).

Table 1: Metamorphic Stages as an Analytical Tool

Stages in Metamorphosis	Characteristics
Egg Stage/ Dormancy Stage	Lack of awareness of self Unexplored identity Unchallenged beliefs and ideals Challenging event
Larva Stage/ Exploration Stage	Searching and exploring my identity, the classroom and school culture
Pupa Stage/ Crystallization Stage	Beginning of internal changes, identity change, and openness to new and differing perspectives
Adult Stage/ Flight Stage	Characterized by transformation and paradigm shift Newly defined sense of self, critical consciousness, and science teacher identity

CHAPTER IV

FINDINGS

This dissertation is about a journey of change in science instruction fostered by a change of identity as a science teacher. This study has relevance because the process utilized by the teacher provides a method of self-examination and identity construction for other science classroom teachers who want to improve their science practices. This study also has relevance because it describes the process of how a classroom teacher takes ownership of self-improvement and teacher agency.

A teacher can authentically and substantively really change their pedagogical practices with time and context after several years and instances of awakening. I think that such awakening and changes in the practices from linear to authentic science teaching constitute a pedagogical metamorphosis which is parallel to that of a philosophical butterfly metamorphosis. Therefore, I link my pedagogical practices from the early days until now, and find myself asking "How did I enter into the process of metamorphosis? What was my pedagogy like then and what is my pedagogy like now? I would like to show the stages of the metamorphic process in my teaching of science since the beginning of my teaching till today. Although one may delight in the beauty of the butterfly, it rarely sees the changes it has gone through to achieve its beauty. In the following sections I will unpack my experiences as an elementary science teacher using the life cycle as an analytical tool shown in Table 1.

Egg Phase: The Beginning of My Journey in the Worksheet World

Figure 12: The Image of an Egg from the Butterfly Cycle

I stood with my binder full of pre-made worksheets

passing on factual predetermined knowledge.

Standing there, waiting for students to finish copying facts and notes.

The humming of boredom and the tapping of pencils and rustling of loose-leaf paper.

My classroom is so lifeless . . .”

(personal journal, November 2017)

When I started teaching science thirteen years ago, I was given a textbook and a day-by-day lesson plan listing the sections in the textbook I was expected to teach that aligned to the curriculum standards. I taught from the book, never letting it leave my side, section by section. I kept the teacher’s edition in my possession so I would know the answers to the questions. I would read the answers to the true/false or multiple-choice questions to my students or ask the student whether they got true or false, without any justification. Historically, planning and implementing science education in public schools revolves around the use of textbooks and a lecture format (Lemke, 1990; Ornstein & Hunkins, 1998).

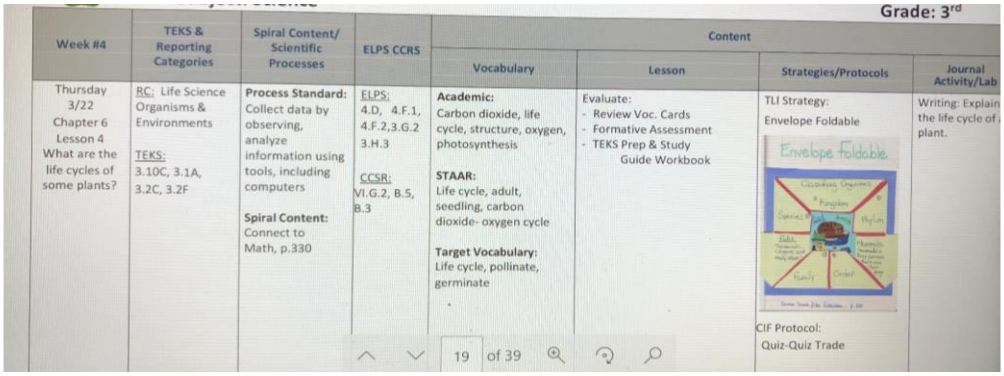
I remember using the teacher edition textbook and lesson plans as a source for instruction rather than teacher-guided experiences or student-centered investigations. It was a laminated poster that had the aligned state standards for third through fifth grade science and a huge binder of science worksheets. When I use the term worksheet, what I am really referring to is one that focuses on drills, such as pages or packets filled with the same questions over and over again that have a right or wrong answer, a one-size-fits-all approach. I was instructed to cross them off as the year progressed so it would be very clear to my students, any visitors, and myself exactly what was happening in my science classroom. In a weird, mechanistic way, it gave me a sense of accomplishment at the end of each lesson to cross off that related standard, confident that I was doing exactly what I was supposed to be doing.

This is a perfect example of the egg phase where teachers like myself lack awareness and live a life of unchallenged beliefs and ideals. This is the phase where teachers experience a standard-dominant model of education focused on a reductive and rigid approach to building knowledge, enforcing conformity of the mind and often dulling curiosity, because at its core, it is designed to reinforce the status quo of the day. In the egg phase of my life cycle, I was seeking approval from the status quo miles from an awakening that would lead to my development of a critical consciousness about how the school culture created linear thinkers not only for my students but also for me. This is nothing new, because the history of education over the past few hundred years shows that it was built from the beginning as a system to reinforce hierarchy, status, and obedience. On the contrary, teaching should be a dynamic process, not one that should be following a uniform path. Unfortunately, once teachers are in the classroom, their teaching is shaped by the demands of particular teaching contexts, the materials, and human resources available to them, educational reform efforts, and policy mandates from schools and states.

> In my first years of teaching, I was really afraid to deviate from a scripted curriculum and take risks. It was a scripted curriculum that consisted of busy sheets, consisting of filling in the blank with words or choosing from a multiple-choice question that had no educational value. (personal journal, November 2017).

During my first years teaching I was in the egg phase, the phase where I only focused on myself as I conformed to the status quo and lacked the experience of a wider understanding of how to teach science. I sat on my authoritative chair and implemented a scripted curriculum with a goal of improving students' standardized test scores. As an authoritative figure in my classroom, I told my students what to do and they followed my instructions. I knew that I needed to demonstrate I had classroom management skills and could control my classroom while delivering a scripted lesson. That is what the administrators were looking for during their classroom walk-throughs. It was standardized testing as the all-seeing tower, "visibility is a trap" (Foucault, 1977, p. 200). It was under this trap and pressure of high-stakes testing, that I adopted a more systematic, low-level, drill-and-kill building type of classroom pedagogy. It was a low-level system that consisted of endless copies and workbooks of state testing material that needed to be drilled over and over until skill mastery was at 100%, but teacher and student motivation was at 0%, crushing intellectual curiosity due to repetitively forcing students to complete the same task or skill after they have clearly demonstrated mastery or proficiency. My lessons were stale, students disengaged, I was bored and the drill and kill never seemed to end.

Table 2: District Lesson Plan



Grade: 3rd

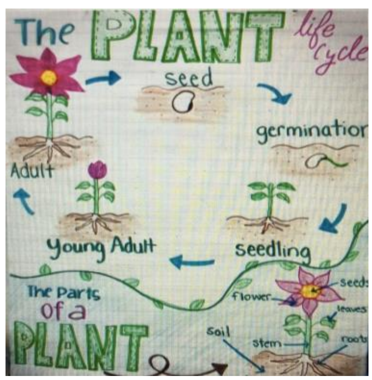
Week #4	TEKS & Reporting Categories	Spiral Content/ Scientific Processes	ELPS CCRS	Content: Vocabulary	Content: Lesson	Content: Strategies/Protocols	Content: Journal Activity/Lab
Thursday 3/22 Chapter 6 Lesson 4 What are the life cycles of some plants?	RC: Life Science Organisms & Environments TEKS: 3.10C, 3.1A, 3.2C, 3.2F	**Process Standard:** Collect data by observing, analyze information using tools, including computers **Spiral Content:** Connect to Math, p.330	ELPS: 4.D, 4.F.1, 4.F.2,3.G.2 3.H.3 CCSR: VI.G.2, B.5, B.3	**Academic:** Carbon dioxide, life cycle, structure, oxygen, photosynthesis **STAAR:** Life cycle, adult, seedling, carbon dioxide- oxygen cycle **Target Vocabulary:** Life cycle, pollinate, germinate	Evaluate: - Review Voc. Cards - Formative Assessment - TEKS Prep & Study Guide Workbook	TLI Strategy: Envelope Foldable Envelope Foldable CIF Protocol: Quiz-Quiz Trade	Writing: Explain the life cycle of a plant.

19 of 39

Table 3: 5E Lesson Plan

<table>
<tr><th>5-E Component</th><th>What Teacher Does</th><th>What Student Does</th></tr>
<tr><td>In theory, the engage is designed to get student interest and assess prior knowledge.

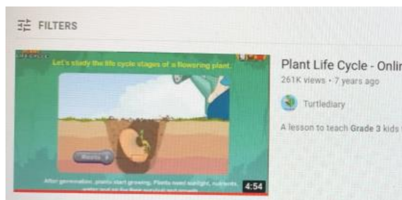
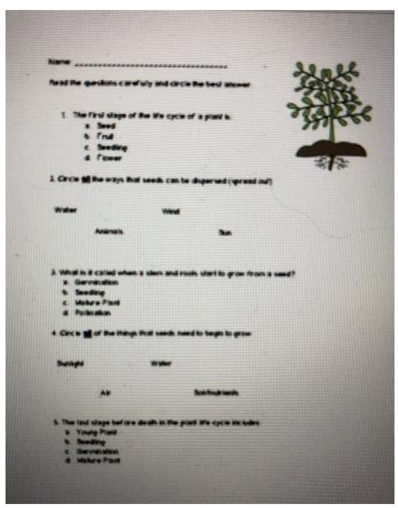
In my practice, the engage was: I tell them, I show them.</td><td>Show students the parts of a plant cycle diagram


</td><td>In theory, students ask how and why questions about the plant life cycle.

In practice, when asked students offer the right answer</td></tr>
<tr><td>Explore:
In theory, students are provided an opportunity to explore plant life cycle phenomena leading to self-discovery.

In my practice:
I give them, I demonstrate...</td><td>I drew a picture of the plant life cycle of a plant. (Draw a rudimentary life cycle of a plant- seed on top, arrow pointing to seed growing roots, arrow pointing to seed with roots and stem, arrow pointing to roots, stem and leaves, arrow pointing to roots, stem, leaves and flower or fruit and then arrow back to seed).</td><td>In theory, students are constructing their explanation of how plant life cycles work. In my practice, students recreate my foldable. This is passive involvement, working in isolation with little or no interaction, and stop as one solution. I'm reinforcing the plant life cycle as a linear process.</td></tr>
</table>

Table 3: Continued

Explain: In theory, students are explaining the phenomena they've just discovered. In my practice, I explain the phenomena	I would ask questions as they share the life cycles that they drew and show and repeat parts of the plant cycle.	In theory: Students explain the plant life cycle. In my practice students Proposes explanations from *thin air*, with no relationship to previous experiences Accepts explanations without justification
In theory: elaborate is an opportunity to deepen understanding of a concept or apply the concept in a different context. In my practice, I read about, and have the students watch a video on the phenomena		In theory, students make real world connections and deeper understanding of concepts. In my practice students, use only labels provided by teacher.
In theory, the evaluate is a summative assessment that demonstrates valid and reliable understanding of what a student has learned. In my practice, I evaluate students through multiple choice tests from textbooks or released STAAR exams.	 Name Read the questions carefully and circle the best answer 1. The first stage of the life cycle of a plant is: a. Seed b. Fruit c. Seedling d. Flower 2. Circle all the ways that seeds can be dispersed (spread out) Water Wind Animals Sun 3. What is it called when a stem and roots start to grow from a seed? a. Germination b. Seedling c. Mature Plant d. Pollination 4. Circle all of the things that seeds need to begin to grow Sunlight Water Air Soil/Nutrients 5. The last stage before death in the plant life cycle includes a. Young Plant b. Seedling c. Germination d. Mature Plant	In theory, students should be able to demonstrate an understanding In my practice students only offer only *yes* or *no* answers and memorized definitions or explanations as answers.

But why was I so compelled to adopt the status quo of a lifeless, drill and kill classroom pedagogy, if my own K-12 experiences were not that of the status quo? As an elementary student, I attended a math and science magnet elementary school where the majority of my learning was hands-on learning supported by engaging field trips. I clearly remember a fifth-grade field trip I took to the Houston Botanical Garden where we took a nature hike through the different habitats and made observations of how organisms survive in the environment, all my five senses were activated and engaged. Another memorable experience as a young science learner was a visit to the Planetarium in Corpus, as part of a field trip. I was so excited to use telescopes but also the computer application with the virtual sky, the interactive star map. I fell in love with science so much that I continued the math and science magnet program at the middle school level where I experienced authentic, problem-based science learning. I remember our eighth grade STEM project that consisted of designing boats. We had to create a boat that would move across water under its own power, and it had to be made of recycled gallons containers and cardboard. We were given about a month to work on our boats as a team, then we participated in the Boat Regatta at the nearby pool to see which watercraft could make it to the other side of the swimming pool without sinking first. All the students were engaged and having a great time learning, little did we know we were already learning engineering and physics concepts.

It was not until high school and college level that I started to experience authoritative learning where it became less hands on and more workbook and rote driven. Then, it was through my student teaching experience that really molded me and compelled me to adopt the status quo due to its heavy focus on state testing and investing their energy and money on state tests and tutorials. Student teaching was supposed to be a critical time to learn and become an authentic confident teacher, gaining a strong teacher agency but the heavy emphasis on drill and kill inhibited me from taking an authentic approach to learning and fell into compliance mode. I remember even feeling threatened that we may lose our position or job if test scores were not raised. Administration would take away our science, writing, and social studies time and even our physical education (P.E.) and music time to provide more math and reading State of Texas Assessment of

Academic Readiness (STAAR) tested instruction. These expectations were made very clear from administration during our grade level meetings. The level of anxiety and stress was higher and higher with each passing year. This pressure, fear, and miserable drill-and-kill curriculum of robotic "teaching to the test" is what kept my identity in the egg phase for the beginning years of my teaching career that consisted of a prepackaged curriculum as opposed to real world authentic learning.

> I could literally feel the energy leave the room, as there was no pulse left during worksheet lessons. My classroom is like a prison where I am taught how to think, how to teach, and how to function within a rigid, tested based, bell-ridden system.
>
> (personal journal, November 2017)

I remained in the egg phase, the first years of teaching, falling victim to the epidemic of classroom boredom, another year in the same blue chair, same wooden desks in rows, same pressure and same expectations. As we see, from the start of public education, students are taught to follow established rules (Dewey, 1956; Frèire, 2001) but I could not continue to connect with what was being put in front me to what was going on within me. I would catch myself saying everyday "pay attention, the test is a month away, if you don't pass, you'll stay in third grade again." It felt dehumanizing, but it was part of the school culture. A culture that consisted of labeling students as a colored score on a data wall. The infamous "data wall war room" where the walls were plastered with graphs and charts showing colleagues names alongside kids' scores. Every time that we had a grade level meeting, or that I warmed up my lunch, or that I was just taking a moment for myself, I was surrounded by data posters. This sacred space communicated how heavily valued standardized data were. Those students who passed got rewarded with a party that consisted of treats and games, and those who did not meet criteria would stay in the classroom as a punishment reviewing the test, but even the students who passed were trapped by being caught up on a treadmill of achievement that they must stay on at all costs throughout the year. It created a culture where the intelligence and abilities of my students were based on a multiple-choice test and a number two pencil. Drill and Kill and boredom had become the elephant in the classroom. There it was, a very large elephant standing in the corner of my classroom. The elephant or the common idea that teaching to the test was the only way to teach.

Hence, my science teacher agency remained static during my first years of teaching. I believe this is, in part, due to my district not providing enough opportunities for professional development that focused on authentic science teaching. My science professional development consisted of lecture-based workshops that handed out spiraling TEKS worksheets, calendars, and end of year voting for the next best science textbook that covered the majority of the Science TEKS that were going to be tested in fifth grade. My authoritative figure impeded rather than supported because I too was treated as a passive learner as opposed to time being spent on teacher collaboration, feedback and reflection as we would analyze student work and model new strategies in real time with each other and even participate in the hands-on labs or authentic based projects that were designing for our students. The workbooks and worksheets were no longer working for me anymore. The feeling of dissonance was causing a great deal of tension on a personal and professional level. I wanted more out of my science class. I had not been ready until now to really take a risk and change the way I taught science, the way I caused learning in science. I needed to take a risk in my pedagogy, to be pedagogically courageous. I then began the larva phase, where I began molting and shedding and outgrowing the traditional practices and exploring my science teacher identity. I began to grow in my questioning, reflection, and understanding of authentic science practices. I broke down and started creating a newer and better version of myself. And at each step, the transformation was active, messy, intentional, and personal.

Larval Stage: Exploring My Identity and Taking Risks

Figure 13: The Image of the Larva from the Butterfly Vycle

Marginalized…

Life on the edge…

Neither leader nor follower…

Caught in the middle…

Where do I pedagogically go from here?

(personal journal, March 2018).

In the larva phase I grow by molting or shedding the traditional practices that I have outgrown. I began to grow in my questioning, reflection, and understanding of authentic science practices. I broke down and started creating a newer and better version of teacher self. And at each step, the transformation was active, messy, intentional, and personal. I unpack this part of my transformation in the following paragraphs.

Now begins the larva phase where I begin searching and exploring my identity, the classroom and school culture. The process of hatching from the egg trying to change my teaching to match my real beliefs about how to teach science was not an easy journey. I spent the first five years of my teaching career with constant doubts and wondering if I was a good science teacher. I knew my students liked me and enjoyed being in my class, but I always felt that I could be more challenging and engaging with my students, especially in science class. I knew I was a good teacher, but nonetheless, a teacher who had forgotten what authentic science teaching could look like as I had experienced in my elementary childhood. Unfortunately, we forget, because most science curriculum found in U.S. public education systems are designed in a linear fashion, despite sometimes referring to higher levels of Bloom's Taxonomy (Bloom, 1956) in the objectives, is at the competence level of describing, explaining, and demonstrating. This leads to rather stilted forms of didactic teaching, the ubiquitous slide show, and creates a passive learner. All of which is unnatural, and we wonder why learners have problems in motivation and learning. This is reflected in the e curricula and adherence to training young people reinforce their social position in the workforce can be seen in the assessment systems that have been adopted. As a consequence, this has resulted in an education system which is fixated on the forms of knowledge which are testable, the type of curricula which are produced to accomplish this and the performance of the teacher or school in achieving good test scores. This provides a top-down accountability system which only requires teachers to be *successful* at replicating someone else's curriculum. In the same way that knowledge has been detached from mind, the curriculum has been separated from those that teach it. This technical rational model of pedagogy has been described by Alexander (2008) as teaching divested of the relationship between the classroom and the wider world.

> I knew I was a good teacher, but nonetheless, a teacher who had forgotten what authentic science teaching could look like. (personal journal, September 24, 2018).

Just as the larva began using its muscles to eat, I used my reflexive muscles to question. I began to question the authenticity of the scientific method used during science fairs and the structure of the district's lesson plans that were quite linear with a fixed time allocated for each topic, followed by a period of dense and rushed revision for the STAAR (State of Texas Assessment of Academic Readiness). In my first years of teaching, I forgot to teach the science standards without teaching in a standardized way. I soon came to realize that memorization of facts and figures could not shape future leaders as problem solvers or critical thinkers. My classroom could not continue with the same commercial wall posters, conformity, and structure, I had to become a disruptor. My first years of teaching I was forced into a box of what made a good teacher. Most of what I did was scripted by other people and felt like I was a puppet or voice for ideas that were not my own and was convinced by my administration that what I was doing was best for kids. The education system didn't want innovation, it wanted compliance from my students and from me.

I then began to remember and reflect that as a child I naturally developed science skills through observing, classifying, reasoning, and predicting and that the common mistake I was committing in my classroom was to only provide facts or a quick answer to a child’s curiosity and exploration as opposed to authentic experiences. Whatever happened to that type of innovative and engaging instruction that nurtured my natural curiosity and love of learning new things as a young child? Instead, my classroom was resembling worksheet factories with children laboring at their desks. Frèire (2001) makes similar observations about that type of pedagogy. These classroom arrangements underscore behavioral patterns that people are expected to follow throughout their lives: walk in a straight line, focus on work, and isolation in a cubicle. The truth is most of my classroom worksheets were boring, repetitive, and included a rather shallow level of information, and in fact were a very poor method of instruction, not augmented by "real world" lessons that foster thinking and problem-solving. I started kindergarten when I was 4 years old and I was very fortunate indeed to have a wonderful teacher who read stories, presented science in the form of child-friendly "learned by doing" natural experiments and a genuine enthusiasm for nurturing our natural curiosity. We never did any worksheets and "homework" consisted of plenty of free time and fresh air and an occasional assignment to collect leaves, rocks, different fabrics or photos to bring to class to discuss. I can honestly say that this "right start" fostered a love of learning that in no way diminished in me even to this day. But if we were to walk into a kindergarten class today, we would be expected to sit at a desk and start filling in endless and monotonous worksheets. My kindergarten class didn't even have desks. We sat on the floor on a rug when the teacher read stories, but most of the time was spent moving about the classroom to various learning stations she had thoughtfully constructed. Although there is still some of that kind of teaching available today, sadly in most schools there is a primary emphasis on filling out worksheets. How is it possible that our elementary students are spending less time outside, and not taking field trips to any science museums, or not being able to garden or design experiments about sunlight and plant growth or even diagram a leaf? Their reference for the world, and their relationship to it, is being severely limited, but teachers and school administrators are worried instead about how well they can pass a multiple-choice test.

> I have this tiny persistent voice inside my head that will sometimes whisper "But what are they really learning? Isn't this a glorified science fair? Is this work really

authentic? Being a good science teacher must mean thinking differently and challenging the traditional approaches to education. (personal journal, October 14, 2018).

The larva continues to devour its food with a great appetite, just like my appetite grew for more knowledge in the understanding that it's not a rigid set of steps that really defines what a scientist does. Therefore, science fairs should provide students with an opportunity to investigate interesting questions, work independently, and engage in authentic science experiences. But despite science fair being an extremely hands-on project, I overlooked it and replaced it with increased standardized testing and textbook learning the first years of my teaching. Unfortunately, in my first years of teaching, I provided less support, more textbook material, basic science fair projects where I did not utilize this opportunity to research a topic of interest to them, but instead was viewed as a burden, where they were required to execute projects strictly using the scientific method. On the contrary, students should be given the chance to do real research, to experience framing a question, deciding what kind of evidence is relevant and figuring out how to collect it, and experience a trial-and-error productive struggle. The classroom then becomes a construction zone, probably the loudest and messiest of the school, but loud and messy for the right reasons. Students would be thinking and learning in a controlled intellectual chaos classroom.

The larva first shedding began when I started to challenge textbook science and science fair. Rather than having students memorize definitions and facts about a science topic such as light, as an effective authentic teacher I now had students investigate various types of objects under sunlight and flashlight. Students would collect evidence to understand how light helps them see, and they'd experiment with different materials to understand how and why shadows are made.

Carl Sagan (Psychology Today, 1996) was right when he said: "Every kid starts out as a natural-born scientist…". But when they spend time in a public school education that focuses on state testing, it becomes clear that the second part of Sagan's quote is also correct: "...then we beat it out of them." Our students are curious and natural born scientists by nature. As I began challenging the traditional approaches to science education, I began teaching science in a way that used relevant everyday events as a basis of science instruction that fostered interest, curiosity, critical thinking, and problem solving. For example, it had rained one day and I posed the following question: How did the water puddle disappear over time? During our investigation the students used thermometers to measure the temperature of a water puddle outside at different times of the day. They used the data to make connections between temperature changes and the shrinking size of the puddle and delve into the reasoning behind it. I started involving students in scientific practices and used an everyday occurrence to teach key scientific concepts such as sunlight, energy and energy transfer.

> I also hated science fairs: Hypothesis ✓ Materials ✓ Procedure ✓ Data✓ Table ✓
>
> I hated it! But I had to do it because it was campus and district mandated.
>
> (personal journal, November 15, 2018.

My second shedding began when I realized that the purpose of science fair was not to give students a chance to do real science but to reinforce the scientific method as the way to reduce science to a linear process with a predetermined outcome. Students should not have to wait until college, or even until after college to do real science, it should start in early childhood.

But I hated it! I had to do it because it was campus and district mandated. I really struggled with this feeling of hating science fairs and of being different for many years. But I could no longer hide my differences. The more I began to change my approach to science teaching, the more I was inspired to take risks. I wanted to see and hear more science talk. It was this constant wondering and doubts that pushed me to keep inventing and reinventing who I am and who I want to be in the science classroom. I welcomed these doubts more, not as that tiny voice critiquing my teaching, but as that tiny voice reminding me that there was a better way to teach science, connect to the real world, and a better way to conduct science fair.

What better way to connect to real world issues than having an autistic student being guided and motivated by his own struggles, channeling his own research into helping children affected by autism just like him. We devoted this third-grade science project to finding out the effectiveness of Brain Gym Activity on autism children's academic learning. His hypothesis for the project was that there would be a significant difference in effectiveness of Brain Gym Activity on children with autism. According to his project findings, Brain Gym had a positive effect on all behavior variables and the results of his study was used to provide information for administrators, educators, and parents who are seeking additional effective classroom holistic approaches in helping students with autism improve in restlessness, fidgety, temper tantrum and inattentive behaviors and academic learning. That project earned him the Science Fair Grand Champion title and became a pivotal point for my career to integrate science fair as part of my authentic science curriculum and aid in the construction of my science teacher identity as an authentic teacher.

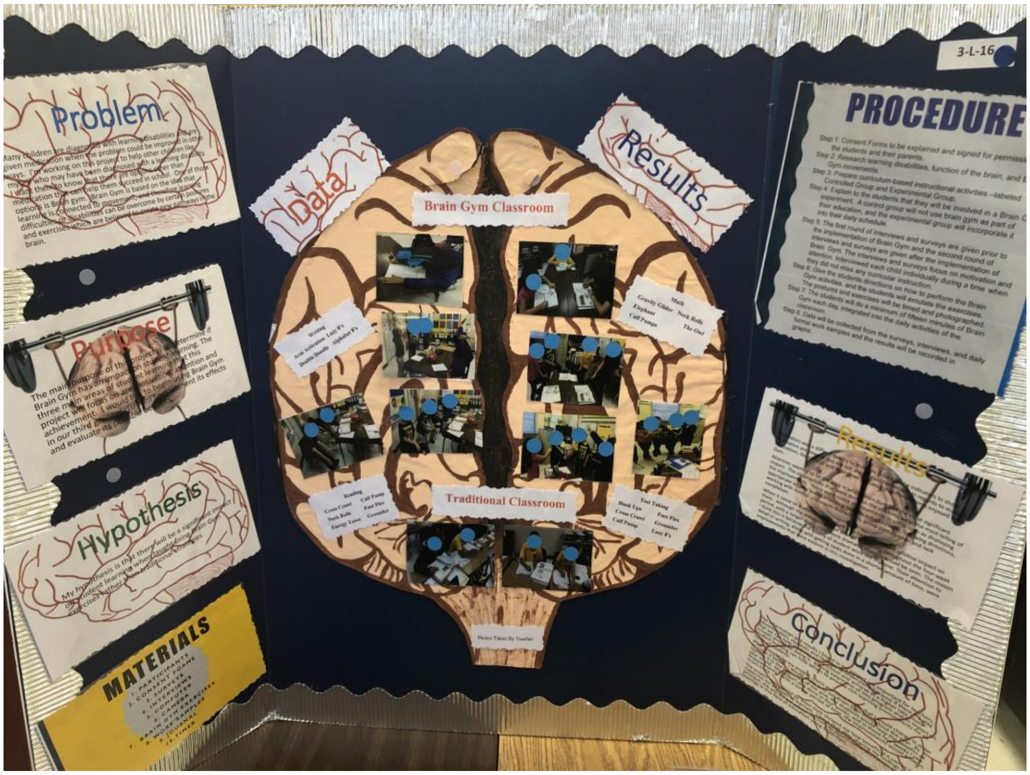


Figure 14: Student Science Fair Project on Brain Gym Exercises

> I try to engage my students with experimentation and investigations, and I try to connect the content with everyday life, to illustrate how scientific concepts apply to our everyday lives. (personal journal, December 10, 2018).

The third shedding began when I realized that young children's daily realities are fertile ground for helping them observe and understand the world around them. For example, investigating community floods in and creating their own sandbag to prevent flooding or investigating ways to produce clean water through biofiltration for poorer communities.

Pupa Stage: Building Teacher Agency through Rebellious Moments

Figure 15: The Image of the Pupa from the Butterfly Cycle

Rebellion

Rise my dear teachers,

Stand up and fight.

Not for yourself,

But for what makes things right.

(personal journal, November 2019)

The pupa phase is characterized by the undergoing transformation between immature and mature stages, reconstructing my science teacher identity**.** Now the vessel begins to break free as it transforms within. Inside this vessel is where experiences took place that led to students making a connection between real life and learning on our campus. I incorporated garden boxes, butterfly habitats, bird feeder and biofiltration projects.

As soon as the larva is done growing and has reached its full length and weight, they form themselves into a pupa, also known as a chrysalis. From the outside of the pupa, it looks as if the larva may just be resting, but inside of the pupa, the larva is rapidly changing. Within the chrysalis the larva is undergoing a remarkable transformation, called metamorphosis. The chrysalis holds the key to how we can define transformation. So, let's focus on the chrysalis because what happens inside is absolutely mind-blowing. A larva makes her chrysalis from the inside out. To prepare, she anchors herself to a home — usually a twig. She then *bursts* her head open to shed her skin. The underlying layer is the chrysalis. The chrysalis protects her and changes color to camouflage with the outside world, with the hope that no one even notices what's about to happen. When larvae break down, they know how to create new, better, versions of themselves. This new version began the internal changes, identity change, and openness to new and differing perspectives and at each step, the transformation was active, messy, intentional, and personal.

> I know what good, authentic science should look like. I know what my students need. There comes a time when you just have to be willing to shut the door, be courageous, dig deep, push boundaries and make science thinkable and doable. My students deserve that. All students deserve that. (personal journal, February, 2020).

By May of each year my journal entries were becoming increasingly daunting and pessimistic. There was tension between my vision and the vision of the district when it came to how and what to teach in science. I felt that my instructional practices were facilitated and supported by two different sources: the district and that of my doctoral science courses—the district scripted curriculum constrained my instruction, school-wide focus on high-stakes assessments. My instructional practices showed far too much time spent on nonlinear content driven sprints instead of process-oriented marathons. I made a promise to myself and to my students that our science learning was going to shift from traditional linear ways to authentic science, and it all began with garden boxes.

Thus began my very first authentic project, the butterfly garden box project, where my classroom planted a small garden to create a butterfly habitat that would allow my students to observe and investigate the butterfly life cycle. Through this project the students would be able to identify the ways in which an organism's habitat provides for its basic needs (plants require air, water, nutrients, and light; animals require food, water, air, and shelter) and recognize that plants and animals have life cycles, and that life cycles vary for different living things. In my first years of teaching, my lesson only consisted of reading The Very Hungry Caterpillar and having them watch a video on the butterfly cycle and draw and label the cycle. This particular year the students were engaged in a class discussion about the foods the caterpillar eats followed by a student-generated list of plants/flowers that might be attractive to real larva and butterflies. The students and parents then helped donate for the garden and explained that they will be planting a butterfly garden. Then they helped me plant the small garden box, and over the year, students were given time to tend the garden and record their observations about larva and butterflies.

Figure 16: Students working on their Garden Box

I used to start the school year with a discussion of the scientific method. It pretty much had to be beaten into their brains every October for science fair. But as the years went by, I questioned the scientific method more as I realized that in reality my students actually had a very shallow understanding and still many misconceptions about the scientific method (Keyes 2010). The scientific process is not linear, it is quite messy and complex and involves changing ideas, revision, creativity, and collaboration. As I walked the aisles of the school cafeteria filled with cardboard tri-fold displays of information that students may have copied off the internet or with prototypes or models that their parents or teachers designed, financed and constructed. I clearly remember thinking that this was all a show where children pretend that they are doing science. I felt like the students were participating on the TV show American Idol, and whoever could memorize and sing the scientific method the best, would win the grand prize. It was all a show that consisted of dramatic presentations while the thinking, the questioning, the process of discovery were sidelined, followed by a right or wrong thinking process.

But the main motive of a science fair should be for students to ask a question about something they wonder about, and to explore ways to discover some new understanding about that question. But, instead, because they are competitions, because they are judged seemingly on objective performance criteria, the entire focus is on outcomes instead of processes. On the contrary, science fairs should provide students with an opportunity to investigate interesting questions, work independently, and engage in what we think of as authentic science experiences that are critical for engaging students in STEM and potentially inspiring them to pursue STEM careers down the road.

> Oh no, we were wrong," they exclaimed as they lowered their faces down with disappointment as their hypothesis was incorrect in their science fair project. I

> could tell by their sad faces that their learning thinking process was over and it was the end of the world. It hit me hard that they had been carrying the image of science as the end game of "facts" and "right or wrong answers" rather than an exploratory scientific process. (personal journal, April 2020).

Why is this happening if young children are full of questions, spawned by true curiosity rather than a desire to impress? Why are they taught that being wrong is like being incompetent? Students need to learn that science has flexibility and is not a rigid, one-way simplistic approaches. In science, it is okay to be wrong. We need to think like a scientist in recognizing that we will occasionally (or more than occasionally) be wrong and knowing how to find out why. Science is a journey, and part of that journey is making errors and being empowered to find out more authentic solutions to real world investigations. Every child has the capacity and propensity to observe, explore, and discover the world around them (NRC, 2012). Early in their science education, students need opportunities to observe phenomena, engage in problem solving, and provide explanations of their thinking (NSTA, 2018). Hence, began my classroom journey on authentic science fair projects with real world impact that led our school to national recognition. Now the project selection phase of my classroom science fair projects became a crucial step in the process. I wanted each student to care and be passionate about their topic and it be connected to a real-world issue. I wanted their research question to include social issues and global concerns that would broaden her students' understanding and awareness of the world around them. Rather than simply completing a project to fulfill an assignment, I wanted my students to emerge with a broader view of the importance of their research—and of the value of STEM in the world beyond the classroom. For example, I had a couple of students who were intrigued with our campus flooding and irrigation system and decided to guide their interest and curiosity, on a hands-on project that allowed them to investigate different filtering methods for removing pollutants from water. They worked in a team, where they designed and built and tested their own water filtration system. Their project had an engineering connection in which environmental engineers worked together to make existing water treatment systems better, and to develop new water treatment systems. Some engineers design state-of-the-art seawater treatment system technologies that process ocean water cost-effectively for safe domestic use. Their science fair project led them to a Grand Champion title where they were able to explore what types of pollutants are removed from water by filtration, design, build and test a water filtration system, and explain the role of engineers in water treatment systems.

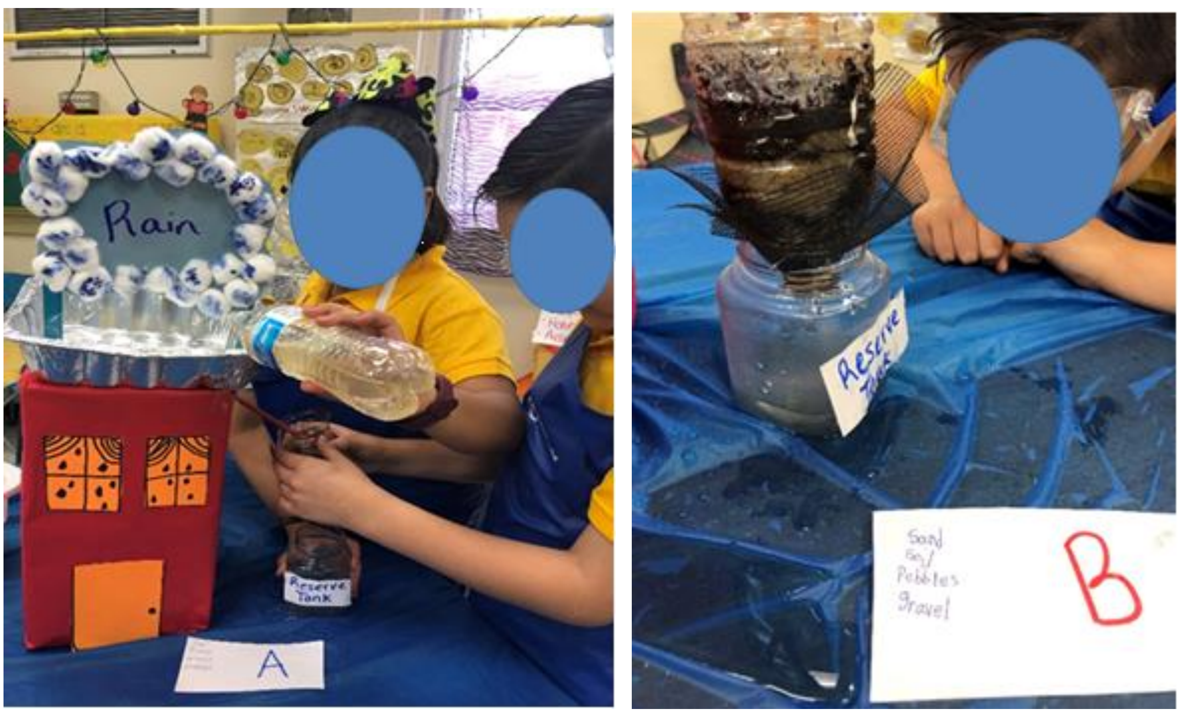


Figure 17: Students working on their Biofiltration Project

Fast forward twelve years, I have come to realize that science is meant to be messy and nonlinear. Before evolving into an authentic science teacher, I had to be apologetic for my classroom chaos, now it is a friendly reminder that students need a space in which they feel comfortable to be themselves in order to develop into the problem solvers, experts, and researchers I know they can be. But with a loud, hands-on classroom, authentic science fair projects being conducted and integration of the garden box, came skepticism from my colleagues about the validity of my science teaching methods. During the first few years of my evolving into an authentic science teacher, I wanted to involve everyone so that they would be excited and find it as interesting and transformative as I did. When that did not happen, I felt rejected by my fellow teachers and unsupported in my efforts. Then it started happening, my students started blooming as scientific thinkers and problem solvers, and winning science fair champion titles year after year from their unique, authentic science fair projects, and performing exceptionally well in fifth grade STAAR assessments. It was then that my colleagues and my administrators started seeking me out to tell me how amazed they were at my students' work and accomplishments and wanted to be part of the authentic scientific teaching wave.

Adult Stage: The Butterfly Shapes the Ecosystem

Figure 18: The Image of the Butterfly from the Butterfly Cycle

I embraced change and came out of my cocoon,

shedding the old, traditional ways.

Breaking free from confinement, stretching my wings

the warmth of growth, spiral, spiral, unwind,

OUT I FLEW!!! (personal journal, April 2021)

As I became an adult butterfly, I was able to explore and take risks in my classroom and help school because I had already identified my strongest beliefs as to what an authentic science classroom community should look like, feel like, and sound like, for myself, my students, and our campus.

Butterflies play a vital role in the ecosystem. They are also called the wild indicators of an ecosystem because they can provide a picture regarding the health of an ecosystem at any particular time. They are sensitive to environmental threats such as habitat destruction and climate change. Due to their sensitivity to the changes in their natural habitat, researchers use butterflies to monitor and observe habitat fragmentation and climate change. Therefore, the more I unpack and dissect what constitutes good science education and effective learning, the more I come to understand that science education becomes more like an ecosystem. As science teachers we have the ability to control or influence parts of this ecosystem. Just like the butterfly, we have the ability to pollinate plants (students and teachers), keep organisms in check (administration), and be part of the food cycle (school). Therefore, the butterfly stage is characterized by transformation and paradigm shift, newly defined sense of self, critical consciousness, and science teacher identity.

> I hope to be a teacher that has an impact on my students, and teaches them to observe, predict, question, and question the world around them, which I have learned, is a wonderful way to introduce elementary students to science," (personal journal, April 2021).

Out emerges the butterfly and takes flight into the world where its goal is to cultivate a classroom of young inquirers where the teacher becomes a co-explorer and guide who cultivates curiosity and challenges students to think and act like scientists as they explore intriguing questions. Students have time and opportunities to explore, experiment, test and refine ideas as they collaboratively build understanding. But it took time, practice, and a paradigm shift in teaching authentic science.

> Projects have gotten more authentic and sophisticated as our students are doing projects around a problem that affects their lives or community." (personal journal, October 2020)

It was another busy day in October, science fair month, and the butterfly moved from classroom to classroom, transferring knowledge in a non-traditional, highly supportive, authentic inquiry-based teaching way, showing teachers how to create plans and projects to lead students in exciting research, experimentation, and discovery. Unlike other years, where students were given due dates and creating traditional exploding volcanoes or foam-painted solar systems s that were completed at the last minute, this year all teachers were on board aiming to link real-world issues with in-classroom effort to their student's science fair project, showcasing student-led inquiry, experimentation and learning to align with new science standards.

Now, our science fair projects consist of authentic learning that is designed around open-ended questions without clear right or wrong answers, or around complex problems with many possible solutions that could be investigated using a wide variety of methods. In contrast, in previous years, we taught the scientific method by having students read about the concept in a textbook, memorize the prescribed process, take a multiple-choice test to determine how well they remember it and come up with a copied science fair project. Our science fair school climate has transformed into authentic learning that is intended to encourage students to think more deeply, raise hard questions, consider multiple forms of evidence, investigate contradictions, and navigate difficult problems and situations that are related to the real world. Researchers have even examined how participation in environmental projects impacts students' agency (Dimick, 2012).

For example, our fifth grade science class was learning water conservation, and they began to conduct an analysis of the school's water usage, investigating potential ways the school might reduce its usage, and then presented a water-conservation proposal to administration that included a variety of recommendations; for example posting signs in bathrooms encouraging students not to leave water running, installing low-flow faucets with automatic on-off sensors, using rain and planting drought-resistant plants in the schoolyard that are watered using the collected rainwater.

Social media also became an essential tool for professional growth, curriculum planning, and student engagement. Today's young generation is increasing in using social media for various purposes, to communicate with their peers and others as part of a global community, therefore there is a necessity for educational institutions to use such social media platforms to connect with these students and to eradicate the barriers of the traditional classrooms. Let's think about the qualities of an effective 21st century science teacher. It is definitely someone who is highly adaptable, constantly inspired, and strongly connected with both students and fellow educators on social media platforms to build personal learning networks, share ideas, and discover best science practices. For example, I used and encouraged our science teachers on campus to use Facebook and Instagram in a variety of ways to enhance authentic science learning. I teamed up with our fourth and fifth grade science teachers to utilize Facebook and Instagram as a means to implement and showcase our authentic science lessons and projects. We began to explore the possibility of creating science lessons uploaded to Facebook and Instagram that students could watch and do at home during remote learning, upload authentic science lessons and projects that other teachers in the district could implement, and showcase a lot of in action photos of our students engaged and enjoying STEM activities. It has also helped us build large and diverse personal learning networks to find like-minded science educators and groups to connect with.

Figure 19a: Student Projects on Social Media

Figure 19b: Student Projects on Social Media

As the old African proverb says, *it takes a village to raise a child*. I strongly believe the answer to real authentic science education is based on creating school and community partnerships that will assist teachers in creating genuine scenarios and provide students with true real world and authentic learning experiences. Authentic learning experiences are those developed to align better with the way learning is achieved in real-world environments (Herrington et al. 2014). So how then did the butterfly help create these authentic learning partnerships? Well, butterflies at all stages are a food source for other animals in the food chain, just as the science teacher is a source of knowledge for the rest of the school and community. To prepare students for the real world, the butterfly started modeling authentic learning experiences and the rest of the school reciprocated and joined in on the fun.

For example, our school now reaches out to the community for funding for authentic science learning projects. Our school, like most, used to place a high priority on the reading and math curriculum but less emphasis on the science curriculum and especially the hands-on lab activities that all science classes need to have. We now want our students to truly go through the scientific process to observe, ask questions, touch, smell, and experiment. We want them to truly understand the difference between physical and chemical changes, understand the components of electricity and weather, and discover how the world really works. We want to give our students the chance to make discoveries on their own but in order to do that we need the basic equipment to get started. So, we now reach out to DonorsChoose, which is an online marketplace where teachers and the community connect to give students the resources they need to learn. We request funds for student authentic projects, trips, supplies, visitors, technology and more. We want our students to step into the classroom and feel like actual scientists because they are using genuine equipment to understand the world around us.

Figure 20: Student Projects Funded by DonorsChoose

I saw firsthand how the ripple effects of changes to teaching and learning at the classroom level catalyzed unexpected and important changes at our school. I strongly believe that science can be cognitively curious. That is, a balanced combination of wonder and curiosity with rigorous critical thought. As science teachers, we have a crucial responsibility to develop our students' ability to think scientifically about problems, both in their immediate lives and in the wider world. In my view, children are already born with all the traits of a good scientist: They are curious, eager to investigate their surroundings, and happy to experiment. But too many students enter elementary school classrooms that extinguish that passion with lessons that are disconnected from their lives and the natural world around them.

Science teachers are amid an exciting and challenging paradigm shift and are considered to be the front liners who are responsible to transmit knowledge. Science education taught in elementary schools must be able to reflect science in the real world, involving real life examples and hands-on learning that will foster a deeper understanding of any scientific concepts taught. Teachers now must be able to acknowledge that they are not only instructors but also facilitators of learning. Teachers must always think of ways to promote creativity, critical thinking, collaboration, and communication into the classroom. Teachers must be able to create an environment where students learn how to be adaptable, analytical, and resourceful in order to succeed in a global environment.

> I see myself as an agent of change. Given enormous pressures brought on by state testing, it is with greater need that the value of science education is advocated. I recall that much of my teaching hours were dedicated to mathematics and language arts, subjects in which the students faced standardized tests. (personal journal, May 2021.)

Through a messy, nonlinear process I describe the codes and themes that emerged through this reflexive journey. The major themes that emerged from analysis of my journals and curriculum were level of critical consciousness, status quo and neoliberalism, power structures, ways of scientific thinking and learning, ways of teaching, teacher agency, student agency, community science, and science and social media networking.

Level of Critical Consciousness

Critical consciousness or *conscientization* is the process of developing awareness of one's own experiences and others through reflection and action and contextualization within social, political, and historical practices that have led to oppression, marginalization, and disenfranchisement (Freire, 1970).

During the egg phase (my first years of teaching), my level of critical consciousness was nonexistent. Not only did I lack an awareness of the way I was teaching was not best for my students, but I also didn't question the established norms such as drill and kill worksheets, nor did I question the negative effect it was having on my students.

> This pressure, fear, and miserable drill-and-kill curriculum of robotic "teaching to the test" is what kept my identity in the egg phase for the beginning years of my teaching career that consisted of a prepackaged curriculum as opposed to real world authentic learning.

> I remained in the egg phase, the first years of teaching, falling victim to the epidemic of classroom boredom, another year in the same blue chair, same wooden desks in rows, same pressure, and same expectations.

During the larva phase my critical consciousness was in its infancy, However, I observed the lack of engagement and disinterest my students expressed toward science as it was mostly textbooks and worksheets. This prompted me to question and challenge the traditional approaches to science education. For example, an awakening began when I realized that the purpose of science fair was not to give students a chance to do real science but to reinforce the scientific method as the way to do science as a linear process with a predetermined outcome.

I soon came to realize that memorization of facts and figures could not shape future leaders as problem solvers or critical thinkers. I have this tiny persistent voice inside my head that will sometimes whisper "But what are they really learning? Isn't this a glorified science fair? Is this work authentic? Being a good science teacher must mean thinking differently and challenging the traditional approaches to education.

During the pupa phase my level of critical consciousness continued to grow, as a result my science teacher identity was being reconstructed shown from my reflexive analysis:

> There comes a time when you just have to be willing to shut the door, be courageous, dig deep, push boundaries, and make science thinkable and doable. My students deserve that. All students deserve that. The scientific process is not linear, it is quite messy and complex and involves changing ideas, revision, creativity, and collaboration.
>
> On the contrary, science fairs should provide students with an opportunity to investigate interesting questions, work independently, and engage in what we think of as authentic science experiences that are critical for engaging students in STEM and potentially inspiring them to pursue STEM careers down the road.
>
> Inside this vessel is where experiences took place that led to students making a connection between real life and learning on our campus.
>
> Science is a journey, and part of that journey is making errors and being empowered to find out more authentic solutions to real world investigations.

During the butterfly phase, the new heights of my critical consciousness were reflected by a paradigm shift, a defined sense of self, and a reconstructed science teacher identity:

> I strongly believe the answer to real authentic science education is based on creating school and community partnerships that will assist teachers in creating genuine scenarios and provide students with true real world and authentic learning experiences.

I strongly believe that science can be described as critical curiosity. That is, a balanced combination of wonder and curiosity with rigorous critical thought.

Science education taught in elementary schools must be able to reflect science in the real world, involving real life examples and hands-on learning that will foster a deeper understanding of any scientific concepts taught.

Status Quo/Neoliberalism

During the egg phase, I conformed to the status quo that emphasized high stakes testing and accountability over authentic learning. This was reinforced by my administration and the professional development workshops I attended:

I was given a textbook and a day-by-day lesson plan.

I was given pages and packets filled with the same questions over and over again that have a right or wrong answer, a one-size-fits-all approach.

I was instructed to cross off the drill and kill skill as the year progressed so it would be very clear to my students, any visitors, and myself exactly what was happening in my science classroom.

It was a scripted curriculum that consisted of busy sheets, consisting of filling in the blank with words or choosing from a multiple-choice question that had no educational value.

Every time that we had a grade level meeting, or that I warmed up my lunch, or that I was just taking a moment for myself, I was surrounded by data posters.

During the larvae phase, my critical consciousness was making me question the linear, top-down accountability system which only required teachers to be successful at replicating someone else's curriculum:

> A reflection of these curricula and adherence to training young people as a workforce can be seen in the assessment systems that have been adopted as an economic good where each assessment consists of pre-packaged tests, on how each student is treated, assessed, and ranked just for high profits.
>
> This provides a top-down accountability system which only requires teachers to be *successful* at replicating someone else's curriculum
>
> These classroom arrangements underscore behavioral patterns that people are expected to follow throughout their lives: walk in a straight line, focus on work, and work in isolation in a cubicle.

During the pupa phase**,** the continuation of the transformation of my critical consciousness made me aware of the harsh reality that science was viewed as the end game of "facts" and "right or wrong answers" rather than the exploratory scientific process:

> I felt like the students were participating on the TV show American Idol, and whoever could memorize and sing the scientific method the best, would win the grand prize.
>
> It was all a show that consisted of dramatic presentations while the thinking, the questioning, the process of discovery were sidelined, followed by a right or wrong thinking process.

> But, instead, because they are competitions, because they are judged seemingly on objective performance criteria, the focus is on outcomes instead of processes.

> It hit me hard that they had been carrying the image of science as the end game of "facts" and "right or wrong answers" rather than the exploratory scientific process.

During the adult phase, my critical consciousness now led me to reevaluate the way science and the scientific method were taught.

> In contrast, in previous years, we taught the scientific method by having students read about the concept in a textbook, memorize the prescribed process, take a multiple-choice test to determine how well they remember it and come up with a copied science fair project.

Power Structures

During the egg phase**,** I was reinforcing the dominant power structures built by colonizing and Western ideologies. My students were taught to follow instructions and not question authority and school based power structures were driving my daily teaching decision making, which affected my students.

> I was expected to teach a curriculum aligned to the standards.

> I remember even feeling threatened that we may lose our position or job if test scores were not raised.

> I would catch myself saying everyday "pay attention" "the test is a month away" "if you don't pass, you'll stay in third grade again."

> Administration would take away our science, writing, and social studies time and even our physical education (P.E.) and music time to provide more math and

reading State of Texas Assessment of Academic Readiness (STAAR) tested instruction.

> It felt dehumanizing, but it was part of the school culture.

During the larvae phase, I began to question the dominant power structures over our teaching and assessment systems, that are designed to reinforce lower-level learning and thinking. A way to further the power structures that were created by white supremacy and colonizing ideologies. I became aware that the district and school-based power structures were driving my daily teaching into compliance and lack of innovation.

> Most of what I did was scripted by other people and felt like I was a puppet or voice for ideas that were not my own and was convinced by my administration that what I was doing was best for kids.

> The education system didn't want innovation, it wanted compliance from my students and from me.

> Their reference for the world, and their relationship to it, is being severely limited, but teachers and school administrators are worried instead about how well they can pass a multiple-choice test.

During the pupa phase, I began to challenge the power structure and began implementing an innovative space of learning that allowed for problem solvers and critical thinkers to flourish.

> Before evolving into an authentic science teacher, I had to be apologetic to administration for my classroom chaos, now it is a friendly reminder that students need a space in which

> they feel comfortable to be themselves in order to develop into the problem solvers, experts, and researchers I know they can be.

During the adult phase**,** my critical consciousness opened up my eyes to the injustices in power structure and called for me to carefully consider the power dynamics between the student and the teacher, so that learning was a joint, con-constructed journey instead of an authoritarian one.

> Teachers now must be able to acknowledge and negotiate that they are not only instructors but also facilitators of learning.

Ways of Scientific Thinking and Learning

During the egg phase, my students were taught to regurgitate the right answer without any consideration that they understood the concepts. I was creating linear scientific thinkers. The students were passive learners who worked quietly with little or no interaction with others, that stopped with one solution: “right" or “wrong” answers.

> I ask for the “right” answer and the students offer the “right” answer.
>
> The students work quietly with little or no interaction, passive involvement, and stop at one solution
>
> The students propose explanations from “thin air”, with no relationship to previous experiences.
>
> The students offer only “yes” or “no” answers and memorized definitions or explanations as answers.

During the larvae phase, my students were taught through textbook material, worksheets, and basic science fair projects that relied on the scientific method until I began to question and challenge what science lessons and science fair projects could do to engage and excite my students in their learning.

> Unfortunately, in my first years of teaching, I provided less support, more textbook material, basic science fair projects where I did not utilize this opportunity to research a topic of interest to them, but instead was viewed as a burden, where they were required to execute projects strictly using the scientific method.

> I started involving students in scientific practices and used an everyday occurrence to teach key scientific concepts such as sunlight, energy, and energy transfer.

> What better way to connect to real world issues than having a student with autism being guided and motivated by his own struggles, channeling his own research into helping children affected by autism just like him. This student was a bright little boy who was hyperactive and would get easily frustrated and act out on certain situations. This little boy would dominate classroom conversations and wanted to talk a lot about his personal interests and struggled in making friendships.

> I try to engage my students with experimentation and investigations, and I try to connect the content with everyday life, to illustrate how scientific concepts apply to our everyday lives.

During the pupa phase, I began to integrate authentic garden boxes and biofiltration projects where the students began to shift their scientific thinking and learning from linear to authentic science.

I incorporated garden boxes, butterfly habitats, bird feeders, and biofiltration projects.

Thus began my very first authentic project, the butterfly garden box project, where my classroom planted a small garden to create a butterfly habitat that would allow my students to observe and investigate the butterfly life cycle.

Then they helped me plant the small garden box, and over the year, students were given time to tend the garden and record their observations about caterpillars and butterflies.

For example, I had a couple of students who were intrigued with our campus flooding and irrigation system and decided to guide their interest and curiosity, on a hands-on project that allowed them to investigate different filtering methods for removing pollutants from water.

Their project had an engineering component in which environmental engineers worked together to make existing water treatment systems better, and to develop new water treatment systems.

During the adult phase, the students were fully immersed into authentic learning that consisted of deep thinking, hard questions, multiple forms of evidence, investigating contradictions, and navigating difficult problems and situations that are related to the real world.

Students have time and opportunities to explore, experiment, test and refine ideas as they collaboratively build understanding.

Projects have gotten more authentic and sophisticated as our students are doing projects around a problem that affects their lives or community.

> Now, our science fair projects consist of authentic learning that is designed around open-ended questions without clear right or wrong answers, or around complex problems with many possible solutions that could be investigated using a wide variety of methods.

> Our science fair school climate has transformed into authentic learning that is intended to encourage students to think more deeply, raise hard questions, consider multiple forms of evidence, investigate contradictions, and navigate difficult problems and situations that are related to the real world.

Ways of Teaching

During the egg phase**,** my students were trained, well behaved and rewarded for providing the right answer. In doing so, I was reinforcing what the system was designed to create compliant individuals who can become part of the working class and ensure they stay there.

> I kept the teacher's edition in my possession so I would know the answers to the questions.

> I would read the answers to the true-false or multiple-choice questions to my students

> It was under this trap and pressure of high-stakes testing, that I adopted a more systematic, low-level, drill-and-kill building type of classroom pedagogy.

> My lessons were stale, students disengaged, I was bored and the drill and kill never seemed to end.

> My classroom is like a prison where I am taught how to think, how to teach, and how to function within a rigid, tested based, bell-ridden system.

During the larvae phase, schools did a great job at masking the child labor with noble mission statements that claim they are producing life-long learners. My classroom resembled a working factory using poor methods of teaching.

> Most of my classroom worksheets were boring, repetitive, and included a rather shallow level of information, and in fact were a very poor method of instruction, not augmented by "real world" lessons that foster thinking and problem-solving.

During the pupa phase**,** my classroom was emerging into an authentic STEM classroom and in the adult phase my ways of teaching fully evolved into creating an environment where students learned how to be adaptable, analytical and resourceful in order to succeed in a global environment.

> I made a promise to myself and to my students that our science learning was going to shift from linear ways to authentic science, and it all began with garden boxes.
>
> Rather than simply completing a project to fulfill an assignment, I wanted my students to emerge with a broader view of the importance of their research—and of the value of STEM in the world beyond the classroom.

During the adult phase, my teaching fully evolved into creating an environment where students learned how to be adaptable, analytical and resourceful in order to succeed in a global environment.

> Out emerges the butterfly and takes flight into the world where its goal is to cultivate a classroom of young inquirers where the teacher becomes a co-explorer and guide who cultivates curiosity and challenges students to think and act like scientists as they explore intriguing questions.

> Their engagement in the authentic science lessons also created a back-and-forth flow of knowledge between the teacher and student, as opposed to the flow of knowledge being one-directional, becoming accountable for their own actions, becoming powerful problem solvers and powerful advocates.

Teacher Agency

During the egg phase, my science teacher agency remained nonexistent during my first years of teaching.

> In my first years of teaching, I was really afraid to deviate from a scripted curriculum and take risks.

> I sat on my authoritative chair and implemented a scripted curriculum with a goal of improving students' standardized test scores.

> I knew that I needed to demonstrate I had classroom management skills and could control my classroom while delivering a scripted lesson.

During the larva phase my science teacher agency was beginning to evolve as I was inspired to become a pedagogical risk-taker and an advocate for curricular reform.

> The more I began to change my approach to science teaching, the more I was inspired to take risks.

I wanted to see and hear more science talk.

During the pupa phase, my science teacher agency was beginning to evolve as I was inspired to become a pedagogical risk-taker and an advocate for curricular reform.

There was tension between my vision and the vision of the district when it came to how and what to teach in science.

Hence, began my classroom journey on authentic science fair projects with real world impact that lead our school to national recognition.

Fast forward twelve years, I have come to realize that science is meant to be messy and nonlinear.

In the adult phase**,** my experiences shaped my identity as a science teacher which was based on a process and not an end product, which led to a continual practice of an anti-oppressive education.

Unlike other years, where students were given due dates and creating traditional exploding volcanoes or foam-painted solar systems s that were completed at the last minute, this year all teachers were on board aiming to link real-world issues with in-classroom effort to their student's science fair project, showcasing student-led inquiry, experimentation and learning to align with new science standards.

For example, I used and encouraged our science teachers on campus to use Facebook and Instagram in a variety of ways to enhance authentic science learning.

As science teachers, we have a crucial responsibility to develop our students' ability to think scientifically about problems, both in their immediate lives and in the wider world.

I see myself as an agent of change. Given enormous pressures brought on by state testing, it is with greater need that the value of science education is advocated.

Student Agency

During the egg phase, my students' agency was static and disempowered, where their curiosity and knowledge remained oppressed.

But if we were to walk into a kindergarten class today, we would be expected to sit at a desk and start filling in endless and monotonous worksheets.

During the larvae phase**,** my students' agency remained static and disempowered, where their curiosity and knowledge remained oppressed.

Our elementary students are spending less time outside, and not taking field trips to any science museums, or not being able to garden or design experiments about sunlight and plant growth or even diagram a leaf?

In the pupa phase, the students were no longer just knowing about science, they were doing science which created an authentic learning environment that led students to make choices and make messes which is what student agency looks like in a classroom.

The classroom then becomes a construction zone, probably the loudest and messiest of the school, but loud and messy for the right reasons. Students would be thinking and learning in a controlled intellectual chaos classroom.

> What better way to connect to real world issues than having a student with autism being guided and motivated by his own struggles, channeling his own research into helping children affected by autism just like him.

> For example, students began investigating community floods and creating their own sandbag to prevent flooding or investigating ways to produce clean water through biofiltration for poorer communities.

In the adult phase, as opposed to rote memorization robots and empty vessels that need to be filled like depositories, students developed their own critical consciousness, acknowledging their agency and developing new knowledge through authentic projects and lessons.

> Rather than worrying about whether or not they'll be able to provide the correct answer to a problem, students learned to develop multiple solutions to a problem by examining a task from different perspectives, using a variety of resources, and separating fact from opinion or speculation.

> Rather than simply committing information to memory or following a specific set of instructions using the scientific method, my students were engaged in authentic learning taking the lead in identifying key problems, asking questions, brainstorming ideas, and going through the process of trial and error in order to find solutions.

> Authentic science also increases engagement and motivation in my students because they understand that their work can have a real-world impact, which in return they are more invested in the outcome.

Community Science

In the egg and larva phases, community science was not evident in my reflexive analysis. However, in the pupa phase I was developing community science into my teaching. Connecting the science classroom to the local community gave the students real-world experiences and helped teachers and schools maximize available resources.

> The students and parents then helped donate for the garden and explained that they will be planting a butterfly garden.

> During the first few years of my evolving into an authentic science teacher, I wanted to involve everyone so that they would be excited and find it as interesting and transformative as I did.

> It was then that my colleagues and my administrators started seeking me out to tell me how amazed they were at my students' work and accomplishments and wanted to be part of the authentic scientific teaching wave.

In the adult phase, I acknowledged the disconnect between schools and communities. We needed a connected science type of curriculum where real-world problems and school-community partnerships are used as contextual scaffolds, as a way to provide the students opportunities for meaningful and challenging science learning.

> Therefore, the more I unpack and dissect what constitutes good science education and effective learning, the more I come to understand that science education becomes more like an ecosystem. As science teachers we have the ability to control or influence parts of this ecosystem.

Just like the butterfly, we have the ability to pollinate plants (students and teachers), keep organisms in check (administration), and be part of the food cycle (school).

For example, our school now reaches out to the community for funding for authentic science learning projects.

So, we now reach out to DonorsChoose, which is an online marketplace where teachers and the community connect to give students the resources they need to learn. We request funds for student authentic projects, trips, supplies, visitors, technology and more. We want our students to step into the classroom and feel like actual scientists because they are using genuine equipment to understand the world around us.

Science and Social Media Networking

Like community science, the science and social media networking theme was not evident in the egg and larva phases of my teaching. It was also absent in the **pupa** phase of my teaching. This theme was evident during the adult phase of my teaching. Science is a collaborative process and science teachers need access to other teachers' examples of good science practices. Hence, networking has the potential to be an effective component of science professional development. Networks promote cooperation within and between schools, exchange of ideas, materials and experiences, and quality science lessons.

Social media also became an essential tool for professional growth, curriculum planning, and student engagement.

We began to explore the possibility of creating science lessons uploaded to Facebook and Instagram that students could watch and do at home during remote

> learning, upload authentic science lessons and projects that other teachers in the district could implement, and showcase a lot of in action photos of our students engaged and enjoying STEM activities.

> It has also helped us build large and diverse personal learning networks to find like-minded science educators and groups to connect with.

I realize the disconnect between my early science learning experiences and how I was teaching. I realized that I was not teaching science in a way that emphasizes hands-on learning that allows for discovery and exploration, rather I was using traditional and didactic forms of instruction such as filling out worksheets. I realize that high stakes standardized testing and science fair competitions strip students of real, authentic scientific thinking. Thus, contributing to reinforcing the existing normalized oppressive schooling practices. I also realized that there was a gap of disconnection between schools and communities. We need a connected science curriculum where real-world problems and school-community partnerships are used as contextual scaffolds, as a way to provide the students opportunities for meaningful and challenging science learning.

> Social media also became an essential tool for professional growth, curriculum planning, and student engagement.

> We began to explore the possibility of creating science lessons uploaded to Facebook and Instagram that students could watch and do at home during remote learning, upload authentic science lessons and projects that other teachers in the district could implement, and showcase a lot of in action photos of our students engaged and enjoying STEM activities.

It has also helped us build large and diverse personal learning networks to find like-minded science educators and groups to connect with.

Table 4: Pattern and Themes Summary Findings

Summary Findings	EGG 	LARVAE 	PUPA 	ADULT 
LEVEL OF CRITICAL CONSSCIOUSNESS	No or Little Awareness	Early stages	Deepening	Heightened
STATUS QUO /NEOLIBERLISM	Maintaining	Beginning to question	Deepening my Questioning	Disrupting
POWER STRUCTURES	Disempowered	Dependency	Transformative	Autonomy
WAYS OF SCIENTIFIC THINKING AND LEARNING	Mechanistic/Linear	Simple	Complex/Inquiry	Sophisticated/Messy/ Authentic
WAYS OF TEACHING	Prescribed	Structured	Guided Inquiry	Open Inquiry
TEACHER AGENCY	Non-existent or Minimal	Underdeveloped	Developing	Transformative
STUDENT AGENCY	Non-existent	Non-Existent or Minimal	Underdeveloped	Developing
COMMUNITY SCIENCE	Non-existent	Non-existent	Developing	Established
SCIENCE AND SOCIAL MEDIA	Non-existent	Non-existent	Developing	Established

The butterfly transformation was not an easy one just as becoming an agent of change was not an easy journey. Once I had administration and teachers on board for the implementation of authentic science teaching, we shared a vision for the future of our school and community. It has been a rewarding experience to have served as a roadmap for teachers, administrators, and the community. If I could compare my roadmap to a phenomenal book, it would be that of *The Martian.* This book focuses on the celebration of science and critical thinking, written mostly from the point of view of the American astronaut Mark Watney, who is accidentally left for dead on the Martian surface. He had limited supplies and resources and his survival was put to the ultimate test in a series of challenges to overcome with math, science, creativity, and perseverance. As a botanist, he needed to create a food supply, needed to use available technology to create a means of communication, and he also needed to engineer transportation in order to have any hope of getting rescued. He also needed to survive alone for as long as four years in the most inhospitable of environments. Mark Watney walked us through his process of problem-solving and critical thinking to survive on Mars, and then returned to train other astronauts on his experiences to become better astronauts.

Just like the Martian, I had limited resources in the classroom and the survival of my identity was put to the ultimate test in a series of challenges from the district and administration that had to be overcome through critical awareness, reflexivity, and innovation. I also needed to survive alone for many years in the most inhospitable environment of high stakes testing where I learned to become a risk taker and disruptor to survive. I too had to walk through a process of problem-solving and critical thinking to survive the traditional education system and return as an Assistant Professor to mentor preservice teachers on my lived experiences to become better science teachers. With that said I was left wondering about Mark Watney's process and experiences in relation to mine as a science teacher. What impact did our process and experiences have in the world of education? How can our own personal experiences be implemented to produce *better Martians* or in my case *better science teachers*? Implications for elementary science teacher education is discussed in the next chapter.

CHAPTER V

THE JOURNEY: IMPLICATIONS, CONCLUSIONS, AND LIMITATIONS

“The Journey has not ended; it has just begun”

Figure 21a: Pre-Service Teacher Observation Lesson

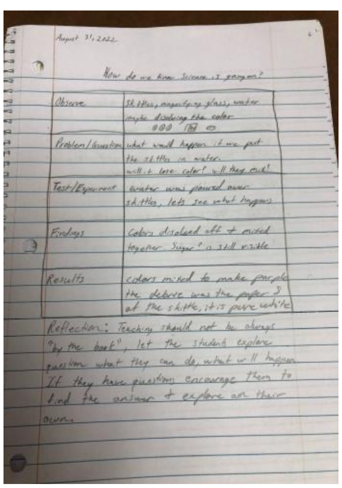


Figure 21b: Reflection Journal

The Journey

I explored my science teacher identity through a reflexive process, using the life cycle of a butterfly as a metaphor, manifested through characteristics associated with becoming an authentic science teacher, where the locus of teacher identity was both an individual and a social process. Throughout my years as an elementary teacher, I challenged myself to shed old patterns, habits, and ideologies that were necessary for radical changes to occur, to benefit my students. I recall the early days of strictly teaching using recitation, direct instruction, seatwork that rewarded obedient students, and a scripted science curriculum. However, as I read about other methods of science teaching through my master's and doctoral classes, I took an introspective glance at my mission as an authentic science teacher. I knew I wanted more for my students. I recall the days when all of my desks were in straight rows, and I insisted that my students remain quiet for the entire class session. I compelled them to listen to me recite science textbook facts and gave them worksheets to solve problems, failing to determine if they had an intuitive understanding of the scientific process. I realized that I had to change the way I facilitated learning. But that change took time and effort on my part to become an authentic science educator. It dawned on me that traditional teaching was not leading to meaningful learning of science. The responsibility was for me to change, not my students. This meant that the agency was mine to create a classroom environment that reflected authentic science learning. Changing my practices did not just happen, and it did not happen overnight. I started out teaching science with the traditional methods in mind but I learned that change can occur because change was needed for increased student learning in my class. I changed because I saw a need to change. I changed because I thought that my students should come first. I had to consciously make a decision to change my practices for the sake of my professional growth to do what is best for my students.

As my science teacher identity evolved, my science practices also changed, greatly impacting my students' perception of science. They approached science from a problem-solving perspective, enabling them to have the same experiences that are authentic to scientists' experiences, where they learn to ask questions and think about solving problems rather than producing rote answers. These types of authentic experiences provided important opportunities for my students to become engaged in real world issues that transcended our classroom walls. The students become critical thinkers and problem solvers that were able to design investigations, share ideas, develop explanations and use evidence to argue their position, as opposed to passive sponges. Rather than discussing hypothetical situations or memorizing information, students were given the opportunity to put their curiosity, skills and knowledge to use in the development of solutions that will be of immediate benefit to their communities and the world at large.

One of the greatest impacts of implementing authentic science in my classroom is that it allowed my students to solve real world problems. With authentic science lessons and projects, their learning paralleled the real-world tasks of scientists in practice as closely as possible. This type of learning in elementary school is critical to developing science identity and interest lays the foundation for a pathway to STEM careers because there is a misconception about STEM being more meaningful for older students. As new research shows, many people believe that "real" science, technology, engineering, and mathematics (STEM) learning doesn't occur until children are older, and that exposure to STEM concepts in early childhood (birth to 8 years) is only about laying a foundation for the serious STEM learning that takes place later (McClure et al. 2017).

When exposed to learning through authentic science, they learned to express their ideas, findings, and beliefs effectively through a variety of media by actually using social media platforms and blogs and journals to start conversations and share ideas. For example, this year my students worked on a group project on how COVID-19 remote learning affected the mental health of students and they brainstormed together in the classroom, shared ideas, and collaborated through a reflection journal and blog, where they created visual presentations of their findings and make sense of the data they collected. When students use real data, they have more incentive to understand what it means. Another impact of authentic science is that it enhances creativity and improves critical thinking in my students. This process encouraged my students to ask questions and think outside the box. It encouraged my students to think for themselves and make their own decisions, able to learn in a more deliberate way and have a much richer experience. Rather than simply committing information to memory or following a specific set of instructions using the scientific method, my students were engaged in authentic learning taking the lead in identifying key problems, asking questions, brainstorming ideas, and going through the process of trial and error in order to find solutions. In the real world, it's rare to be faced with a situation where there's only one correct approach or solution, and this is something authentic learning helped my students understand. Rather than worrying about whether or not they'll be able to provide the correct answer to a problem, students learned to develop multiple solutions to a problem by examining a task from different perspectives, using a variety of resources, and separating fact from opinion or speculation. Authentic science also increases engagement and motivation in my students because they understand that their work can have a real-world impact, which in return they are more invested in the outcome. Their engagement in authentic science lessons also created a back-and-forth flow of knowledge between the teacher and student, as opposed to the flow of knowledge being one-directional, becoming accountable for their own actions, becoming powerful problem solvers and powerful advocates.

Implications

The metamorphosis of a butterfly cannot transform larvae into butterflies if larvae are absolutely secure in their status and safe in self-assumption. You cannot stay a larva, if you want to become a butterfly. Much like that analogy, many teachers do not develop into butterflies. Rather, many teachers have experiences that prepare them to be textbook driven science teachers and do not develop into authentic science teachers. Through this process I was brave enough to drop old, linear teaching beliefs and let my old identity be broken down and allow a new authentic identity to emerge. This process described my lived experiences and transformed my experiences into knowledge that can now be shared with other educators and my preservice teacher students in my science method courses.

My goal is that my dissertation provides a way to improve science teacher education, science classroom practices (specifically for beginning and preservice teachers), teacher learning journey (including an evolving science identity). The findings from this study extend the literature on elementary science teacher education as a way to help preservice elementary teachers develop reflexive practices, a strong science teacher identity, and agency. The goal is that elementary teachers develop ways of teaching science that reflect the way science is done.

Reform recommendations for teacher education emphasize high-quality training programs to prepare effective and reflective teachers (Amobi, 2005; Amobi & Irwin, 2009; Karlstrom & Hamza, 2019). Suggested effective approaches in science methods courses for teacher preparation include incorporating field experiences (Liakopoulou, 2012), microteaching experiences (Amobi, 2005; Fernandez, 2005), and reflection on teaching practices (Amobi & Irwin, 2009; Karlstrom & Hamza, 2019; Loughran, 2002). However, studies have argued that teacher education programs fall short in preparing preservice science teachers (Darling-Hammond & Cobb), primarily due to the disconnect between theory and practice (Loughran, 2006). Therefore, one of the implications of this study is the importance of developing as a reflexive practitioner to enhance understanding and ones' teaching. In many ways, reflexivity can help teachers develop self-efficacy toward their practice. Teachers who have a higher self-efficacy in their field may be able to cross more easily into different fields of practice because they have a greater understanding of their own beliefs as well as confidence in their ability to influence student learning (Bandura, 1977). Unfortunately, most pre-service teachers who enter the science classroom teach the way science was taught to them, reducing it to a linear, mechanistic way through rote memorization and worksheets. Currently, teacher education programs are criticized for their inability to provide preservice teachers with opportunities to learn how to develop either of these essential characteristics, both because of coursework that fails to integrate theory and practice and due to limited opportunities to engage in long-term teaching practice (Darling-Hammond, 2006).

Pre-service and practicing elementary teachers need support to be able to effectively connect theory learned in university coursework to actual classroom science teaching. Teachers not only need to develop the ability to reflect on their practice, but they also need to be able to affect changes in their teaching based on their reflection. Many science teacher education programs do not support new teachers to develop as reflective practitioners and do not provide them with tools necessary to identify problems and transform their teaching. I advocate for a strong connection between the theory we learn about in our university teacher preparation programs, the research we conduct on how people learn, and the practices of teachers in classrooms.

Furthermore, based on the discussion and implications drawn from the findings, the following recommendations are made:

- Transform curriculum in teacher preparation courses so that preservice elementary teachers connect theory to practice and expertise in a way that develops a strong and confident science teacher identity and who enacts their agency to create authentic science learning environments.
- Use reflexivity through journaling or video recording as a tool for all preservice elementary science teachers to show the effect of change or understanding of possible transformation needed to develop strategies that promote connectivity and authentic examination.

Therefore, I plan to continue this line of research by using video recordings as an approach to preservice science teacher education to foster teachers' ability to notice and reflexively interpret events captured during teaching practice with the intent of transforming classroom practice. Through this approach, video would become a tool with which teachers connect theory and practice, and through dialogue, develop an appreciation for how one can inform the other. In doing so, we elaborate on the construct of reflexivity as a potential foundation for changing practices in the science classroom and illustrate the ways in which reflexivity and action emerged from dialogic encounters around video analysis.

Preservice and Novice Elementary Teachers

As an elementary science teacher, I strongly believe in the implementation of authentic science practices in the elementary science classroom. My study has helped me to think about preservice and novice teachers in my science education undergraduate courses and the importance of developing their awareness of their science identity as well as the importance of agency in science. Time must be spent tending to the evolution of their science identity. Part of the preservice and beginner teachers' education needs to prepare teachers to become reflexive practitioners who can navigate the education system with a strong sense of agency. Encouraging reflexivity as part of their preservice methods courses will help them to continue being a reflexive practitioner in their own classroom. The reflexive pieces can be carried out in various ways, verbally, written, and visually to foster the importance in their future as teachers.

Classroom Practice

Improving classroom teaching starts with the teacher's desire to improve. I conducted my study because I saw the need for improvement in my teaching, and I wanted to better understand the process. If preservice elementary science teachers are given the opportunity to explicitly develop their agency, the sooner they develop a better understanding of who they want to be as a teacher will lead to better learning environments for their students. This can be accomplished in their preservice teacher education through reflexivity as a way to critique their own pedagogy, even though the process requires vulnerability and is a humbling one.

Elementary science teachers, especially beginning ones, need to be involved actively in making decisions to improve their practice of teaching. This means making choices to improve their school science knowledge and their pedagogy. Traditional ways of teaching science through lectures, focusing on passing standardized tests, and following the scientific method are not sufficient as the way to do science. The importance of including authentic based science learning as part of their planning that keeps classroom teachers on their trajectory should be emphasized in their pre-service courses. The idea that the students need to be active during well designed authentic science activities in order to be part of the learning process should be a part of classroom practice. Students should be actively involved in posing questions that allow them to investigate their answers, which gives students ownership. The importance of observing what students are doing and using their ideas is vital to transforming oneself as an educator. Lessons and questioning need to be expertly used to ensure that the students feel involved and empowered. There will be moments of tension but making reflection a part of the daily process will help work through some of the issues.

Learning Journey

This journey will help others on their own teacher learning journey transform their science identity, take ownership, increase confidence and increase awareness surrounding the choices they make as science teachers. Taking the time to be reflexive on what was learned about teaching science that day, whether it is verbal, written or visual, collaborating with an experienced mentor who has gained the trust of the teacher is vital to the teacher's learning journey. The sharing of the experience also needs to be shared with others so that many teachers will want to be a part of a similar experience. After the journey with the mentor and improved efficacy has occurred the teacher could take the role of a coach or a collaborator in small groups to discuss the importance of planning with a trajectory and the teacher’s confidence in their science pedagogy and knowledge of school science.

Limitations

Beyond the above advantages, there also lies some limitations to qualitative research. Denzin and Lincoln (2008) explain, “qualitative researchers study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them” (p. 4). In qualitative research there is less emphasis on counting numbers of people who think or behave in certain ways and more emphasis on explaining why people think and behave in certain ways. Qualitative research is best used to answer how and why questions and is not well suited to generalizable what, when and who questions. Silverman (2010) argues that qualitative research approaches sometimes leave out contextual sensitivities, and focus more on meanings and experiences. According to (Bowen 2006) these personal experiences and knowledge influence the observations and conclusions related to the research problem which then achieving credibility comes into question. To manage such credibility, researchers engage in reflexivity and seek to build self-awareness regarding their own influence on the research project (Drisko, 1997). Reflexivity is defined as a process of introspection on the role of subjectivity in the research process. It is a continuous process of reflection by researchers on their values (Denzin & Lincoln, 2011) and of recognizing, examining, and understanding how their social background, location and assumptions affect their research practice. Therefore, reflexivity involves a thoughtful consideration of one's standpoint through reflection that may occur through keeping a personal journal and engaging in dialog with peers (Johnson & Waterfield, 2004). Ultimately, the journaling and dialogue brings a spirit of openness and accountability to the research process.

Reflexivity makes the research process not only a mere data collection process but rather makes it an enriching process where the understanding obtained is holistic and in-depth. But reflexivity also comes with its own set of challenges and limitations as well. Reflexivity takes a lot of time, self-discipline and patience which thus makes the process of research tedious as well. It can at times become very challenging for the researcher especially emotionally because it might uncover all the frustrations/anger/feeling overwhelmed/self-doubt etc. while reflecting on one's' own thoughts, emotions and actions thus affecting the researcher and also the participant and the researched topic as well.

It is also essential to consider and report on how my role as the researcher may have affected what I observed, the data collection process, and how the findings were interpreted in light of my role. I served in the role of the primary science teacher throughout the duration of the study. It is possible that my bias for best authentic science practices impacted how the results were interpreted. However, I tried to minimize the impact of my personal biases by engaging in reflexivity throughout the study. Reflexivity is “an attitude of attending systematically to the context of knowledge construction, especially to the effect of the researcher, at every step of the research process” (Cohen & Crabtree, 2006). I engaged in reflexivity by keeping a reflective journal where I recorded regular entries during the research process, which included critically inspecting the entire research process and the methodological decisions made and the reasons for them (Schwandt, 2007). Critical self-reflection was done where I examined my own personal biases and how these biases may have influenced interpretations of the findings. Pillow (2003) also cautioned against excessive reflexivity, and argues that reflexivity is not a way to solve the “problem” of subjectivity but opens the researcher to a fuller, more “connected knowing”

Conclusion

As I reflect on the moments of my first year of teaching, I am reminded of a quote that I often say to myself as sort of a mantra: *In the mind of the beginner, there are infinite possibilities*. Although I am proud of what I have learned at this point in my journey, I must also remember that I remain unfinished. I find this empowering, for "it is our awareness of being unfinished that makes us educable" (Freire, 1998, p. 58). Reflecting on my first year of elementary teaching and crafting my reflexive narrative has helped me to figure out another story to live in my development as a science educator and as a learner. If I can continue to see teaching and learning as lifelong processes, I relieve myself of the need to have it all figured out. I do not have to be an expert; rather I can enjoy the process, open to the opportunities that lay ahead. If I can reflect on my experiences, acknowledge and learn from my mistakes, and maintain the "capacity to renew [myself] each day" (Freire, 1985, p. 15), I can only imagine the possibilities that will continue to unfold as I now embark as an Assistant Professor of Practice for science education courses. With that said, education needs a revolution. A new generation of teaching that challenges everything we've done in the past and starts over with a blank canvas where the focus is the students. We use the paintbrush of research-based pedagogy and paint strokes of the best and most impactful science pedagogical practices.

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BIOGRAPHICAL SKETCH

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